SIMEC Mining:

Tahmoor Coking Coal Operations – Longwalls W1 and W2

Subsidence Predictions and Impact Assessments for Natural and Built Features due to the Extraction of the Proposed Longwalls W1 and W2 in Support of the Extraction Plan Application

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A	Draft issue	DJK	JB	Apr-19
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Report produced to: Support the Extraction Plan Application to be issued to the Department of Planning and Environment.

Previous reports: MSEC647 (Revision A) – Longwalls 31 to 37 - Subsidence Predictions and Impact Assessments for Natural and Built Features in Support of the SMP Application (December 2014).

Background reports available at *www.minesubsidence.com*[1]:

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)

[1] Direct link: http://www.minesubsidence.com/index_files/page0004.htm

Tahmoor Coking Coal Operations (TCCO) owns and operates Tahmoor Mine, an existing underground coal mine that is located approximately 80 km south-west of Sydney in the Southern Coalfield of NSW. Tahmoor Coal is a wholly owned entity within SIMEC Mining Tahmoor Coking Coal.

TCCO has completed the extraction of Longwall 31 (LW31) and, at the time of this report, was in the process of mining Longwall 32 (LW32). The longwalls are being extracted in accordance with the current Development Consent (DA 67/98) and Subsidence Management Plan Approval.

TCCO previously submitted a Subsidence Management Plan Application (SMP Application) for LWs 31 to 37 in the Bulli Seam in December 2014. Mine Subsidence Engineering Consultants (MSEC) prepared Report No. MSEC647 (Rev. A), which provided subsidence predictions and impact assessments on natural and built features due to the proposed extraction of these longwalls in support of the SMP Application.

TCCO has reviewed its mine plan based on many factors, including feedback received from the community following submission of the SMP Application in 2014 and additional information gathered from underground conditions, which influenced the orientation of the proposed longwalls.

The modified mine plan proposes to continue underground mining operations by the extraction of Longwalls W1 and W2 (LW W1-W2) in the *Western Domain*, to the north of the currently active longwall series.

The proposed LW W1-W2 are located to the west of the township of Picton, between Matthews, Cedar and Stonequarry Creeks, the Main Southern Railway and the currently active longwall series. The layouts of the completed, active and proposed longwalls at the mine are shown in Drawings Nos. MSEC1019-01 and MSEC1019-02, in Appendix E.

A number of natural features and items of surface infrastructure have been identified within the vicinity of the proposed longwalls, including creeks, steep slopes, the Main Southern Railway and the Picton-Mittagong Loop Line and associated infrastructure, public roads and associated infrastructure, drainage culverts, potable water infrastructure, sewer infrastructure, gas infrastructure, electrical infrastructure, telecommunications infrastructure, building structures, farm dams, groundwater bores and survey control marks.

TCCO is preparing an Extraction Plan Application for LW W1-W2, which will be submitted to the Department of Planning and Environment (DP&E). MSEC has been commissioned by TCCO to:

- prepare subsidence predictions for the existing and proposed longwalls;
- identify the natural and built features in the vicinity of the proposed longwalls;
- provide subsidence predictions for each of these surface features;
- prepare impact assessments, in conjunction with other specialist consultants, for each of the natural and built features; and
- recommend management strategies and monitoring.

This report should be read in conjunction with the Extraction Plan being prepared by TCCO and in conjunction with the reports from the other specialist consultants engaged by TCCO for the Extraction Plan.

Chapter 1 provides background information on the study, including the mining geometry, surface and seam and overburden lithology.

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

Chapter 3 provides an overview of the methods that have been used to predict the mine subsidence movements resulting from the extraction of the longwalls.

Chapter 4 provides the maximum predicted subsidence parameters resulting from the extraction of each of the longwalls.

Chapters 5 and 6 provide descriptions, predictions and impact assessments for each of the natural and built features that have been identified within the Study Area. Recommendations for each of these features are also provided, which have been based on the predictions and impact assessments.

The overall findings of the assessments undertaken by MSEC are that the levels of impact and damage to identified natural features and built infrastructure are manageable and can be controlled by the preparation and implementation of Subsidence Management Plans, many of which have already been developed and are being successfully implemented during mining at Tahmoor Mine.

These management plans are developed in consultation with the owners of infrastructure and relevant government agencies. The findings in this report should be read in conjunction with all other associated consultant reports.

Recommended management measures generally include monitoring of ground movements and the condition of surface features. Some mitigation measures are recommended to mitigate or avoid the risk of serious consequences should impacts occur to some critical surface features.

It is recommended that Tahmoor Mine continues to develop management plans to manage the potential impacts for the surface features within the future mining areas.

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

Figures

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

Drawings

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Drawing No.	*Description*	*Rev.*
MSEC1019-01	General layout	A
MSEC1019-02	Development Consent boundaries	A
MSEC1019-03	Mine Subsidence Districts	A
MSEC1019-04	Urban areas	A
MSEC1019-05	Surface level contours	A
MSEC1019-06	Bulli Seam floor contours	A
MSEC1019-07	Bulli Seam depth of cover contours	A
MSEC1019-08	Geological structures	A
MSEC1019-09	Land drainage	A
MSEC1019-10	Hidden creeks	A
MSEC1019-11	Cliffs and steep slopes	A
MSEC1019-12	Railways	A
MSEC1019-13	Local roads	A
MSEC1019-14	Bridges, tunnels and culverts	A
MSEC1019-15	Potable water and sewerage infrastructure	A
MSEC1019-16	Gas infrastructure	A
MSEC1019-17	Electrical infrastructure	A
MSEC1019-18	Telecommunications infrastructure	A
MSEC1019-19	Heritage & Archaeological sites	A
MSEC1019-20	Groundwater bores, drillholes and survey marks	A
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MSEC1019-22	Age of houses	A
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MSEC1019-24	House construction	A
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MSEC1019-28	Predicted total subsidence contours after LW W1	A
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1.1. Background

Tahmoor Coking Coal Operations (TCCO) is located approximately 80 km south-west of Sydney in the township of Tahmoor, New South Wales (NSW). It is managed and operated by SIMEC Mining. TCCO has completed the extraction of Longwall 31 (LW31) and, at the time of this report, was in the process of mining Longwall 32 (LW32). The longwalls are being extracted in accordance with the current Development Consent (DA 67/98) and Subsidence Management Plan Approval.

TCCO previously submitted a Subsidence Management Plan Application (SMP Application) for LWs 31 to 37 in the Bulli Seam in December 2014. Mine Subsidence Engineering Consultants (MSEC) prepared Report No. MSEC647 (Rev. A), which provided subsidence predictions and impact assessments on natural and built features due to the proposed extraction of these longwalls in support of the SMP Application.

TCCO has reviewed its mine plan based on many factors, including feedback received from the community following submission of the SMP Application in 2014 and additional information gathered from underground conditions, which influenced the orientation of the proposed longwalls.

The modified mine plan proposes to continue underground mining operations by the extraction of Longwalls W1 and W2 (LW W1-W2) in the *Western Domain*, to the north of the currently active longwall series.

The proposed LW W1-W2 are located to the west of the township of Picton, between Matthews, Cedar and Stonequarry Creeks, the Main Southern Railway and the currently active longwall series. The layouts of the completed, active and proposed longwalls at the mine are shown in Drawings Nos. MSEC1019-01 and MSEC1019-02, in Appendix E. The locations of LW W1-W2 have been overlaid on a 2018 aerial photograph in Fig. 1.1.

A number of natural features and items of surface infrastructure have been identified within the vicinity of the proposed longwalls, including creeks, steep slopes, the Main Southern Railway and the Picton-Mittagong Loop Line and associated infrastructure, public roads and associated infrastructure, drainage culverts, potable water infrastructure, sewer infrastructure, gas infrastructure, electrical infrastructure, telecommunications infrastructure, building structures, farm dams, groundwater bores and survey control marks.

TCCO is preparing an Extraction Plan Application for LW W1-W2, which will be submitted to the Department of Planning and Environment (DP&E). MSEC has been commissioned by TCCO to:

- prepare subsidence predictions for the existing and proposed longwalls;
- identify the natural and built features in the vicinity of the proposed longwalls;
- provide subsidence predictions for each of these surface features;
- prepare impact assessments, in conjunction with other specialist consultants, for each of the natural and built features; and
- recommend management strategies and monitoring.

A comparison between the longwalls proposed in the previous 2014 SMP Application and the current layout of LW W1-W2 is provided in Fig. 1.2. The key differences are listed below.

- LW W1-W2 do not mine directly beneath Matthews, Cedar and Stonequarry Creeks, whilst the previously proposed LWs 33 to 37 were located directly beneath the creeks. The change in mine plan will substantially reduce the severity and extent of mining-induced impacts on the creeks.
- LW W1-W2 and future planned longwalls W3 and W4 will progressively extract each longwall from west to east, whilst the previously proposed LWs 33 to 37 were sequenced in the opposite direction.

  From a mine subsidence perspective, the change in direction reduces the impact of transient subsidence effects on houses within the Stonequarry Estate, and also allows TCCO to track mining-induced movements as the mine extends towards the Picton Railway Tunnel on the Main Southern Railway, which is a substantial and significant item of civil infrastructure.

Chapter 1 provides background information on the study, including the mining geometry, surface and seam and overburden lithology.

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

Chapter 3 provides an overview of the methods that have been used to predict the mine subsidence movements resulting from the extraction of the longwalls.

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Chapters 5 and 6 provide descriptions, predictions and impact assessments for each of the natural and built features that have been identified within the Study Area. Recommendations for each of these features are also provided, which have been based on the predictions and impact assessments.

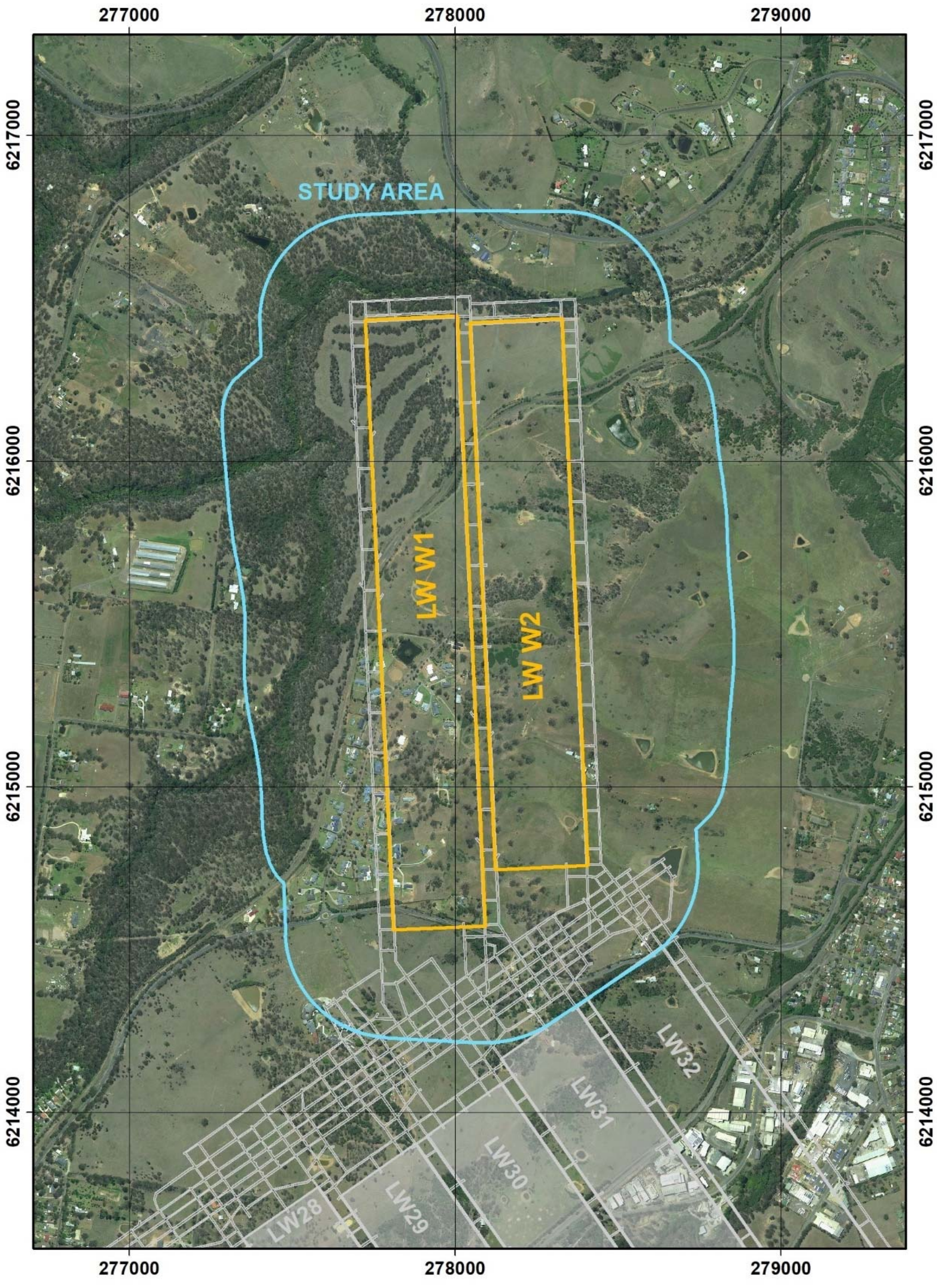

Fig. 1.1 Aerial photograph showing proposed longwalls and the Study Area

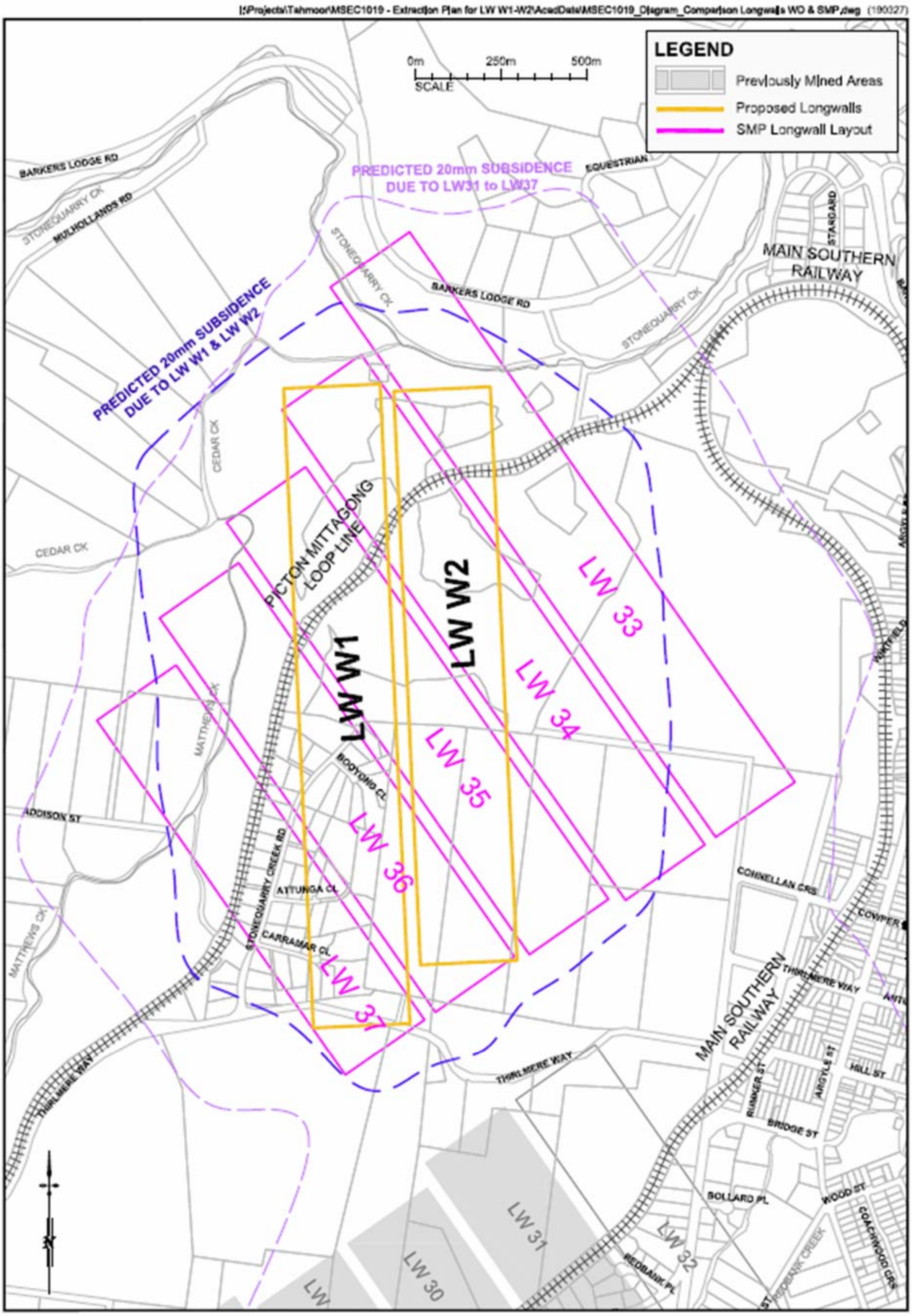

Fig. 1.2 Comparison between mine layouts for LW W1-W2 (2019 Extraction Plan) and LWs 33 to 37 (2014 SMP Application)

1.2. Mining geometry

The layouts of the LW W1-W2 are shown in Drawings Nos. MSEC1019-01 and MSEC1019-02. A summary of the dimensions of the longwalls is provided in Table 1.1.

Table 1.1 Geometry of the longwalls

Longwall	Overall void length including installation heading (m)	Overall void width including first workings (m)	Overall tailgate chain pillar width (m)
LW W1	1875	283	-
LW W2	1685	283	39

The lengths of longwall extraction excluding the installation headings are approximately 9 m less than the overall void lengths provided in Table 1.1. The longwall face widths excluding the first workings are 272 m. The longwalls will be extracted within the Bulli Seam towards the main headings (i.e. from north to south).

1.3. Mining Lease Boundaries

The mining lease boundaries are shown in Drawing No. MSEC1019-02.

The proposed longwalls will extract coal within two mining leases, ML 1376 and ML 1539. The Tahmoor North Mining Lease for the rural areas is ML 1376. The Tahmoor North Mining Lease for the railways is numbered ML 1539. The original mining lease for Tahmoor Mine is CCL 716.

1.4. Planning Approval Boundaries

The planning approval boundaries are shown in Drawing No. MSEC1019-02.

Development consent (DA 57/93) was granted in 1994 for land within ML 1376. Development consent (DA 67/98) was granted in February 1999 for mining beneath certain urban areas and railway land not included within ML 1376, and this area is covered by ML 1539. Development consent was modified in 2006, 2012 and 2018.

The predicted limit of subsidence from the extraction of LW W1-W2 lies wholly within the 1994 and 1999 consent boundaries. It does not encroach into the "two areas shown in black crosshatching in Figure 2" of the 1999 Consent (as amended in 2018 and reproduced in blue crosshatching in Drawing No. MSEC1019-02).

1.5. Mine Subsidence Districts

The boundaries of the Mine Subsidence Districts (MSDs) are shown in Drawing No. MSEC1019-03. It can be seen from this drawing that the Study Area is wholly within the Picton MSD.

The Picton MSD was proclaimed in July 1997. It was extended following a review by Subsidence Advisory NSW (SA NSW) in 2017. SA NSW extended MSDs where future mining was planned to occur. The Picton MSD was extended in 2017 to include all land within the Study Area.

1.6. Urban and Rural Areas

The extent of urban and rural areas, as defined for the purposes of this Study Area, is shown in Drawing No. MSEC1019-04. Urban areas include the urban areas within ML 1539 as defined in the development application (DA 67/98), and the urban areas within ML 1376, which have been defined by current Wollondilly Shire Council zoning boundaries.

1.7. Surface and seam levels

The surface level contours are shown in Drawing No. MSEC1019-05. The longwalls are located beneath a small ridgeline with a high point of approximately 286 metres above Australian Height Datum (m AHD) within the Study Area.

The surface falls toward Matthews, Cedar and Stonequarry Creeks in the north-western part of the mining area and towards Redbank Creek in the south-eastern part of the mining area. The minimum surface level is approximately 166 m AHD at Stonequarry Creek at the most downstream section, in the north-western part of the Study Area.

The longwalls are proposed to extract coal from the Bulli Seam. TCCO proposes to extract a constant height of 2.1 m.

The seam floor contours and depth of cover contours are shown in Drawings Nos. MSEC1019-06 and MSEC1019-07, respectively. The Bulli Seam dips towards the north-east with an average gradient of 5 % (i.e. 1 in 20) across the mining area. The depths of cover directly above the proposed longwalls vary between a minimum of 455 m above the commencing end of LW W1 and a maximum of 535 m on the eastern edge of LW W2.

The levels of the natural surface and the Bulli Seam are illustrated along Cross-section A and Long-section B in Fig. 1.3 and Fig. 1.4, respectively. The locations of these sections are shown in Drawings Nos. MSEC1019-05 to MSEC1019-07. The definition of the Study Area is provided in Section 2.1.

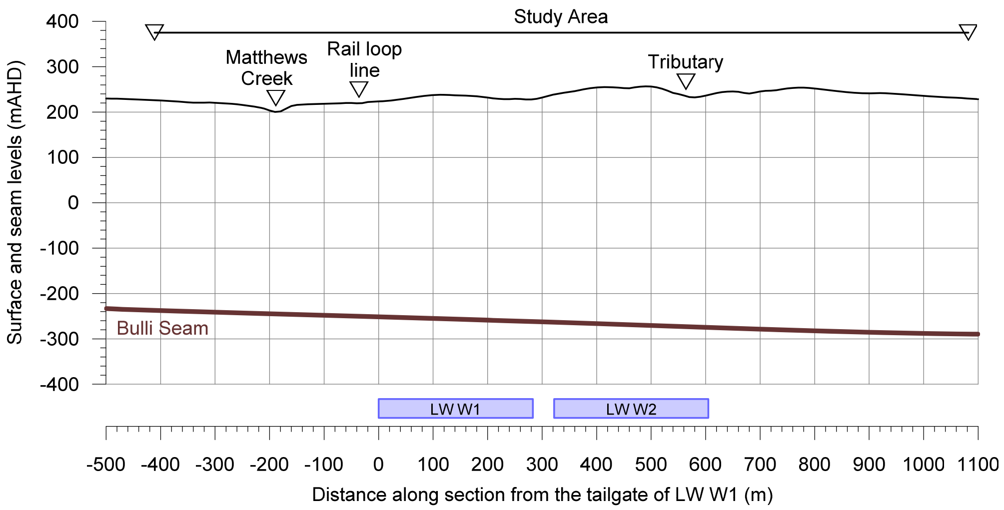

Fig. 1.3 Surface and seam levels along Cross-section A

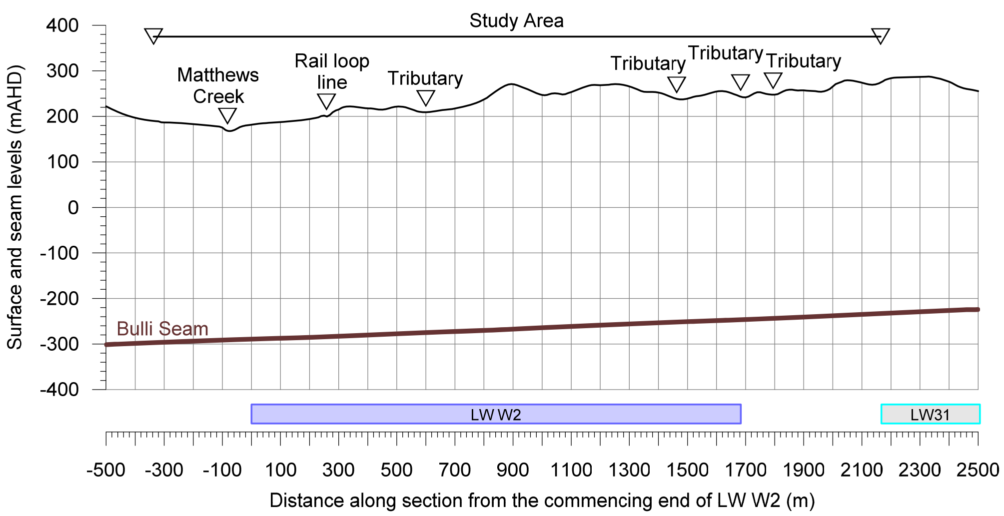

Fig. 1.4 Surface and seam levels along Long-section B

1.8. Geological details

TCCO lies in the southern part of the Permo-Triassic Sydney Basin, within which the main coal bearing sequence is the Illawarra Coal Measures, of Late Permian age. The Illawarra Coal Measures contain four workable seams, the uppermost of which is the Bulli Seam, and it is this seam that is proposed to be extracted by LW W1-W2.

A typical stratigraphic section for TCCO (Borehole TNC30) is shown in Fig. 1.5. Borehole TNC30 is located south of Longwall 31 near Remembrance Drive.

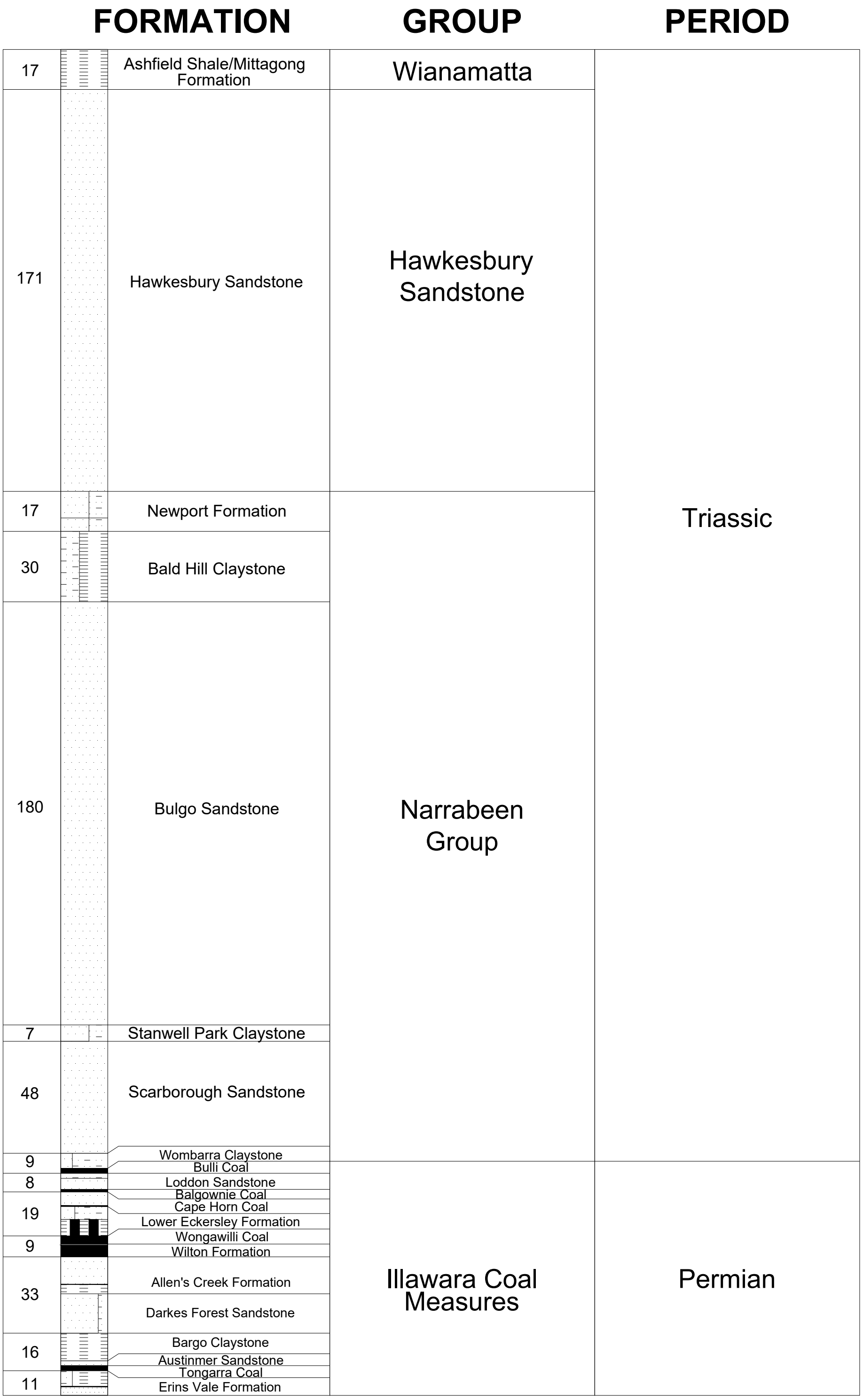

Fig. 1.5 Typical stratigraphic section at Tahmoor (Borehole TNC30)

The sediments that form the overburden to the Bulli Seam belong to the Hawkesbury Tectonic Stage that comprise three stratigraphic divisions. The lowest division is the Narrabeen Group, which is subdivided into a series of interbedded sandstone and claystone units. It ranges in age from Lower to Middle Triassic and varies in thickness up to 310 m. Overlying the Narrabeen Group is the Hawkesbury Sandstone, which is a series of bedded sandstone units which dates from the Middle Triassic and has a thickness of up to 185 m. Above the Hawkesbury is the Wianamatta Group, which consists of shales and siltstones and is poorly represented in this region, having a thickness of only a few tens of metres.

The major sandstone units are interbedded with other rocks and, though shales and claystones are quite extensive in places, the sandstone predominates. The major sandstone units are the Scarborough (Narrabeen Group), the Bulgo (Narrabeen Group) and the Hawkesbury Sandstones (Hawkesbury Sandstone) and these units vary in thickness from a few metres to as much as 200 m. The rocks exposed in the river gorges and creek alignments belong to the Hawkesbury Sandstone.

The other rocks generally exist in discrete but thinner beds of less than 15 m thickness or are interbedded as thin bands within the sandstone. The major claystone unit is the Bald Hill Claystone, which lies above the Bulgo Sandstone at the base of the Hawkesbury Sandstone. This claystone varies in thickness and is, in some places, more than 25 m thick. Due to the nature of the clay, which swells when it is wetted, it tends to act as an aquitard.

The geological structures identified at seam level are shown in Drawing No. MSEC1019-07. No significant geological structures have been identified within the Western Domain from underground workings by TCCO.

The Nepean Fault is located east of the mining area. TCCO commissioned an engineering geologist from Strata Control Technology (SCT, 2018a and 2018b) to undertake site inspections and mapping of the Nepean Fault. This work has provided detailed information on the nature and location of the Nepean Fault and second order geological structures associated with the fault.

The Nepean Fault is mapped as "*an en-echelon distribution of first order faults with major offsets. Ramps are developed between these en-echelon fault surfaces. Numerous first order north-south faults, each of limited extent, step across the area investigated.*" (SCT, 2018a).

SCT further advise that the fault is sub-vertical from surface to seam, based on site investigations and geological information gathered by Tahmoor Coking Coal Operations since 2014. The cross-section provided by SCT (2018a) has been reproduced in Fig. 1.6.

In addition to the mapped first order faults, SCT has mapped second order faults, which are described as "*mainly conjugate sets of strike slip faults and splay faults being observed between the en-echelon first order faults*." (SCT, 2018a).

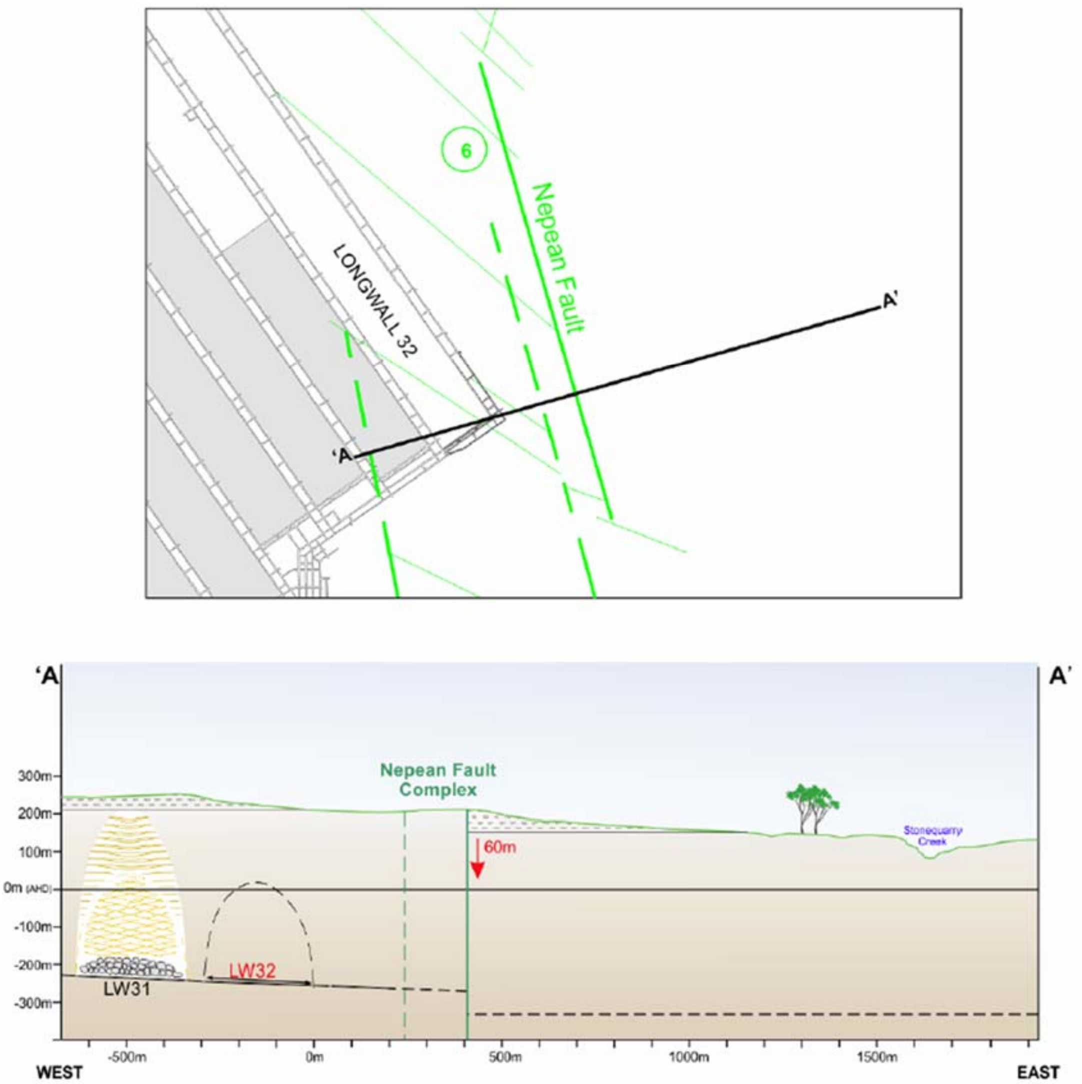

Fig. 1.6 Cross-section of Nepean Fault near Longwall 32 by SCT (2018a)

The geological structures as mapped by SCT (2018a) have been overlaid with built structures within and adjacent to LW W1-W2. These are shown in Drawing No. MSEC1019-08.

Mapped first order faults and second order conjugate faults associated with the Nepean Fault are located to the east of the Study Area.

The surface lithology is illustrated in Fig. 1.7, which shows the proposed longwalls overlaid on Geological Series Sheet 9029, which is published by the NSW Department of Planning & Environment Division of Resources and Geoscience, formerly the Department of Primary Industries (DPI).

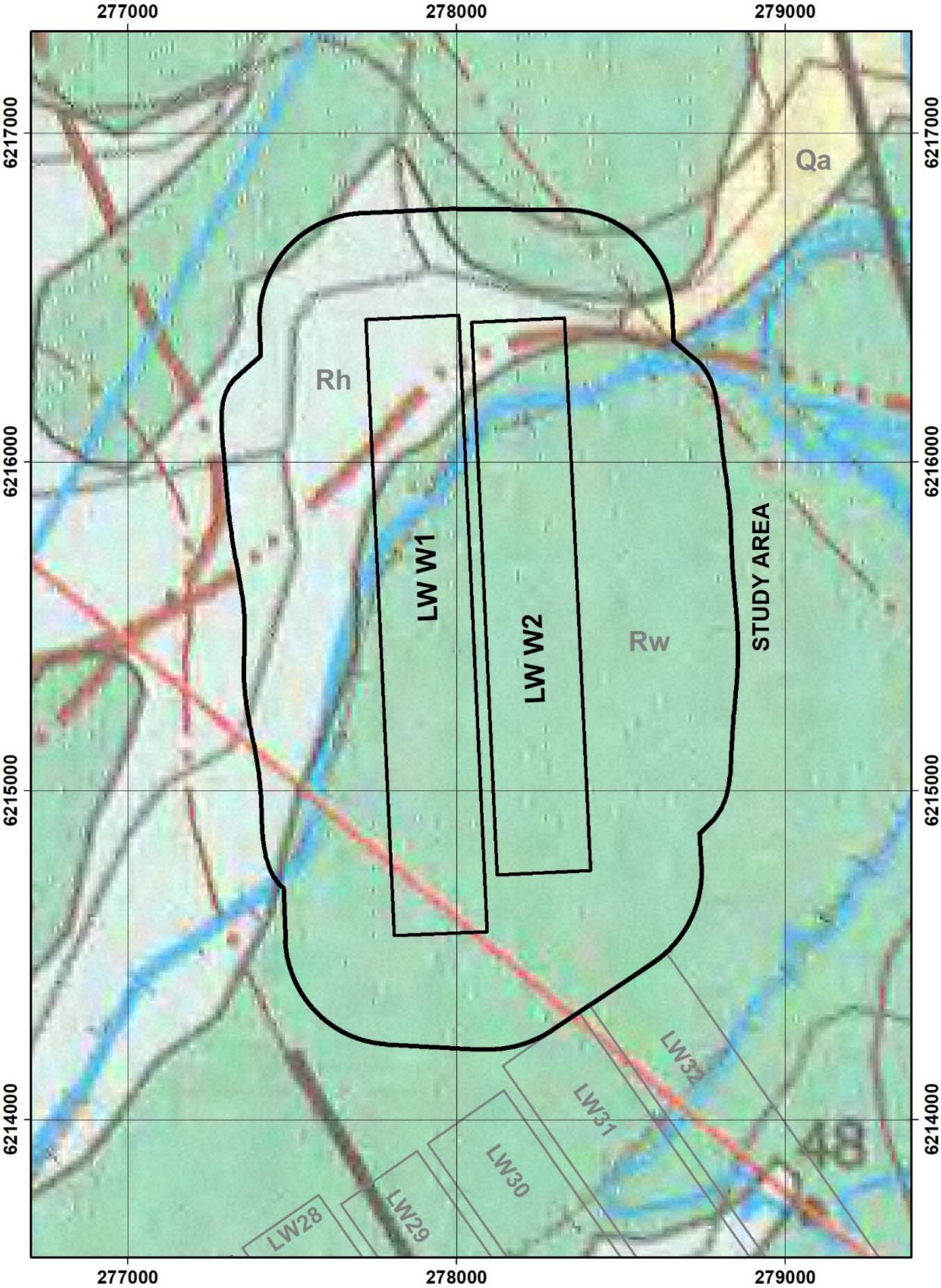

Fig. 1.7 Surface lithology within the Study Area (DPI Geological Series Sheet 9029)

The surface lithology above the proposed longwalls generally comprises the Wianamatta Group (Rw), with the Hawkesbury Sandstone Group (Rh) exposed in Matthews, Cedar and Stonequarry Creeks.

2.1. Definition of the Study Area

The *Study Area* is defined as the surface area that could be affected by the mining of LW W1-W2. The extent of the Study Area has been calculated by combining the areas bounded by the following limits:

- A 35° angle of draw from the extents of LW W1-W2;
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour, resulting from the extraction of LW W1-W2; and
- Features that could experience far-field or valley related movements and could be sensitive to such movements.

The depths of cover contours for the Bulli Seam are shown in Drawing No. MSEC1019-07. The depths of cover directly above LW W1-W2 vary between 455 m and 535 m. The 35° angle of draw, therefore, has been determined by drawing a line that is a horizontal distance varying between 320 m and 375 m around the extent of the longwall mining area.

The predicted limit of vertical subsidence, taken as the predicted total 20 mm subsidence contour due to the extraction of LW W1-W2, has been determined using the Incremental Profile Method, which is described in Chapter 3. The predicted subsidence contours, including the 20 mm subsidence contour, due to LW W1-W2 are shown in Drawing No. MSEC1019-27. The predicted subsidence contours represent the additional movements due to LW W1-W2 only.

The predicted 20 mm subsidence contour is located outside the 35° angle of draw adjacent to the tailgate of LW W1 and adjacent to the maingate of LW W2. The predicted 20 mm subsidence contour is located within the angle of draw adjacent to the longwall commencing and finishing ends. The Study Area based on the combined 35° angle of draw and the predicted 20 mm subsidence contour is shown in Drawing No. MSEC1019-01.

In addition to the above, investigations have been undertaken within 600 m of the extents of LW W1-W2 within Matthews, Cedar and Stonequarry Creeks. A minimum of 600 metres from the nearest edge of longwalls was recommended in the independent inquiry report titled “Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield – Strategic Review” (NSW Department of Planning (DoP), 2008).

There are additional features that are located outside the Study Area that could experience either far-field horizontal movements or valley related movements. The surface features that could be sensitive to such movements have been identified and have also been included in the assessments provided in this report. These features include survey control marks and groundwater bores.

2.2. Natural and built features within the Study Area

The major natural and built features within the Study Area can be seen in the 1:25,000 Topographic Map of the area, published by the Central Mapping Authority (CMA), called *Picton 9029-4-S*. The longwalls and the Study Area have been overlaid on an extract of the CMA map in Fig. 2.1.

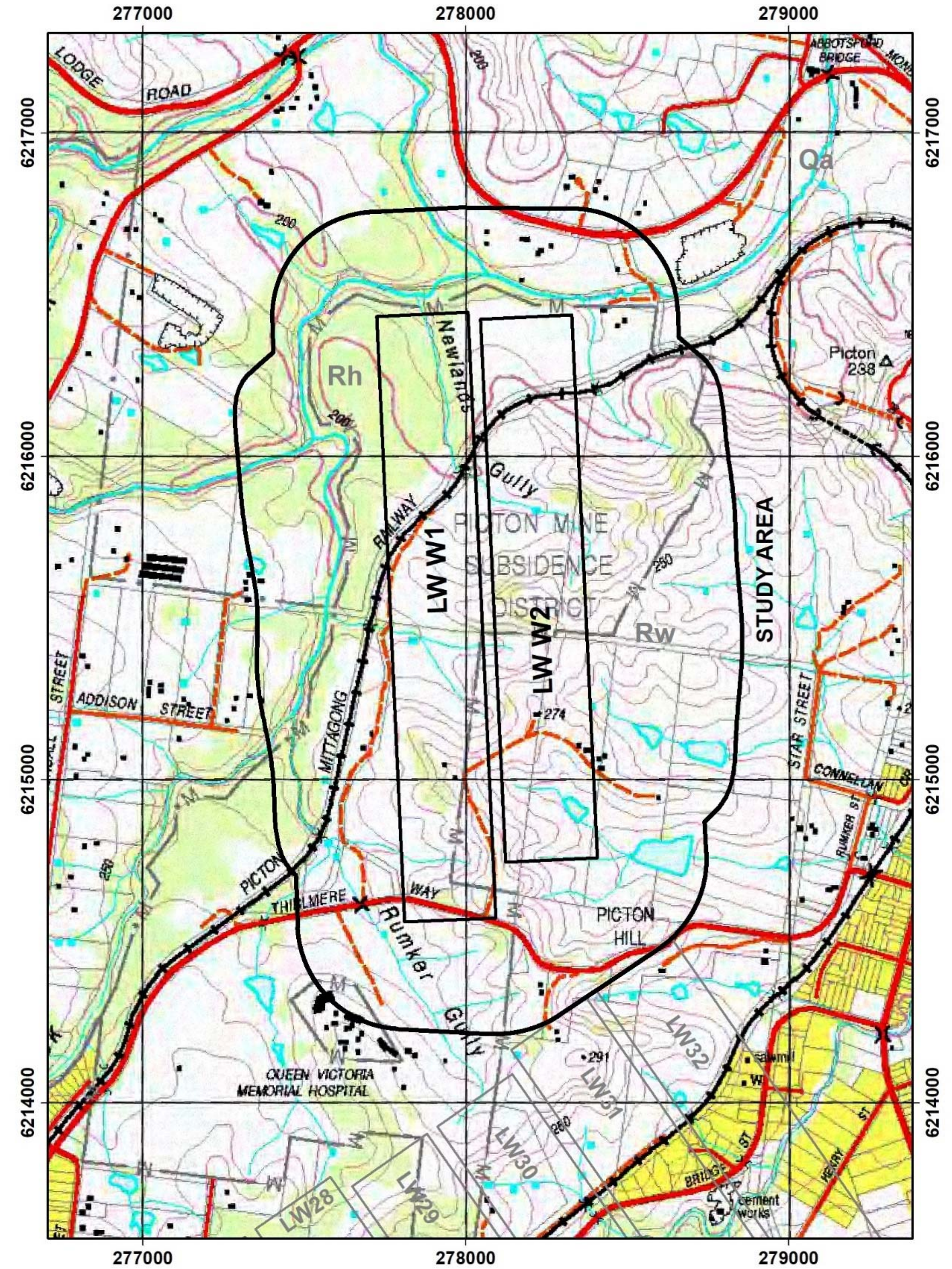

Fig. 2.1 The longwalls and Study Area overlaid on CMA Map *Picton 9029-4-S*

A summary of the natural and built features located within the Study Area is provided in Table 2.1. The locations of these features are shown in Drawing Nos. MSEC1019-09 to MSEC1019-21. Descriptions, predictions and impact assessments for the natural and built features are provided in Chapters 5 and 6. The section number references are provided in Table 2.1.

Table 2.1 Natural and built features within the Study Area

Item	Within Study Area	Section number reference
NATURAL FEATURES		
Catchment Areas or Declared Special Areas	✓	5.1
Rivers or Creeks	✓	5.2 to 0
Aquifers or Known Groundwater Resources	✓	5.5
Springs	×	
Sea or Lake	×	
Shorelines	×	
Natural Dams	×	
Cliffs or Pagodas	✓	5.6
Steep Slopes	✓	5.7
Escarpments	×	
Land Prone to Flooding or Inundation	×	
Swamps, Wetlands or Water Related Ecosystems	✓	5.10
Threatened or Protected Species	✓	5.11
National Parks	×	
State Forests	×	
State Conservation Areas	✓	5.1
Natural Vegetation	✓	5.12
Areas of Significant Geological Interest	×	
Any Other Natural Features Considered Significant	×	
PUBLIC UTILITIES		
Railways	✓	6.1 & 6.2
Roads (All Types)	✓	6.3
Bridges	×	
Tunnels	✓	6.6
Culverts	✓	6.4
Water, Gas or Sewerage Infrastructure	✓	6.7, 6.8 & 6.9
Liquid Fuel Pipelines	×	
Electricity Transmission Lines or Associated Plants	✓	6.10
Telecommunication Lines or Associated Plants	✓	6.11
Water Tanks, Water or Sewage Treatment Works	✓	6.15
Dams, Reservoirs or Associated Works	×	
Air Strips	×	
Any Other Public Utilities	×	
PUBLIC AMENITIES		
Hospitals	✓	6.12
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	✓	6.12

Item	Within Study Area	Section number reference
FARM LAND AND FACILITIES		
Agricultural Utilisation or Agricultural Suitability of Farm Land	×	
Farm Buildings or Sheds	✓	6.14
Tanks	×	
Gas or Fuel Storages	×	
Poultry Sheds	×	
Glass Houses	×	
Hydroponic Systems	×	
Irrigation Systems	×	
Fences	✓	6.16
Farm Dams	✓	6.17
Wells or Bores	✓	6.18
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	✓	0 & 0
ITEMS OF ARCHITECTURAL SIGNIFICANCE	×	
PERMANENT SURVEY CONTROL MARKS	✓	6.23
RESIDENTIAL ESTABLISHMENTS		
Houses	✓	
Flats or Units	×	
Caravan Parks	×	
Retirement or Aged Care Villages	✓	6.12
Associated Structures such as Workshops, Garages, On-Site Waste Water Systems, Water or Gas Tanks, Swimming Pools or Tennis Courts	✓	6.25, 6.25.1 & 6.25.2
Any Other Residential Features	✓	6.25
ANY OTHER ITEM OF SIGNIFICANCE	×	
ANY KNOWN FUTURE DEVELOPMENTS	✓	6.27

3.0 OVERVIEW OF MINE SUBSIDENCE AND THE METHODS THAT HAVE BEEN USED TO PREDICT THE MINE SUBSIDENCE PARAMETERS FOR THE LONGWALLS

3.1. Introduction

The following sections provide overviews of conventional and non-conventional mine subsidence parameters and the methods that have been used to predict these movements. Further information is also 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 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 1000.
- **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 distances between two points increase and **Compressive strains** occur when the distances between two points decrease. 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 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), and vice versa.

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 and strain.

Far-field horizontal movements and the method used to predict such movements are described further in Section 4.7.

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 the case over a large part of the Study Area, the observed subsidence profiles along monitoring 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, curvatures and strains at very shallow depths of cover where the collapsed zone above the extracted longwalls extends up to or near to the surface.

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

- sudden or abrupt changes in geological conditions;
- steep topography; and
- valley related mechanisms.

Non-conventional movements due to geological conditions, steep topography 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 4.5 includes those resulting from both conventional and non-conventional anomalous movements. The impact assessments for the natural and built features, which are provided in Chapters 5 and 6, 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 increased horizontal movements in the downslope direction 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 the increased horizontal movements include the development of tension cracks at the tops and sides of the steep slopes and compression ridges at the bottoms of the steep slopes.

Further discussions on the potential for downslope movements for the steep slopes within the Study Area are provided in Section 5.7.

3.4.3. Valley related movements

The streams within the Study Area will be affected by valley related movements, which are commonly observed in the Southern Coalfield. 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.

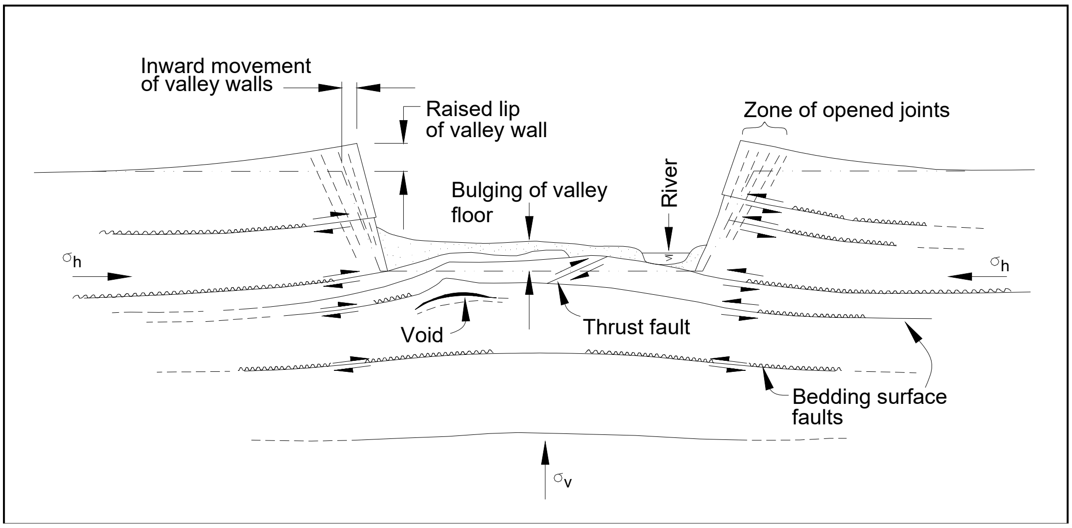

Fig. 3.1 Valley formation in flat-lying sedimentary rocks (after Patton and Hendren 1972)

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 downslope 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 horizontal 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 for the streams in the vicinity of the mining area have been determined using the empirical method outlined in ACARP Research Project No. C9067 (Waddington and Kay, 2002), referred to as the 2002 ACARP method.

More recently, the empirical prediction method has been refined based on further research undertaken as part of ACARP Research Project No. 18015 (Kay and Waddington, 2014), referred to as the 2014 ACARP method. This method only provides predictions for valley closure and not for upsidence.

The predictions based on the 2002 ACARP method can be directly compared with the predictions provided in previous MSEC subsidence reports for TCCO and with other case studies from the Southern Coalfield. This method has also been more widely used and tested than the more recent 2014 ACARP method. The assessments provided in this report, therefore, have been based on the predictions obtained using the 2002 ACARP method.

The reliability of the predicted valley related closure movements is discussed in Section 3.9.

The predicted strains resulting from valley related movements have been determined using the monitoring data for longwalls which have previously mined directly beneath and adjacent to streams in the Southern Coalfield. The predicted valley related strains are discussed with the impact assessments for the streams provided in Chapter 5.

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*.

3.5. The Incremental Profile Method

The predicted conventional subsidence parameters for the proposed longwalls have been determined using the Incremental Profile Method (IPM), which has been developed by MSEC. The method is an empirical model based on a large database of observed monitoring data from previous mining within the Southern, Newcastle, Hunter and Western Coalfields of NSW.

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

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

Subsidence predictions made using the IPM use the database of observed incremental subsidence profiles, the longwall geometries, local surface and seam information and geology. The method tends to over-predict the conventional subsidence parameters (i.e. is slightly conservative) where the mining geometry and geology are within the range of the empirical database. The predictions can be further tailored to local conditions where observed monitoring data is available close to the mining area.

Further details on the IPM are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*.

3.6. Review of the IPM

The use of the IPM at the TCCO has been continually reviewed and refined based on the latest available ground movement monitoring data. The subsidence model has been reviewed after the completion of each longwall as part of the End of Panel reports.

Initially, the subsidence predictions for the longwalls at TCCO were based on the standard model for the Southern Coalfield. In 2009, the IPM was refined using the extensive monitoring data that had been collected during the extraction of LW22 to LW25 at the mine. The details of this calibration were outlined in Section 3.6 of Report No. MSEC355 (Rev. B).

A detailed review of the IPM was carried out in 2014, based on the monitoring data that had been collected during the extraction of LW22 to LW28. It was found that the calibrated IPM generally provided reliable predictions at TCCO. However, exceedances occurred in the areas of increased subsidence above LW24A and above the south-eastern ends of LW25 to LW27.

The IPM has again been reviewed based on the latest monitoring data. The following sections review the predictions obtained using the subsidence model based on the monitoring lines located outside the areas of increased subsidence. Discussions on the areas of increased subsidence are provided in Section 3.7.

3.6.1. Comparison of measured and predicted vertical subsidence

Comparisons of the measured and predicted profiles of vertical subsidence are provided along: Bridge Street in Fig. 3.2; Brundah Road in Fig. 3.3; the Main Southern Railway in Fig. 3.4; and Remembrance Drive in Fig. 3.5.

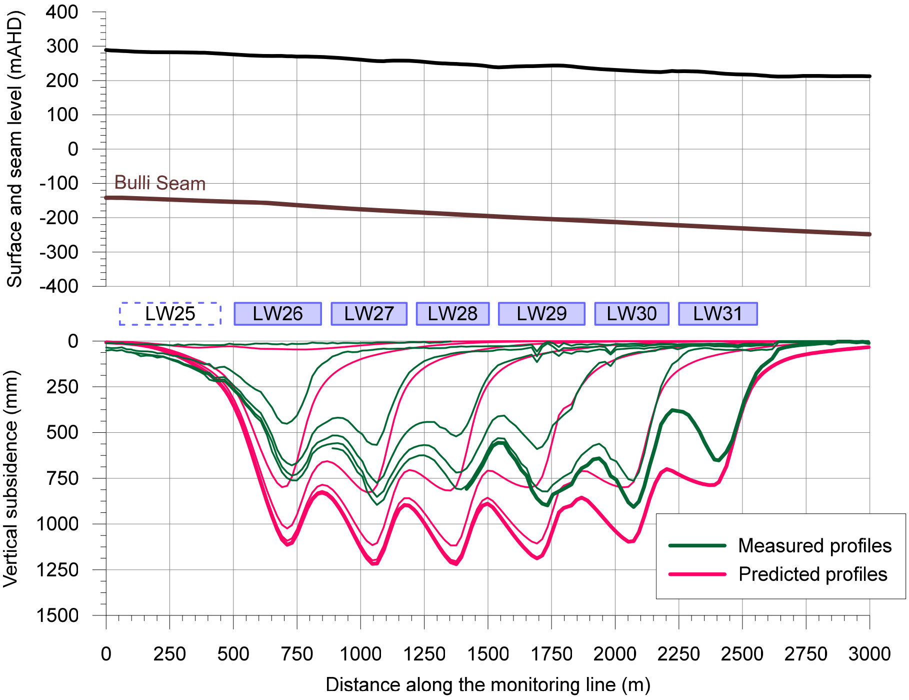

Fig. 3.2 Measured and predicted vertical subsidence along Bridge Street

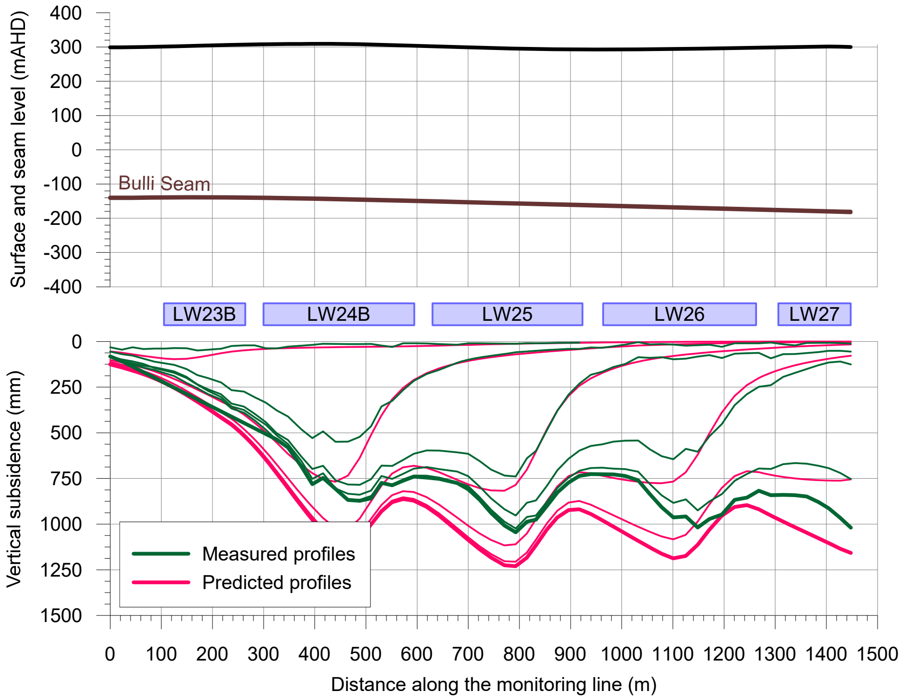

Fig. 3.3 Measured and predicted vertical subsidence along Brundah Road

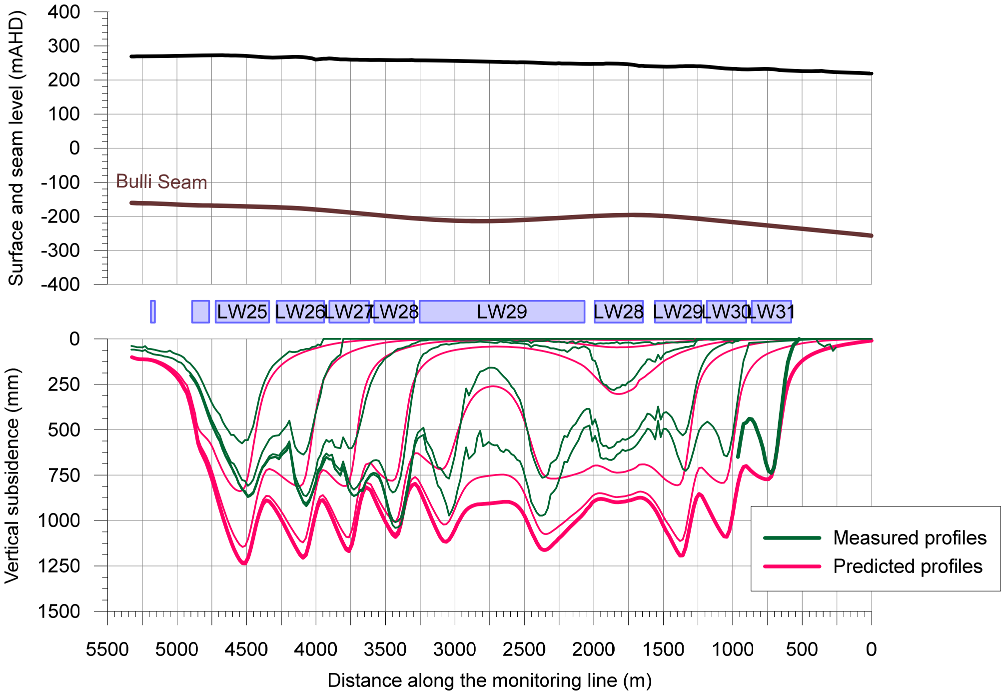

Fig. 3.4 Measured and predicted vertical subsidence along the Main Southern Railway

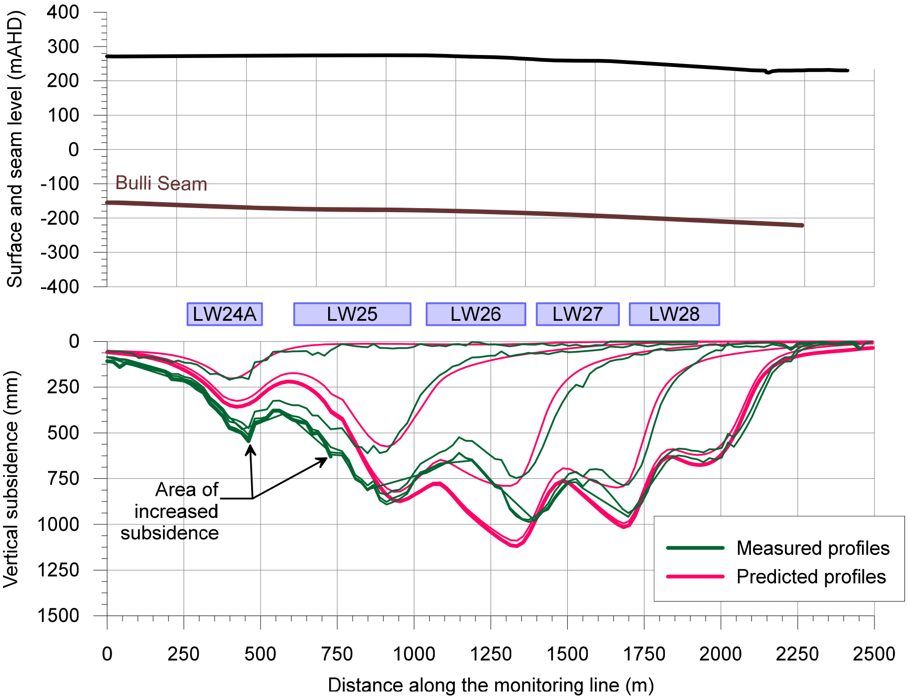

Fig. 3.5 Measured and predicted vertical subsidence along Remembrance Drive

The maximum measured vertical subsidence directly above each of the extracted longwalls was typically less than the maximum values predicted. The measured vertical subsidence was greater than the predicted values above LW24A and above the south-eastern ends of LW25 to LW27. These exceedances occurred in the areas of increased subsidence, such as along the southern end of Remembrance Drive (refer to the left-side of Fig. 3.5). Further discussions on the areas of increased subsidence is provided in Section 3.7.

The measured profiles of vertical subsidence reasonably matched the predicted profiles, although the magnitudes were smaller. In some cases, the low-level subsidence measured outside of the mining area was greater than predictions. However, the exceedances were generally less than 50 mm and these were accompanied by only low levels of tilt, curvature and strain.

There is a lateral shift between the measured and predicted profiles of vertical subsidence along some monitoring lines. This can occur due to the surface slope or seam dip. The impact assessments for point features have been based on the maximum predicted values within 20 mm of their extents to account for the potential lateral shift.

A comparison between the maximum measured and maximum predicted incremental vertical subsidence for the monitoring lines at the mine, due to the extraction of each of LW22 to LW31, is provided in Fig. 3.6. These data exclude the sections of monitoring lines that are located within the areas of increased subsidence, which is discussed separately in Section 3.7. The data also exclude monitoring lines that do not extend across the full width of the active longwall.

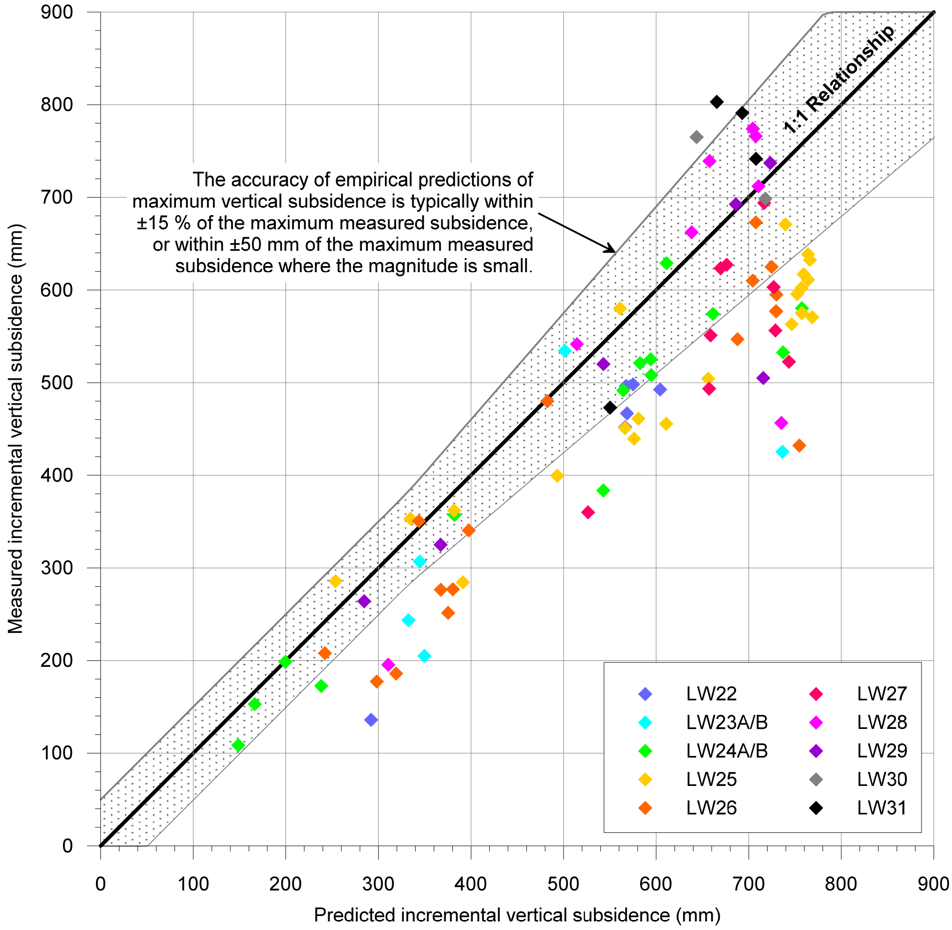

Fig. 3.6 Comparison of maximum measured and maximum predicted incremental vertical subsidence due to LW22 to LW31

The maximum measured incremental vertical subsidence was typically less than the maximum predicted incremental vertical subsidence or was within +15 % or +50 mm of the maximum predicted values. There are two cases where the maximum measured incremental vertical subsidence was greater than +15 % of the maximum predicted values, along the Optical Fibre Line due to LW30 and along Stilton Lane due to LW31.

A comparison between the maximum measured and maximum predicted total vertical subsidence for the monitoring lines at the mine, after the extraction of each of LW22 to LW31, is provided in Fig. 3.7. In all cases, the maximum measured total vertical subsidence was less than the maximum predicted vertical subsidence or was within +15 % or +50 mm of the maximum predicted values.

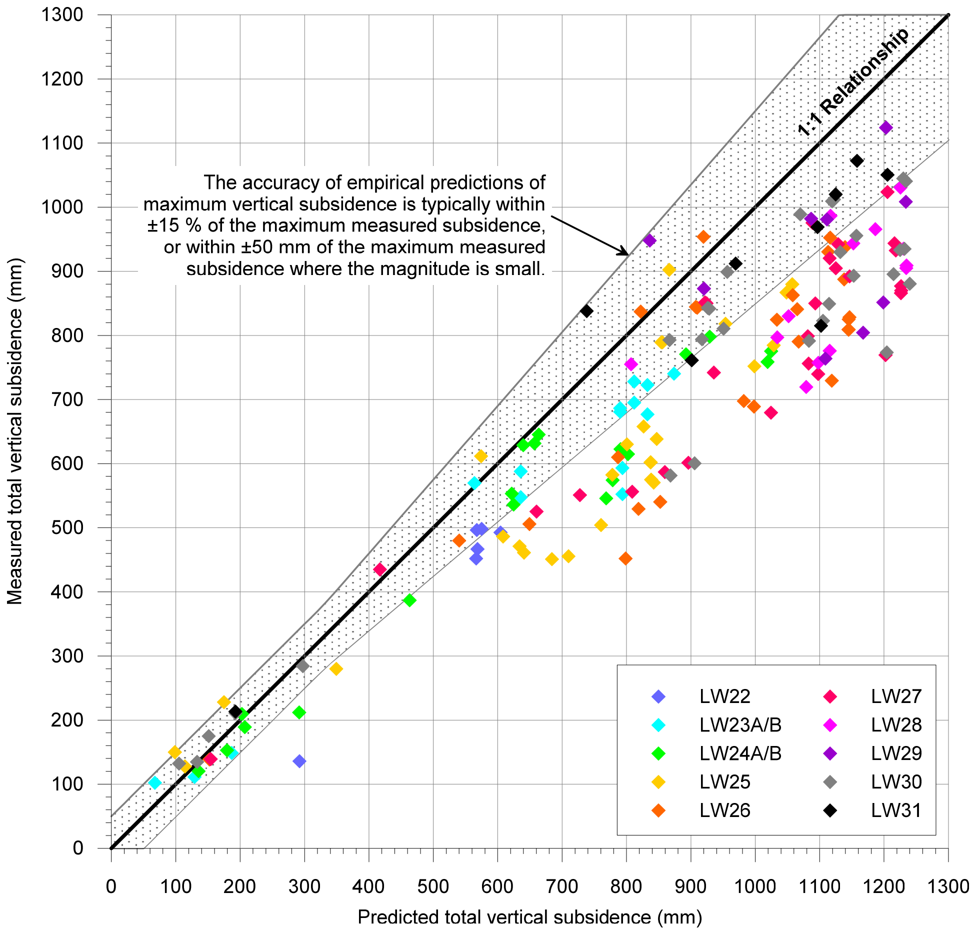

Fig. 3.7 Comparison of maximum measured and maximum predicted total vertical subsidence after each of LW22 to LW31

The distribution of the ratio of the maximum measured to maximum predicted total vertical subsidence for the monitoring lines above LW22 to LW31 is illustrated on the left-side of Fig. 3.8. As per previous, these data exclude the sections of monitoring lines that are located within the areas of increased subsidence and the monitoring lines that do not extend across the full width of the active longwall. A gamma distribution has been fitted to the data and this is shown on the left-side of Fig. 3.8. The probabilities of exceedance based on the fitted gamma distribution are shown in the right-side of this figure.

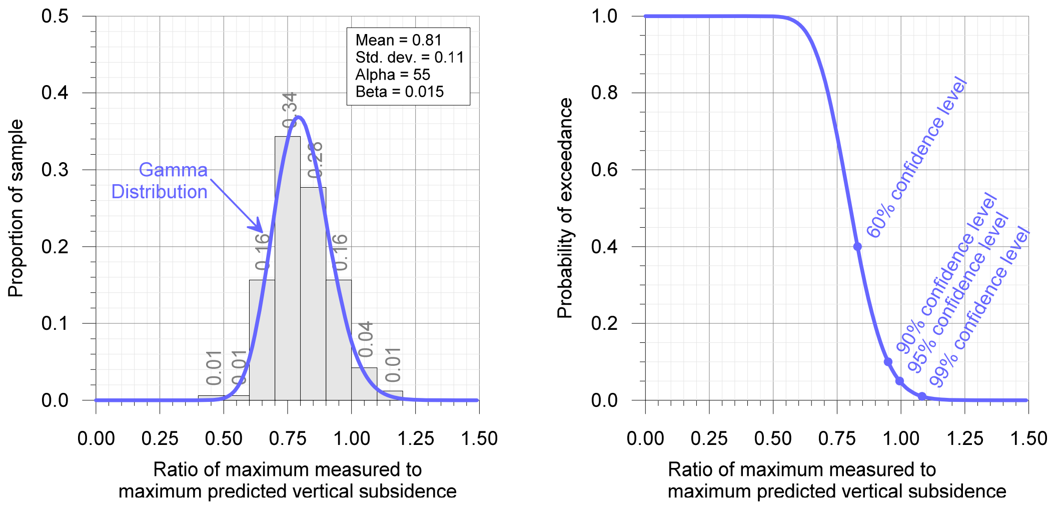

Fig. 3.8 Distribution of the ratio of maximum measured to maximum predicted total vertical subsidence due to LW22 to LW31

The mean ratio of the maximum measured to maximum predicted total vertical subsidence for the monitoring lines is 0.81. That is, the maximum measured vertical subsidence was, on average, 81 % of the maximum predicted values outside the areas of increased subsidence. The maximum measured subsidence was, at most, +10 % greater than the maximum predicted value. Greater subsidence was measured within the areas of increased subsidence, which were excluded from this dataset, and are discussed further in Section 3.7.

The 95 % confidence level approximately represents a ratio of maximum measured to maximum predicted total vertical subsidence of 1.0. That is, there is approximately a 5 % probability that the maximum measured total subsidence exceeds the maximum predicted total value along each of the monitoring lines.

It is considered that the calibrated IPM provides reasonable, if not, slightly conservative predictions of vertical subsidence outside the areas of increased subsidence. LW W1-W2 are located away from the Nepean Fault and the Bargo River. It is therefore expected that the calibrated IPM will provide reasonable, if not, slightly conservative predictions of vertical subsidence for these proposed longwalls.

3.6.2. Comparison of measured and predicted subsidence for single panels

Observed subsidence above single panels is typically more variable than above subsequent longwall panels in a series. The variations are due to different strengths of the overburden strata above the panel, which is supported on all four sides of the longwall.

A review of observed subsidence for single panels at TCCO has been conducted. A summary of observed maximum subsidence against predictions from the calibrated IPM is provided in Fig. 3.9.

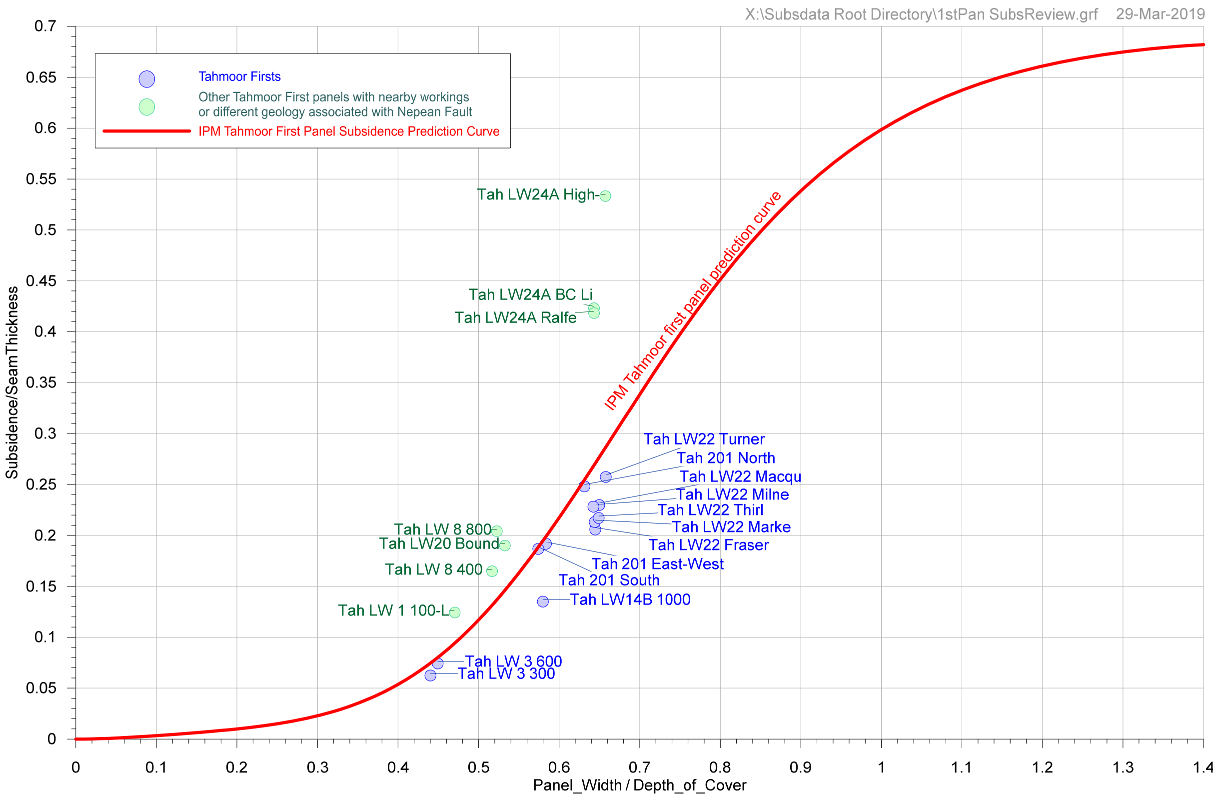

Fig. 3.9 Comparison between observed and predicted maximum subsidence for single panels at TCCO

It can be seen from Fig. 3.9 that there has been a reasonable correlation between predicted and observed maximum subsidence for single panels at TCCO, particularly Longwall 22. Some variations have been observed, however, in other locations. In these cases, highlighted in green in Fig. 3.9, special circumstances exist and these are described below.

- Tahmoor Longwall 1 – This panel is located adjacent to total extraction workings and is not, therefore, an isolated single panel.
- Tahmoor Longwall 8 – This panel is located adjacent to total extraction workings and is not, therefore, an isolated single panel. It is also located near the Nepean Fault, which is discussed further in Section 3.7.
- Tahmoor Longwall 20 – This panel is located adjacent to total extraction workings and is not, therefore, an isolated single panel.
- Tahmoor Longwall 24A – This panel is located adjacent to total extraction workings and is not, therefore, an isolated single panel. It is also located near the Nepean Fault, which is discussed further in Section 3.7.

A comparison between measured and predicted profiles of vertical subsidence along Thirlmere Way are provided in Fig. 3.12 after the mining of LWs 22 and 23A at TCCO. These panels are representative of LW W1-W2, being the first two panels in a series.

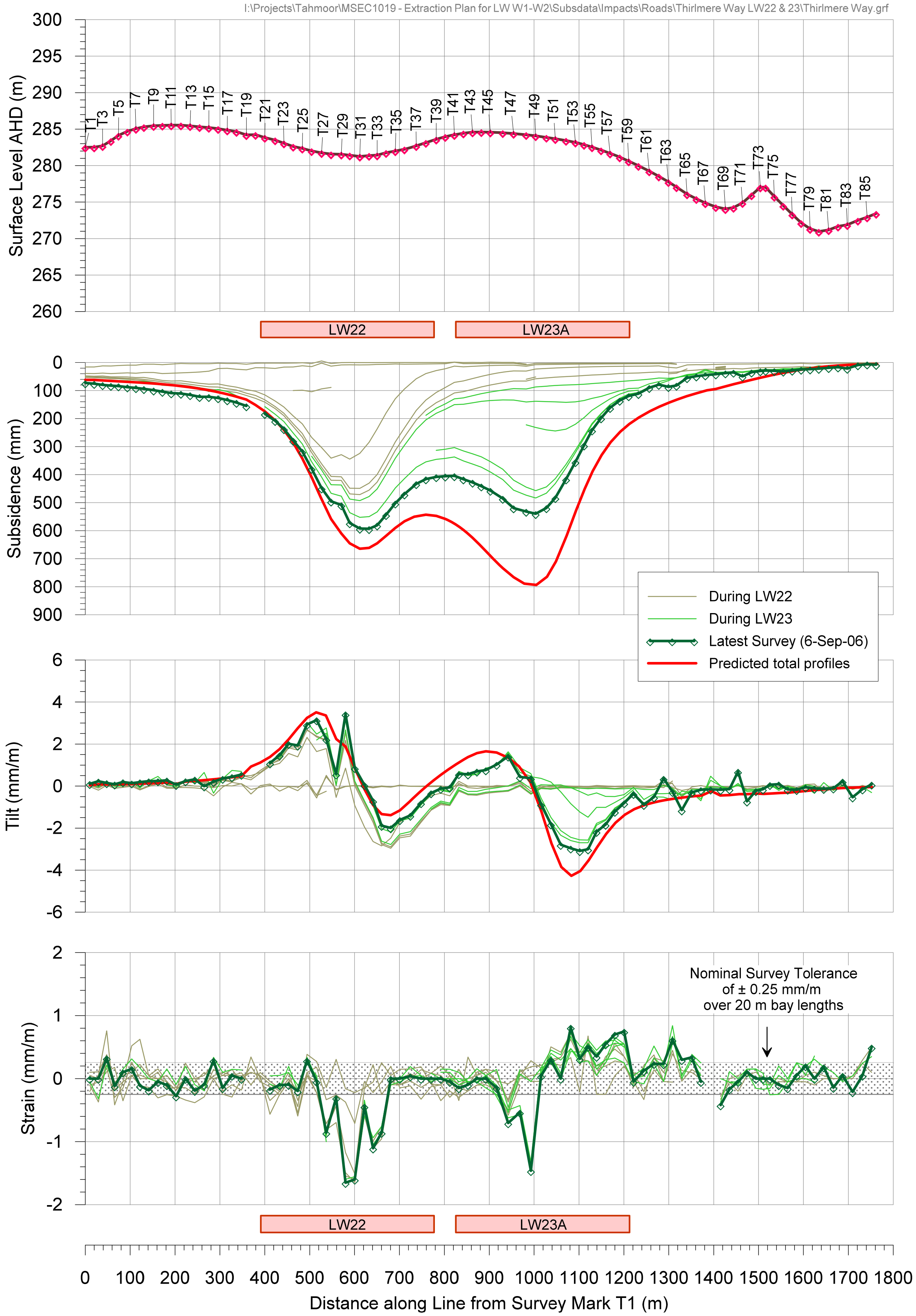

Fig. 3.10 Comparison between measured and predicted subsidence and tilt profiles along Thirlmere Way during the mining of LWs 22 and 23A at TCCO

Whilst there is a reasonable correlation between measured and predicted subsidence for the single panel at LW22, it can be seen from the overall comparison at TCCO that actual subsidence above LW W1 could be greater than predicted. There are also other cases in the Southern Coalfield where measured subsidence above a single panel has been substantially less than predicted.

It is therefore recommended that monitoring be conducted during the early stages of extraction of LW W1 to compare observations with predictions. TCCO has extensive experience in successfully managing potential subsidence impacts on surface features, even when actual subsidence is substantially greater than the magnitudes that have been predicted above single panel LW W1. It is recommended that subsidence management plans be developed to manage potential impacts that could occur if greater than predicted subsidence occurs.

3.6.3. Comparison of measured and predicted tilt

The measured and predicted tilts along Bridge Street, Brundah Road, the Main Southern Railway and Remembrance Drive are represented by the slopes of the vertical subsidence profiles shown in Fig. 3.2 to Fig. 3.5. The maximum slopes of the measured profiles of vertical subsidence are reasonably similar to the maximum slopes of the predicted profiles for these monitoring lines. It can then therefore be inferred that the maximum measured and maximum predicted tilts are reasonably similar.

The maximum tilts generally occur adjacent to the maingate of the last extracted longwall in the series. Localised tilts greater than the predictions were measured at stream crossings, due to valley related effects, and in locations of irregular ground movement.

A comparison between the maximum measured and maximum predicted total tilts for the monitoring lines at the mine, after the extraction of each of LW22 to LW31, is provided in Fig. 3.11. These data exclude the sections of monitoring lines that are located within the areas of increased subsidence, which is discussed separately in Section 3.7. The data also exclude the localised tilts due to valley related upsidence or irregular ground movements.

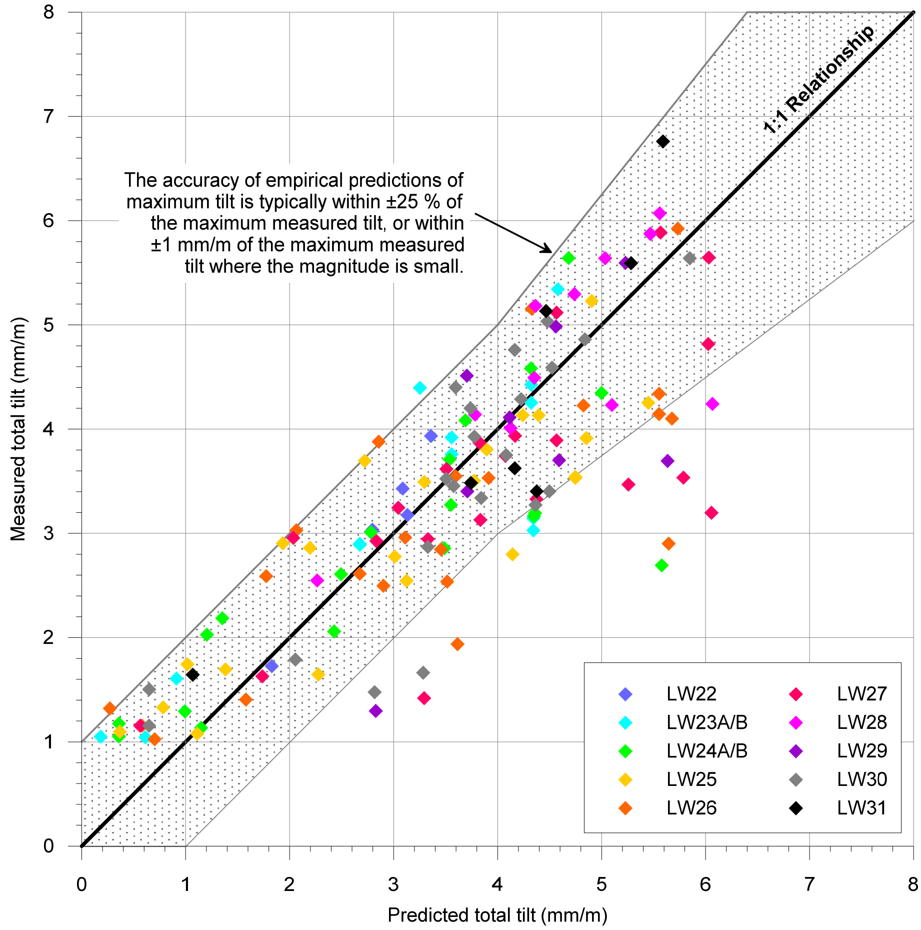

Fig. 3.11 Comparison of maximum measured and maximum predicted total tilts after each of LW22 to LW31

The maximum measured total tilts were typically between ±25 % or ±1 mm/m of the maximum predicted values, or less. It is considered therefore that the calibrated IPM provides reasonable predictions of tilt outside the areas of increased subsidence.

3.6.4. Comparison of measured and predicted curvature

It is more difficult making meaningful comparisons between the measured and predicted curvatures. The reason for this is that survey tolerance can be a large proportion of the measured curvatures and therefore this can result in very irregular profiles. The survey tolerance for relative vertical movements is typically around ±3 mm, which equates to a survey tolerance for curvature of approximately 0.05 km^{-1} over a 20 m bay length. This represents a reasonable proportion of the measured curvatures that are typically in the order of 0.05 km^{-1} to 0.15 km^{-1}.

In order to make meaningful comparisons, the measured curvatures can be derived from smoothed profiles of measured vertical subsidence. The smoothing removes the small deviations that result from survey tolerance, disturbed survey marks and other minor variabilities. The profiles of measured vertical subsidence can be smoothed using Savitzky-Golay or Loess algorithms. These methods remove the localised deviations or variabilities, but they do not reduce the overall maxima. This is illustrated along Brundah Road in Fig. 3.12.

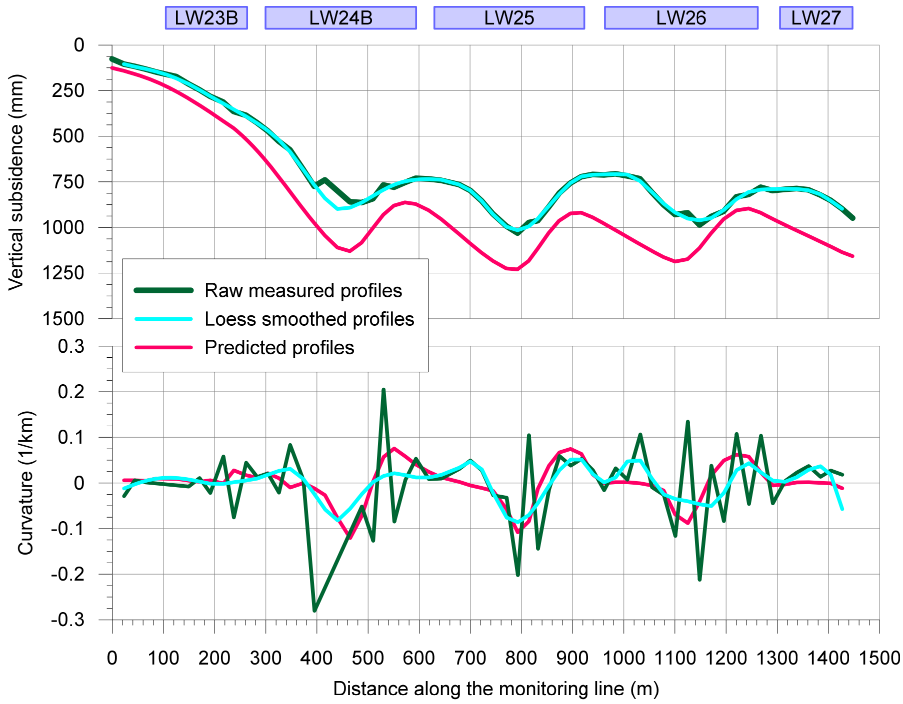

Fig. 3.12 Measured and predicted vertical subsidence and curvature along Brundah Road

The smoothed profile of vertical subsidence, obtained using the Loess algorithm, reasonably matches the raw measured profile of vertical subsidence, but the small deviations have been removed. The smoothed profile has not reduced the maximum values or increased the minimum values.

The profile of raw measured curvature is very irregular due to the small irregularities in the measured vertical subsidence profile resulting from survey tolerance, disturbed survey marks and localised movements. The smoothed profile of curvature derived from the smoothed profile of vertical subsidence more clearly shows the locations of overall hogging curvature and overall sagging curvature, rather than the localised curvatures at each mark.

The profile of predicted curvature reasonably matches the smoothed profile of curvature. The areas of hogging curvature and the areas of sagging curvature reasonably coincide. The maximum predicted curvatures are also similar to the maximum values based on the profile of smoothed curvature. Similar results are obtained for the other monitoring lines.

It is considered therefore that the calibrated IPM provides reasonable predictions of the overall or global curvature along the monitoring lines. Localised irregularities can exceed the predicted values due to survey tolerance, disturbed survey marks and irregular ground movements.

3.7. Areas of increased subsidence compared to the predictions

The extraction of longwalls at the mine has generally resulted in mine subsidence movements that were typical of those observed above other collieries in the Southern Coalfield of NSW at comparable depths of cover.

However, several locations where greater subsidence was observed compared to the predicted values were identified:

- over LW24A and the southern parts of LW25 to LW27, and
- over LW8 and along the 800-Line, and over LW13 and along the 900-Line.

It is not a coincidence that there are many faults and dykes at these locations, that they are near the Nepean Fault and they are near major river valleys or gorges. The extents of these zones of increased subsidence are discussed in more detail below.

3.7.1. Zone of increased subsidence near Nepean Fault and the Bargo River Gorge

During the mining of LW24A at Tahmoor Mine, substantially increased subsidence was observed and further increases in observed subsidence compared to the predicted subsidence was observed during LW25.

These increased levels of subsidence were a very unusual event for the Southern Coalfield and immediate investigations were undertaken to identify why it occurred. The conclusions of these studies were published in 2011 in a paper by W. Gale and I. Sheppard, which advised that the increased levels of subsidence were likely to be associated with the proximity of these areas to the Nepean Fault and the Bargo River Gorge and a recognition of the impact of a weathered zone of joints and bedding planes above the water table, which reduced the spanning capacity of the strata below this highly weathered section. This later recognition was determined after extensive computer modelling of factors that may have caused the increased subsidence.

Further subsidence monitoring has occurred over LW26 and LW27 within and around this zone of increased subsidence since 2011. A summary of the monitoring results over LW24A to LW31 is shown in Table 3.1. It can be noted that the zone of increased subsidence extends over LW24A to LW27, though the extent of the increase in subsidence has reduced in magnitude as each longwall was extracted as shown in the table below. It can also be noted that the maximum observed subsidence only slightly exceeded the maximum predicted for LW28 to LW31, with the difference being within the accuracy of the subsidence prediction methods.

Table 3.1 Maximum measured and maximum predicted incremental and total vertical subsidence within the zones of increased subsidence above LW24A to LW31

Longwall	Assumed average seam thickness extracted in zone (m)	Maximum measured incremental vertical subsidence and proportion of seam thickness (mm)	Maximum predicted incremental vertical subsidence and proportion of seam thickness (mm)	Relative increase in incremental vertical subsidence	Maximum measured total vertical subsidence and proportion of seam thickness (mm)	Maximum predicted total vertical subsidence and proportion of seam thickness (mm)	Relative increase in total vertical subsidence
LW24A	2.20	1169 (53%)	500 (23%)	2.34	1262 (57%)	800 (36%)	1.58
LW25	2.20	1216 (55%)	610 (28%)	2.00	1361 (62%)	900 (41%)	1.51
LW26	2.25	893 (40%)	730 (32%)	1.22	1050 (47%)	900 (40%)	1.17
LW27	2.15	823 (38%)	710 (33%)	1.16	896 (42%)	800 (37%)	1.12
LW28	2.10	755 (36%)	710 (34%)	1.06	827 (39%)	785 (37%)	1.05
LW29	2.10	737 (35%)	700 (33%)	1.05	769 (37%)	725 (35%)	1.06
LW30	2.10	765 (36%)	700 (33%)	1.09	783 (37%)	725 (35%)	1.08
LW31	2.10	776 (37%)	700 (33%)	1.11	811 (39%)	725 (35%)	1.12

Further details of the observed zones of increased and normal subsidence over LW24A to LW27 are shown in longitudinal cross sections along LW24A to LW31 as Fig. 3.13 to Fig. 3.19 and a discussion on these details is presented below.

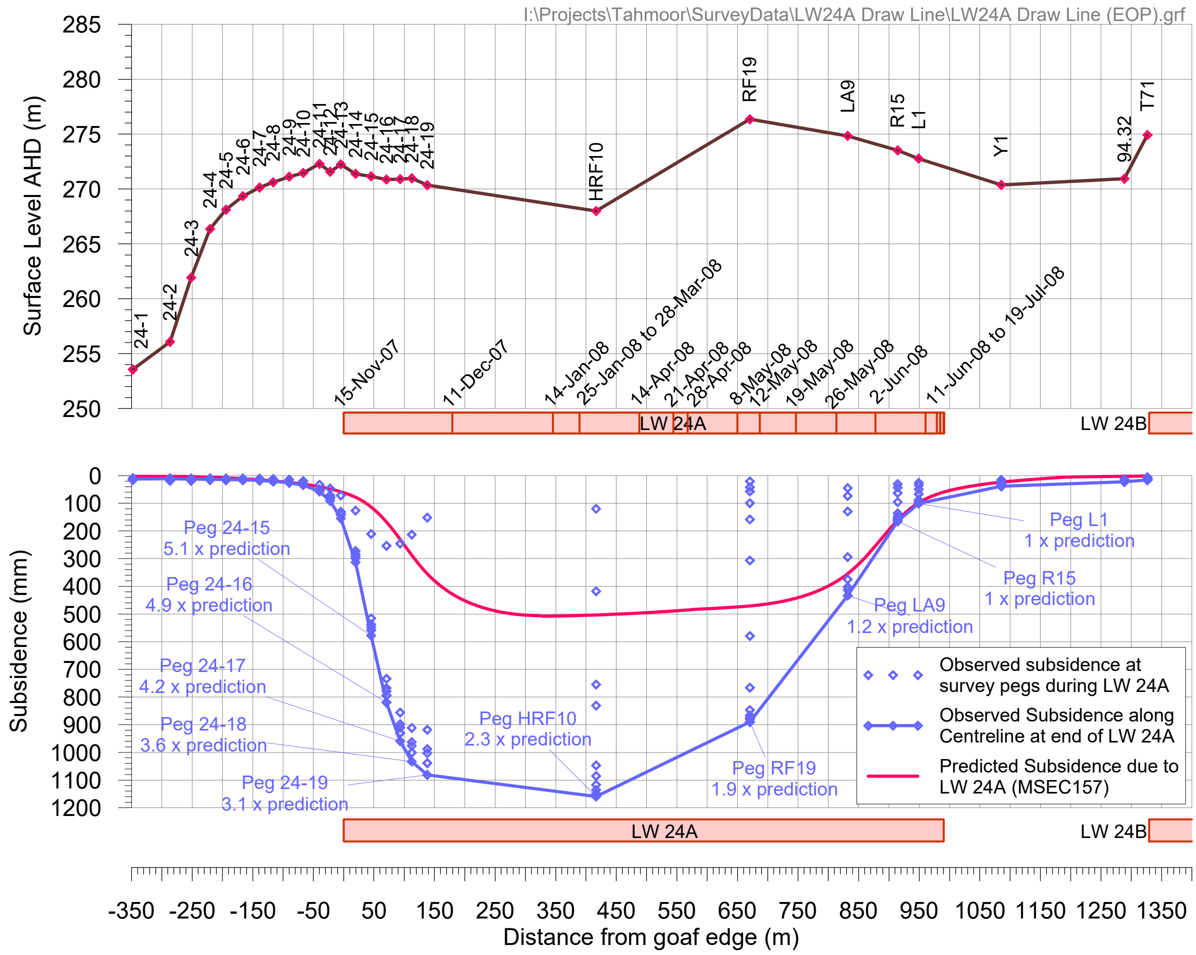

Fig. 3.13 Measured incremental vertical subsidence along the centreline of LW24A

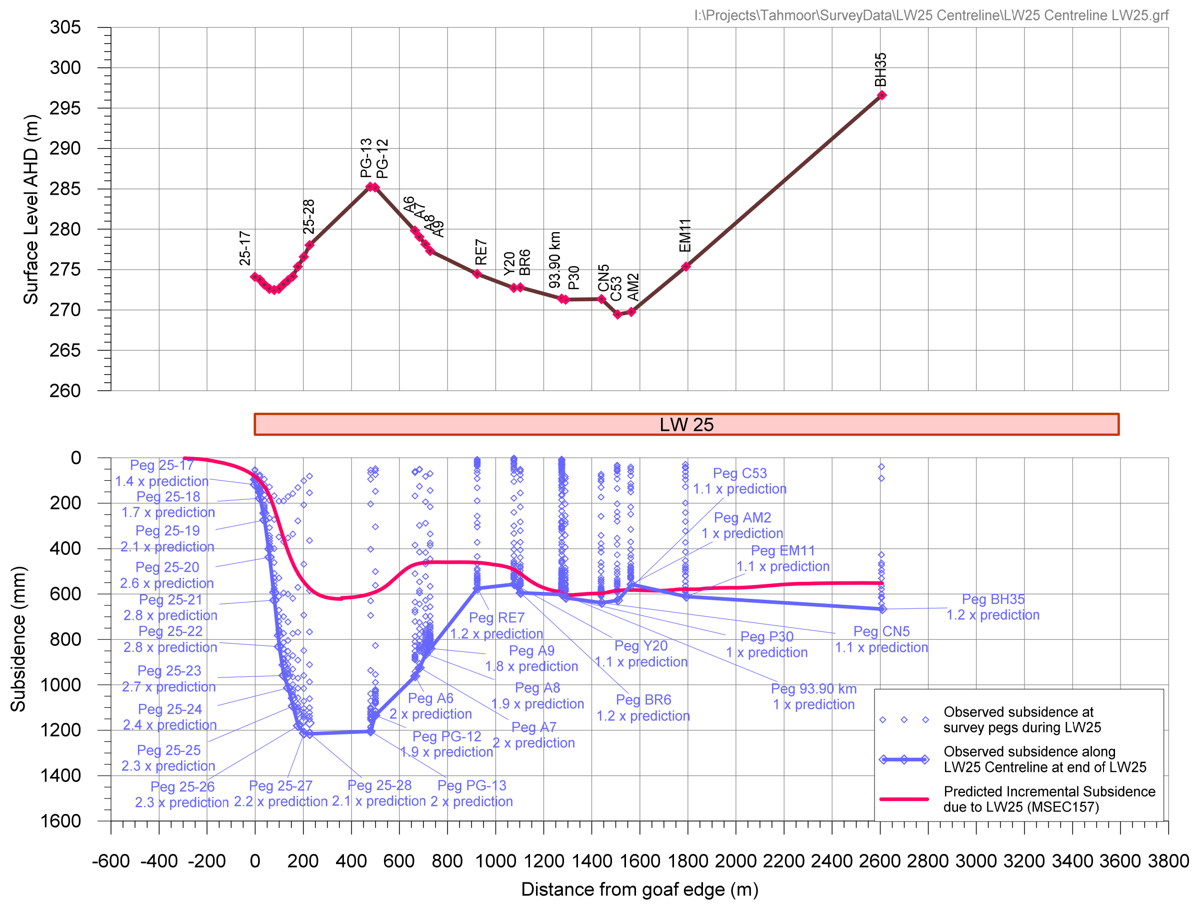

Fig. 3.14 Measured incremental vertical subsidence along the centreline of LW25

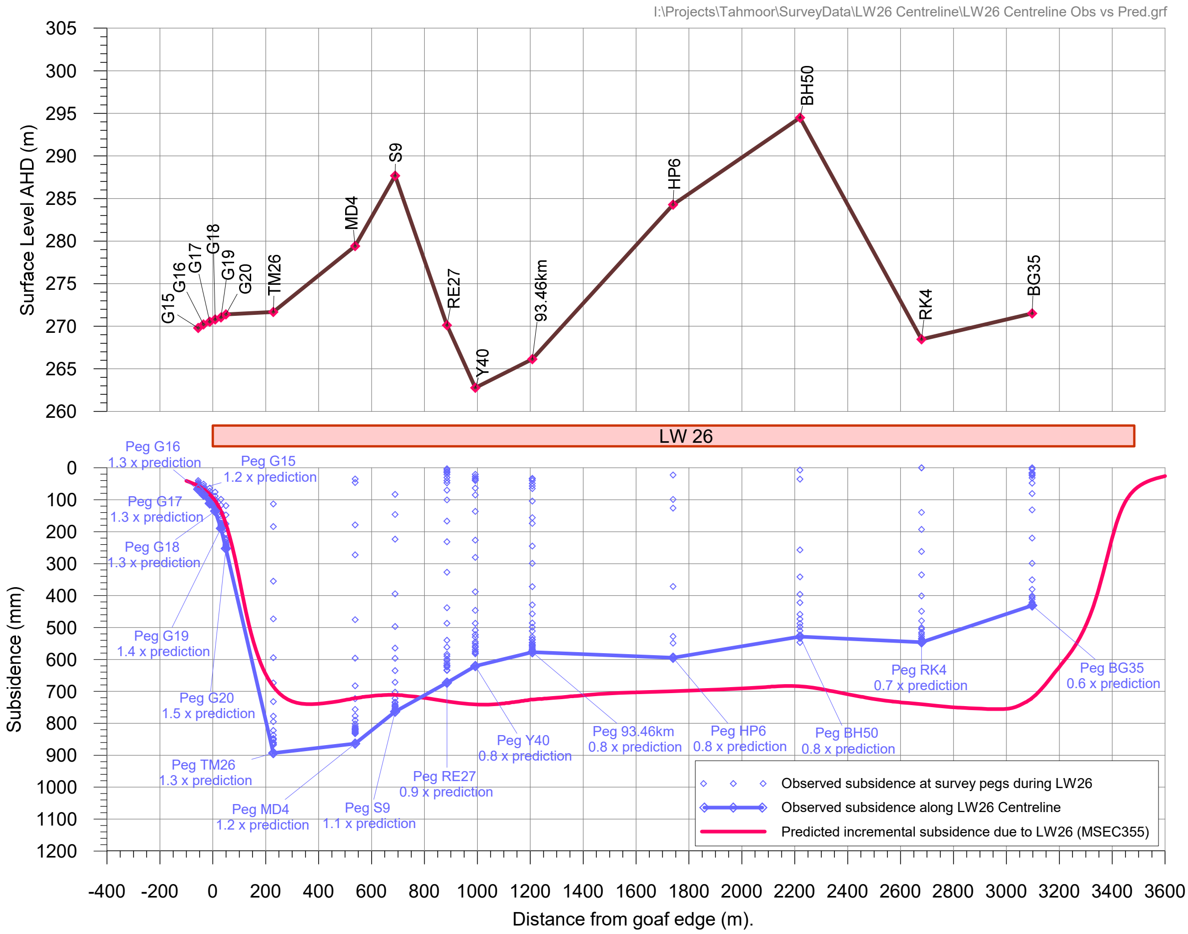

Fig. 3.15 Measured incremental vertical subsidence along the centreline of LW26

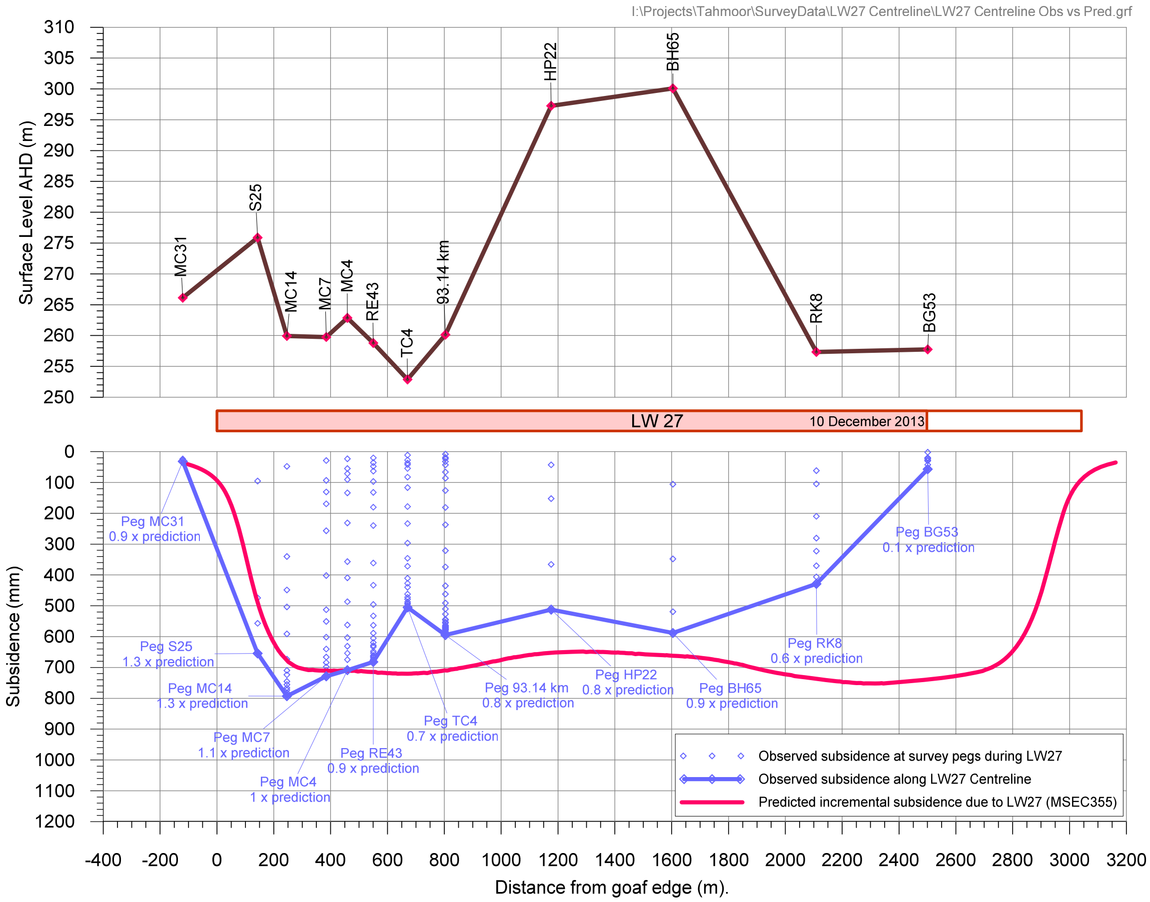

Fig. 3.16 Measured incremental vertical subsidence along the centreline of LW27

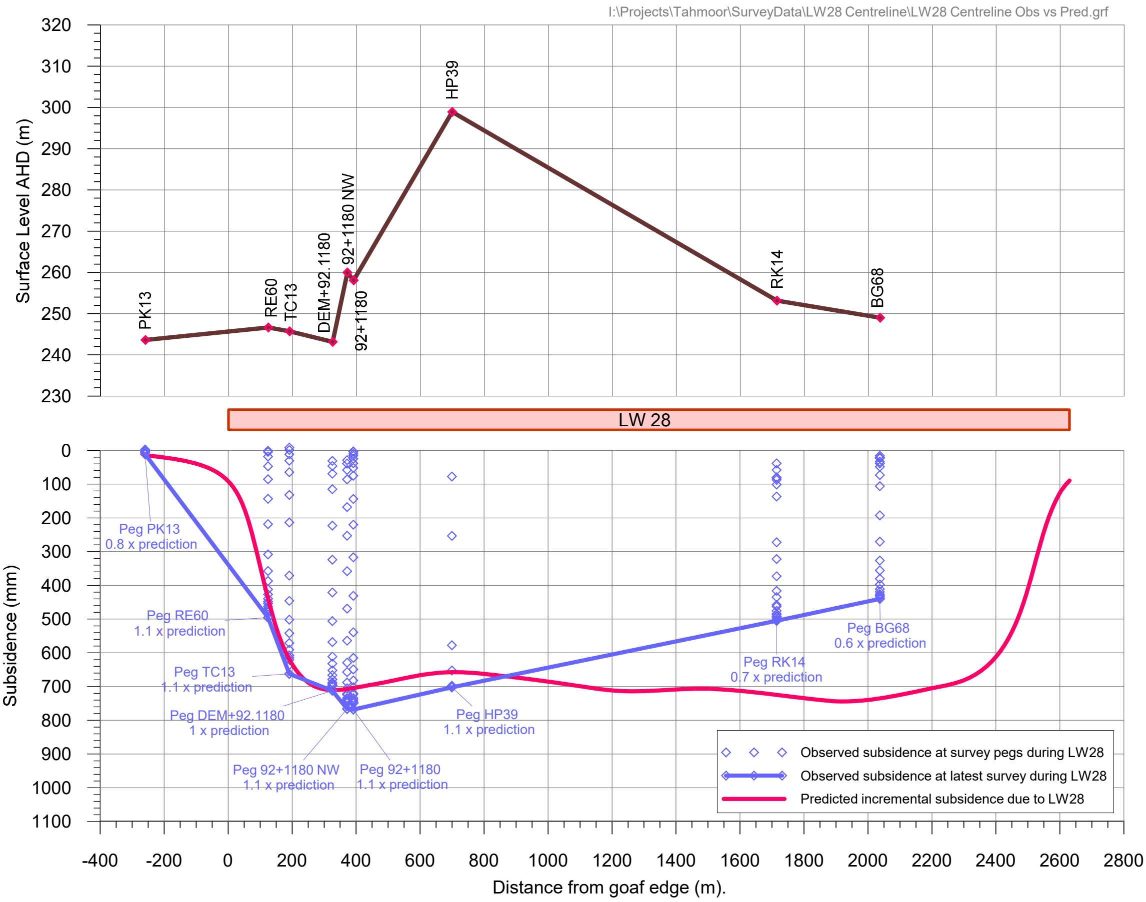

Fig. 3.17 Measured incremental vertical subsidence along the centreline of LW28

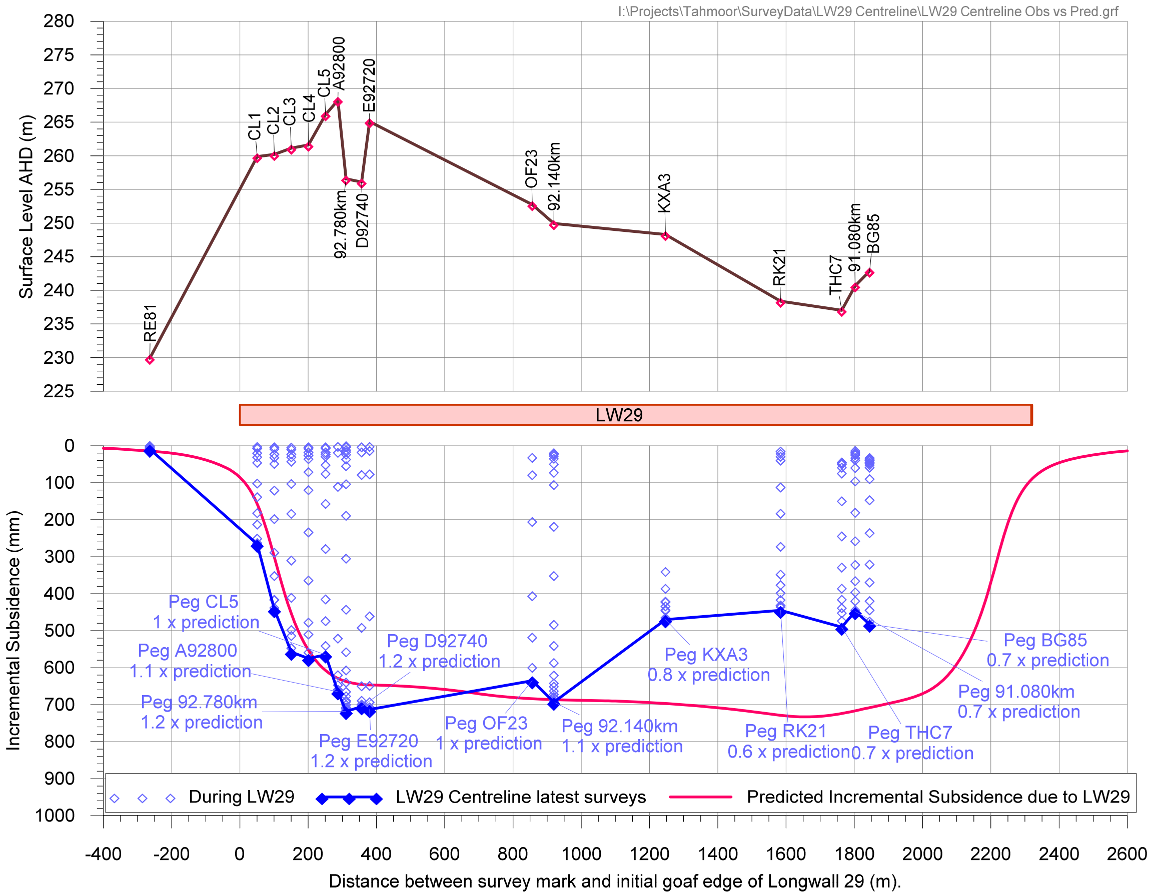

Fig. 3.18 Measured incremental vertical subsidence along the centreline of LW29

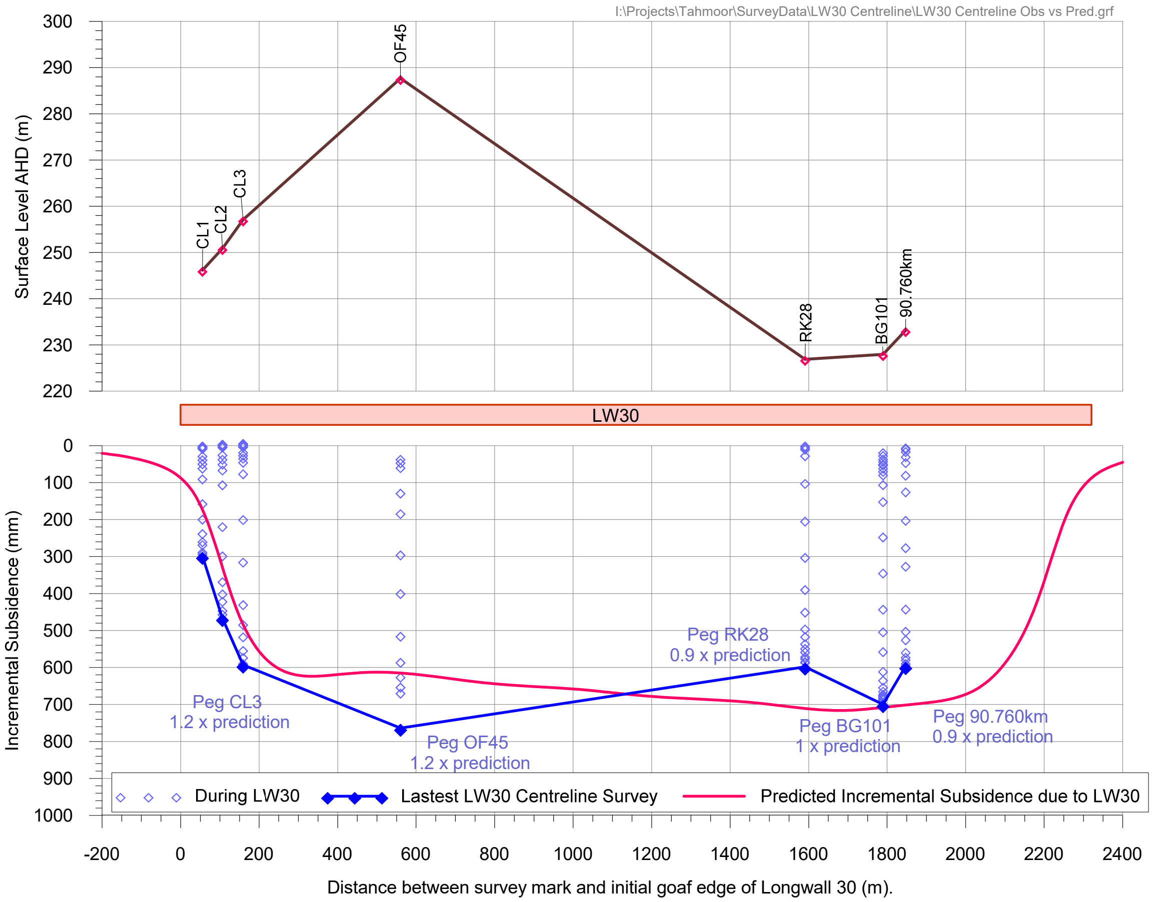

Fig. 3.19 Measured incremental vertical subsidence along the centreline of LW30

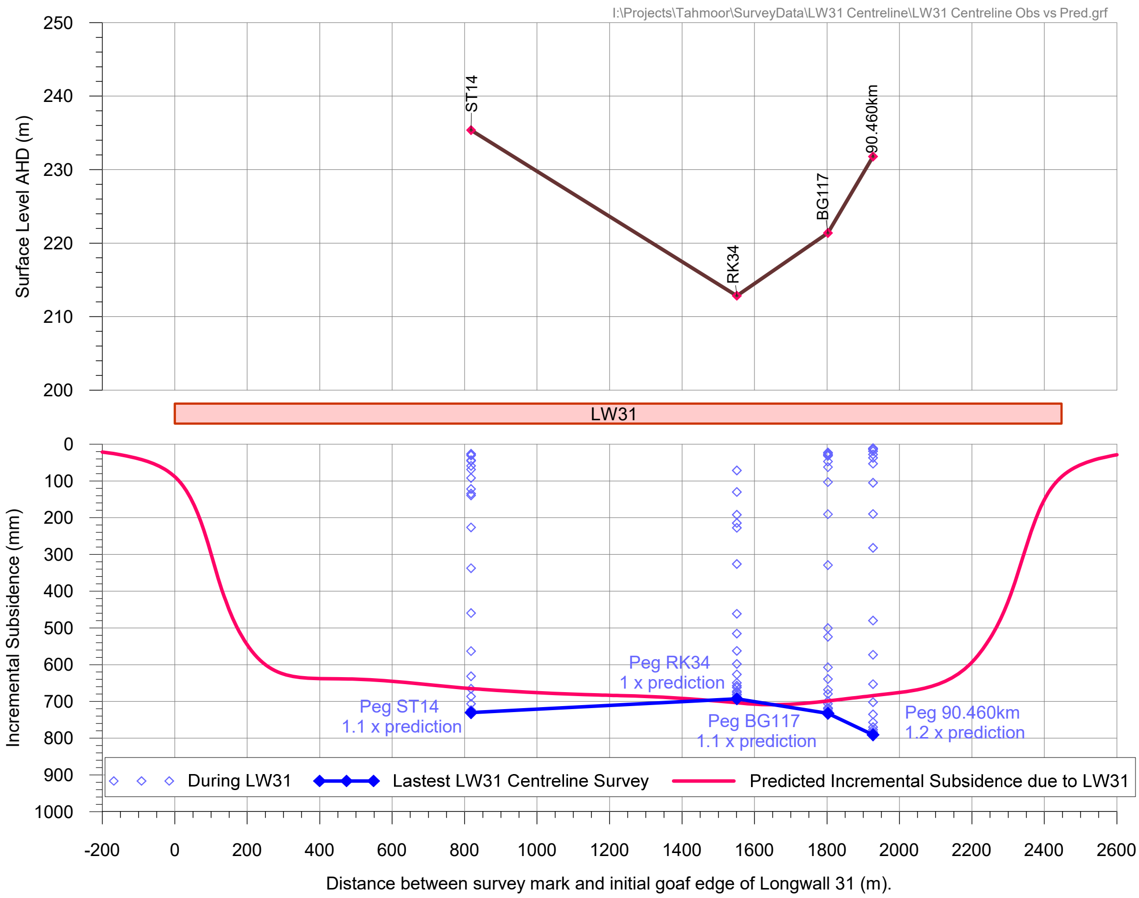

Fig. 3.20 Measured incremental vertical subsidence along the centreline of LW31

Observed increased subsidence during the mining of LW24A

- Fig. 3.13 shows the surface levels, the locations of survey pegs along the centre of LW24A and the observed incremental subsidence profiles at these survey pegs. It can be seen that the greatest increase in observed subsidence was in an area above the southern half of LW24A that is closer to the Bargo River Gorge, closer to the Nepean Fault Zone and within 100 metres of a smaller fault zone that, like several other parallel faults, runs off the Nepean Fault in an en-echelon style and within 140 metres of previous total extraction workings in the 204 panel. The extent of the increased subsidence then gradually reduced in magnitude towards the northern half of the longwall, which was directly beneath the urban area of Tahmoor.
- It can be seen from Fig. 3.13 that the observed subsidence was similar to the predicted levels near Peg R15 on Remembrance Drive. Survey pegs RF19 and LA9 were located within a transition zone where subsidence gradually reduced from areas of maximum increased subsidence to areas of normal subsidence.

Observed increased subsidence during the mining of LW25

- Fig. 3.14 shows the observed incremental subsidence at survey pegs located along the centreline of LW25. It can be seen that the greatest increase in observed subsidence was in an area above the southern half of LW25 that is closer to the Bargo River Gorge and closer to the Nepean Fault Zone.
- The observed incremental subsidence is similar to but only slightly more than was predicted at Peg RE7 and is similar to the prediction at Peg Y20 and at all pegs located further along the panel. Survey pegs A6, A7, A8 and A9 are located within a transition zone where subsidence has gradually reduced from areas of maximum increased subsidence to areas of normal subsidence.

Observed increased subsidence during the mining of LW26

- Fig. 3.15 shows the observed incremental subsidence at survey pegs located along the centreline of LW26. Increased incremental subsidence was observed during the first stages of mining LW26, but at a reduced magnitude compared to the incremental subsidence observed above LW24A and LW25.
- Observed subsidence reduced along the panel until Peg Y40 on York Street, where it was less than prediction. Survey pegs S9 and RE27 are located within a transition zone where subsidence has gradually reduced from areas of maximum increased subsidence between Pegs TM26 and MD4 to areas of normal subsidence at Peg Y40 and beyond.

Observed increased subsidence during the mining of LW27

- Fig. 3.16 shows the observed incremental subsidence at survey pegs located along the centreline of LW27. Increased incremental subsidence was observed during the first stages of miningLW27, but at a reduced magnitude compared to the incremental subsidence observed above LW24A, LW25 and LW26.
- As shown in Fig. 3.16 the observed subsidence reduced along the panel until Peg 93.140 km on the Main Southern Railway. Survey pegs MC4, MC7, RE43 and TC4 are located within a transition zone where subsidence has gradually reduced from areas of maximum increased subsidence between Pegs MC14 and 93.140 km to areas of normal subsidence along the Railway and beyond.

Observed subsidence during the mining of LW28

- Fig. 3.17 shows the observed incremental subsidence at survey pegs located along the centreline of LW28. It can be seen that observed subsidence has returned to normal levels, and within 6 % of subsidence predictions.
- As shown in Fig. 3.17, there is a reasonable correlation between the observed and predicted subsidence profile along the centreline of LW28.

Observed subsidence during the mining of LW29 to LW31

- Tahmoor Coking Coal Operations has completed extraction of LW29 to LW31.
- The experiences observed during this period of time have found that maximum subsidence has continued at a similar level as observed during the mining of LW28.

3.7.2. Analysis and commentary on the zone of increased subsidence over LW24A to LW27

The cause for the increased subsidence was investigated during the extraction of LW25 by Strata Control Technology (SCT) on behalf of Tahmoor Mine as discussed in the previously referenced paper by Gale and Sheppard (2011).

These investigations concluded that the areas of increased subsidence were consistent with localised weathering of joint and bedding planes above a depressed water table adjacent to an incised gorge. This conclusion was further confirmed in further recent report by Gale W. of SCT (2013a), who confirms that:

> "*Longwall panels 24A and 25 both show increased maximum subsidence to approximately 1.0-1.2m, where predicted subsidence was in the order of 0.5 - 0.8m. In the study by Gale and Sheppard, (2011), it became apparent that the increased subsidence is likely to be due to reduction in joint friction and stiffness due to the weathering process in the strata above the water table where the water table is considerably lower due to the Bargo Gorge. The intact rock properties were not changed, only the properties of the joints were altered*."

There have been many locations where monitoring near faults has revealed little increase of observed subsidence and there are many locations where monitoring near deep gorges and valleys has revealed little increase in observed subsidence. In summary, it appears that the location of the zones of increased subsidence is linked to both the;

- close proximity and the alignment of the Nepean Fault, which is within 1,000 metres of these zones, and,
- close proximity to the Bargo River Gorge, which is approximately 100 metres deep, within 700 metres of these zones. The presence of the Bargo River Gorge has permitted groundwater flows to weather the joint and bedding plane properties of the surrounding strata.

In light of the above conclusions and observations, three areas or zones have been identified from the observed subsidence monitoring above the extracted LW24A to LW27 at the mine:

- Maximum increased subsidence zone – where the observed vertical subsidence is substantially greater than the predicted subsidence.
- Transition zone – where the subsidence behaviour appears to be transitioned between areas of maximum increased subsidence and normal subsidence.
- Normal subsidence zone – where the observed vertical subsidence is within the normal range and correlates well with predictions.

The locations of the three zones were plotted on a plan using the surveyed pegs that were identified along the centrelines above LW24A to LW31 as a guide. This plan, Fig. 3.21, shows that the transition zone is roughly consistent in width above LW24A, LW25 and LW26 and possibly slightly narrower above LW27. The orientation of the transition zone is also roughly parallel to the Nepean Fault and the magnitude of the increased subsidence above LW26 and LW27 is reduced compared to LW24A and LW25. There was little to no increased subsidence identified above LW28 to LW31.

It can be seen in Fig. 3.21, that as the alignment of the Nepean Fault moved further away from the Bargo River gorge and above LW26 and LW27, the magnitude of increased subsidence reduced, indicating that the cause of the movements is clearly linked to the proximity of the Bargo River. This observation confirms the findings of Gale and Sheppard (2011) that the increased subsidence is linked to localised weathering of joint and bedding planes above a depressed water table adjacent to the incised gorge of the Bargo River and the presence of the major fault.

The interpolated location of the Nepean Fault within the Tahmoor North lease has recently been updated for Tahmoor Mine by SCT (2018). The revised mapping describes the Nepean Fault as comprising a series of en echelon faults, rather than one continuous geological structure.

The change in understanding of the Nepean Fault is significant because the finding could provide an alternative explanation for the observed return to normal subsidence above LW28 to LW30, as the fault linked to increased subsidence above LW24A to LW27 terminated beyond LW29.

Prior to the mining of LW32, it was therefore considered possible that subsidence might return to higher than normal levels during the mining of LW32. It was noted, however, the observations above previously extracted LW30 and LW31 indicate that subsidence has been developing close to normal levels. Recently received monitoring results during the mining of LW32 has found that increased subsidence has developed above the commencing end of LW32 at levels similar to those observed above LW26. It also appears that the magnitude of subsidence is reducing along the panel as the longwall face progresses.

LW W1-W2 are located further away from the Nepean Fault and its associated geological structures than LWs 24A to 32. The potential for increased subsidence to occur is therefore considered to be low.

It is therefore recommended that monitoring be conducted during the early stages of extraction of LW W1 to compare observations with predictions. TCCO has extensive experience in successfully managing potential subsidence impacts on surface features, even when actual subsidence is substantially greater than the magnitudes that have been predicted above single panel LW W1. It is recommended that subsidence management plans be developed to manage potential impacts that could occur if greater than predicted subsidence occurs.

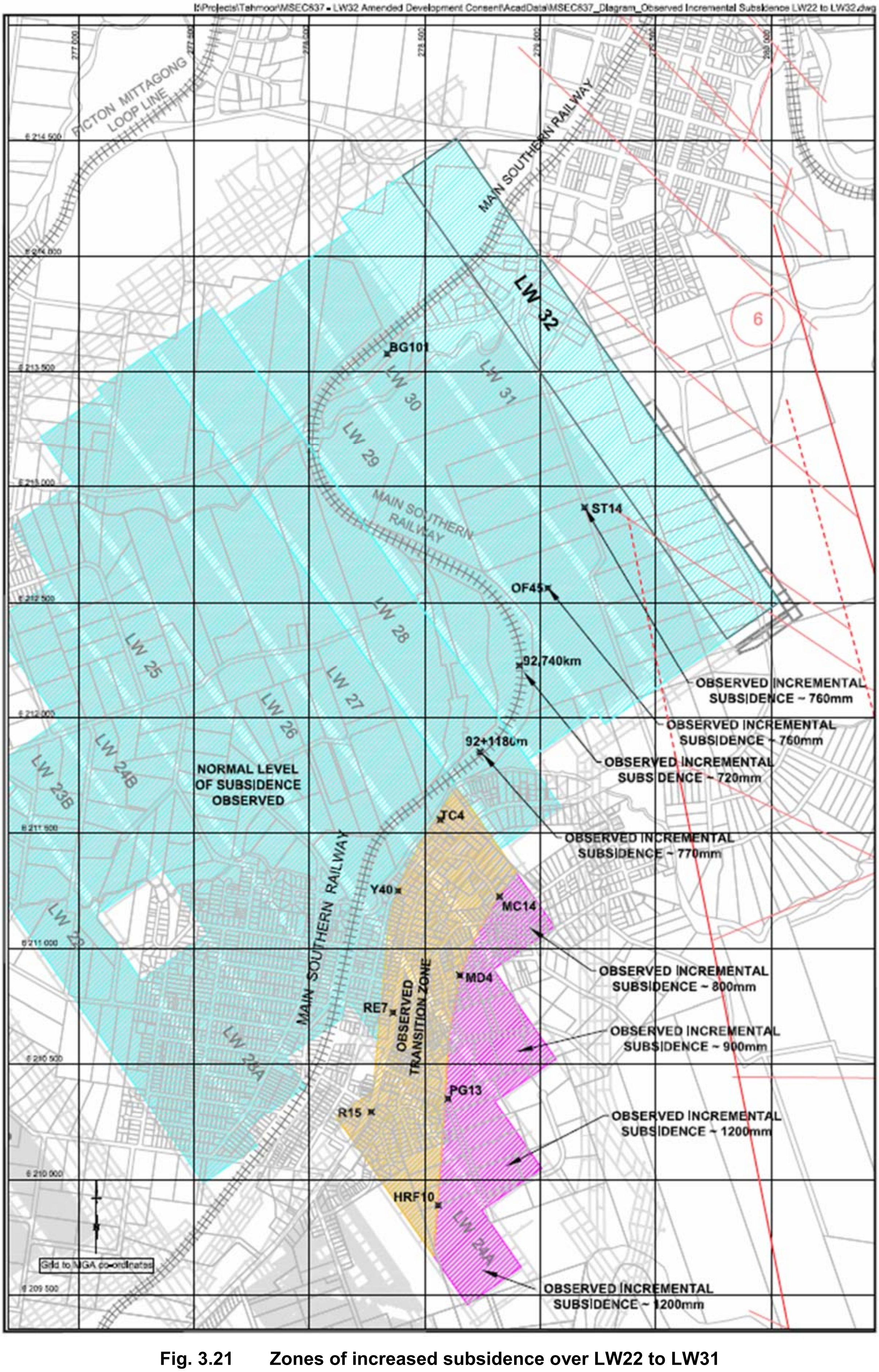

Fig. 3.21 Zones of increased subsidence over LW22 to LW31

3.8. Numerical model

A numerical model has been developed for the mine using Universal Distinct Element Code (UDEC). This method is a two-dimensional Discrete Element Method (DEM) comprising deformable elements that interact via compliant contacts (Itasca, 2015). The numerical modelling has been undertaken to supplement the predictions obtained using the empirical IPM.

The UDEC model has been derived from the *base model* that was developed for the Southern Coalfield for mining in the Bulli Seam (Barbato, 2017). The numerical model has been updated for the local stratigraphy (refer to Section 1.8) and has been calibrated for the local mining conditions using the available ground monitoring data.

3.8.1. Calibration of the UDEC model

The UDEC model has been calibrated using the available ground monitoring from LW22 to LW31. The void widths of these existing longwalls are 283 m and the solid chain pillar widths vary between 35 m and 40 m. The depths of cover to the Bulli Seam vary between 420 m and 500 m, with an average of 450 m. The width-to-depth ratios for the existing longwalls vary between 0.48 and 0.67, with an average of 0.63. The maximum mining height was 2.1 m.

The element (i.e. block) size adopted in the numerical model has been based on Block Type B1 for the *base model* (refer to Section 6.4.3.1 of Barbato, 2017). Minor adjustments of the element sizes have been made to suit the depths of each stratigraphic unit. The element aspect ratio has been taken as 1.5:1.0 (H:V) as per the *base model*.

The horizontal *in situ* stress has been based on Stress Type S2 for the *base model* (refer to Section 6.4.4 of Barbato, 2017). The stress at the surface is 1.5 MPa and the stress gradient through the overburden strata is 36 kPa/m.

The parametric analysis of the *base model* (refer to Section 6.9 of Barbato, 2017) showed that the appropriate material and joint properties are dependent on the other properties adopted in the numerical model, including the element size and aspect ratio. The appropriate properties are also dependent on the depth of cover and mining height, as these affect the relative contributions of vertical subsidence due to sagging of the overburden strata and pillar compression.

The material and joint properties have been calibrated for the local conditions using the available ground monitoring data. The initial calibration of the numerical model using the ground monitoring data from Areas 3A and 3B at the Mine found that the *base model* (i.e. Material Type M1 and Joint Type J2) underpredicted the vertical subsidence above the longwalls and the chain pillars.

The magnitudes and the profiles of vertical subsidence obtained from the numerical model better matched those measured in Area 3A by adopting joint strength parameters (i.e. cohesion and friction angle) that were 85 % of those used in the *base model*. The bulking ratio in the caving zone was also reduced from 1.03 to 1.01 to account for the seam roof comprising the Wombarra Claystone rather than the Coal Cliff Sandstone.

A comparison between the modelled and measured vertical subsidence are illustrated in Fig. 3.22 based on the Bridge Street monitoring line and in Fig. 3.23 based on the Railway Deviation monitoring line. The monitoring data have been normalised so that the distances are transverse to the longwalls so as to match the UDEC model.

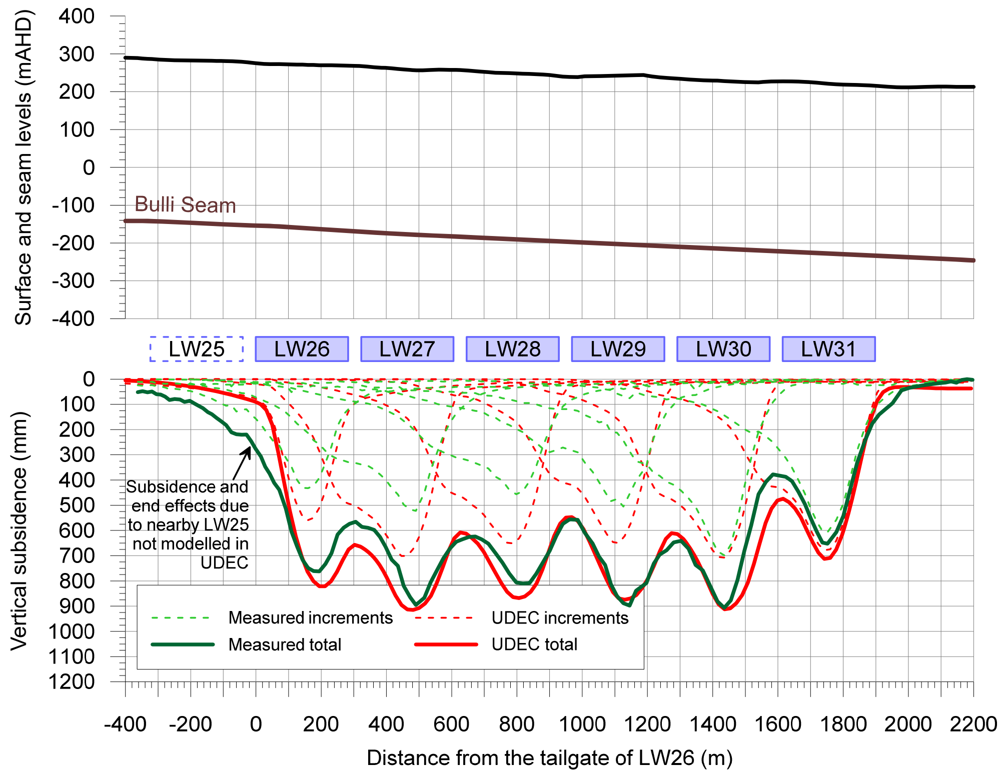

Fig. 3.22 Comparison of modelled and measured vertical subsidence along Bridge Street

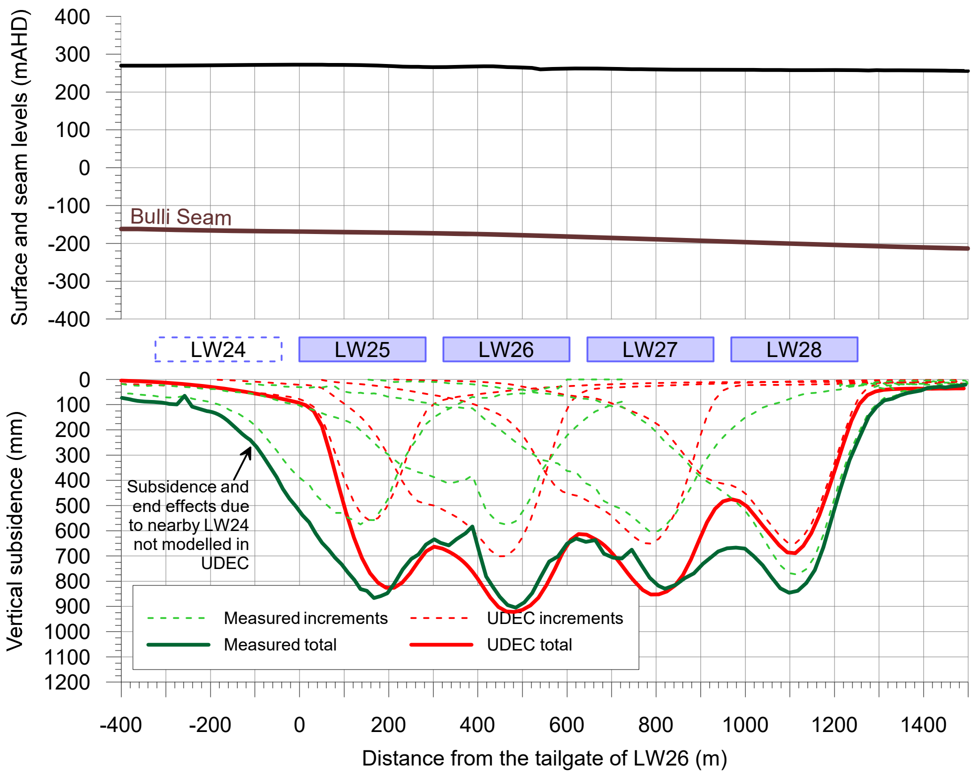

Fig. 3.23 Comparison of modelled and measured vertical subsidence along the Railway Deviation

It is considered that the profiles of vertical subsidence obtained from the UDEC model reasonably match the measured profiles along the Bridge Street and Railway Deviation monitoring lines. The numerical model slightly overpredicts the vertical subsidence adjacent to the tailgate of LW26 along Bridge Street and adjacent to the tailgate of LW25 along the Railway Deviation. However, these exceedances occurred due to subsidence from other adjacent longwalls that were not included in the numerical model.

3.8.2. UDEC model for LW W1-W2

The widths of LW W1-W2 are 283 m and the solid pillar widths are 40 m. The edges of the numerical model have been taken as 600 m from the nearest longwall edges. The overall width of the model therefore is 1806 m. The average depth of cover to the Bulli Seam along the centreline of the proposed longwalls is 500 m. The width-to-depth ratio of each of the proposed longwalls therefore is 0.57. It is proposed that the longwalls will extract a constant height of 2.1 m.

A summary of the stratigraphy adopted in the UDEC model is provided in Table 3.2. The element sizes have been based on Block Type B1 of the *base model*, with minor adjustments to suit the depths of each stratigraphic unit.

Table 3.2 Stratigraphy adopted in the UDEC model

Unit	Thickness (m)	Depth to base on unit (m)	Block size (H x V, m x m)
Wianamatta Group	20	20	6.0 x 4.0
Hawkesbury Sandstone	170	190	15.0 x 10.0
Newport/Garie Formations	20	210	7.5 x 5.0
Bald Hill Claystone	30	240	7.5 x 5.0
Bulgo Sandstone	180	420	15.0 x 10.0
Stanwell Park Claystone	10	430	7.5 x 5.0
Scarborough Sandstone	60	490	15.0 x 10.0
Wombarra Claystone	10	500	7.5 x 5.0
Bulli Coal	3	503	1.5 x 1.0
Sub-Bulli	100	603	15.0 x 10.0

Summaries of the material and joint properties adopted in the UDEC model are provided in Table 3.3 and Table 3.4, respectively. The joint normal stiffness and shear stiffness have been taken as 30 GPa/m and 3 GPa/m, respectively. The parameter analysis of the joint stiffness properties found that the numerical model is not sensitive to these two parameters (refer to Section 6.9.4 of Barbato, 2017).

Table 3.3 Material properties adopted in the UDEC model

Unit	Density (kg/m^3)	Bulk modulus (GPa)	Shear modulus (GPa)	Cohesion (MPa)	Friction angle (deg.)	Tensile strength (MPa)
Wianamatta Group	2700	5.00	2.32	6.0	25	0.5
Hawkesbury Sandstone	2400	3.33	2.00	7.0	34	0.5
Newport/Garie Formations	2400	3.45	2.48	4.0	30	0.5
Bald Hill Claystone	2700	5.0	2.31	6.0	25	0.5
Bulgo Sandstone	2500	5.56	4.17	10	30	0.5
Stanwell Park Claystone	2700	6.17	4.07	9.0	30	0.5
Scarborough Sandstone	2500	7.47	5.37	7.0	38	0.5
Wombarra Claystone	2600	6.90	4.96	10	25	0.5
Bulli Coal	1500	1.54	0.97	2.0	25	0.5
Sub-Bulli	2500	8.00	4.80	15	25	0.5

Table 3.4 Joint properties adopted in the UDEC model

Unit	Cohesion (MPa)		Friction angle (deg.)	
	Peak	Residual	Peak	Residual
Wianamatta Group	2.34	1.40	18.0	10.8
Hawkesbury Sandstone	2.13	1.28	21.1	12.7
Newport/Garie Formations	1.91	1.15	20.4	12.2
Bald Hill Claystone	2.34	1.40	18.0	10.8
Bulgo Sandstone	3.83	2.30	20.4	12.2
Stanwell Park Claystone	2.34	1.40	20.4	12.2
Scarborough Sandstone	2.76	1.66	22.1	13.3
Wombarra Claystone	2.55	1.53	18.7	11.2
Sub-Bulli	3.61	2.17	18.7	11.2

The modelled profiles of vertical subsidence obtained from the UDEC model for the proposed LW W1-W2 are illustrated in red in Fig. 3.24. The predicted profiles based on the IPM are shown in blue in this figure for comparison.

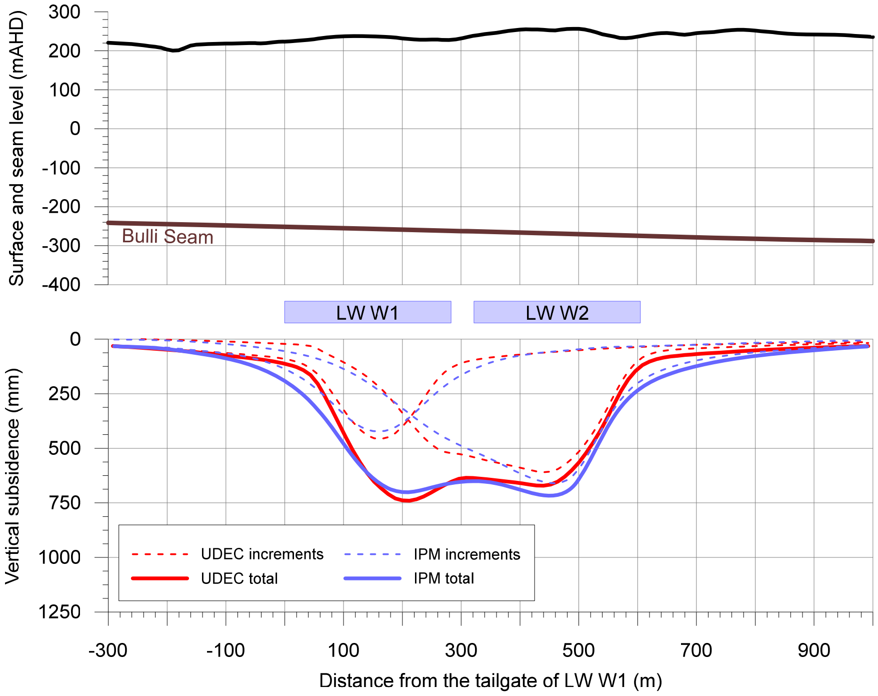

Fig. 3.24 Modelled profiles of vertical subsidence for the proposed LW W1-W2

The profiles of vertical subsidence obtained from the UDEC model reasonably match those predicted using the IPM. The maximum vertical subsidence directly above each of the proposed longwalls are reasonably similar, with the magnitudes being within ±15 %. The numerical model predicts slightly less vertical subsidence above the tailgate of LW W1 and above the maingate of LW W2 compared with that obtained from the IPM.

The maximum predicted tilts and curvatures obtained from the UDEC model are similar to the maximum predicted values based on the IPM. The numerical model predicts slightly higher tilt and curvature above the tailgate of LW W1 due to the lower vertical subsidence in this location.

It is considered that the profiles of vertical subsidence obtained from the UDEC model reasonably match those predicted using the IPM. It is not considered necessary, therefore, to further calibrate the IPM based on the outcomes of the numerical model.

The modelled profiles of vertical subsidence and horizontal movement through the overburden strata are illustrated in Fig. 3.25. The profiles have been taken through the centreline of LW W2, midway between the centreline and tailgate (referred to as the quarter point) and at the tailgate of this longwall.

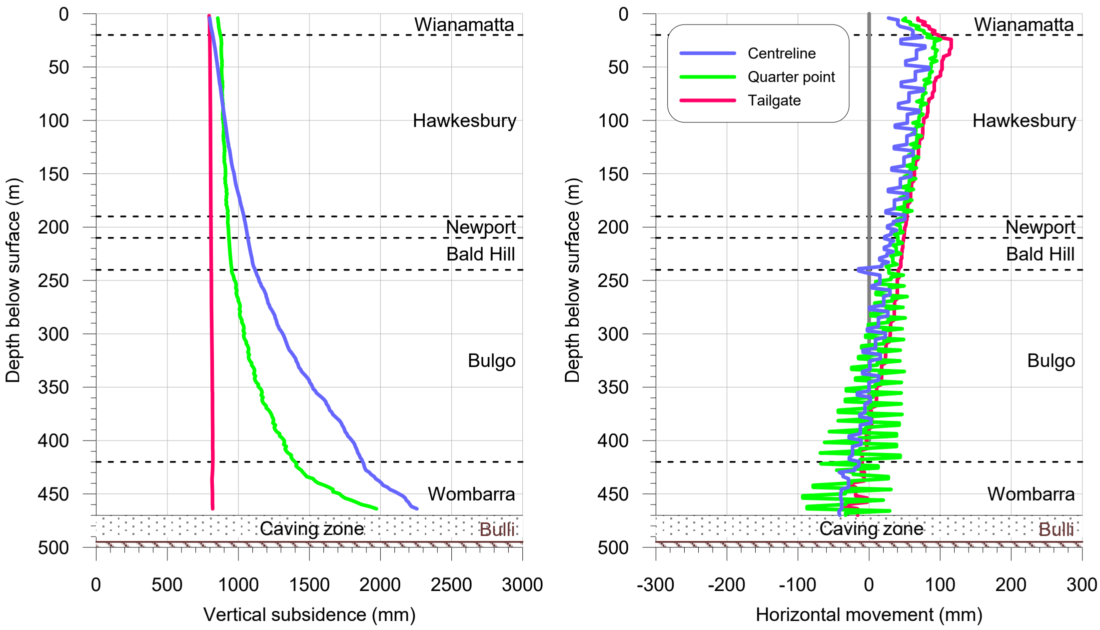

Fig. 3.25 Modelled profiles of vertical subsidence and horizontal movement through the overburden at the centreline, quarter point and tailgate of LW W2

The vertical subsidence at the longwall centreline varies between 35 % of the mining height at the surface through to 100 % of the mining height at the caving zone. The vertical subsidence adjacent to the longwall tailgate is 30 % of the mining height through most of the overburden.

The vertical strain (over a 20 m height) within the Hawkesbury Sandstone varies between approximately 0.5 mm/m at the surface and 2 mm/m at the base of the unit. The maximum vertical strain within the Hawkesbury Sandstone occurs at the longwall centreline with the strains reducing towards the longwall maingate and tailgate.

The vertical strain within the Bulgo Sandstone, at the longwall centreline, varies between approximately 3 mm/m at the top, 6 mm/m near mid-height and 4 mm/m at the base of the unit. The vertical strain at the quarter-points of the longwall vary between approximately 2 mm/m at the top and 12 mm/m at the base of the Bulgo Sandstone.

The vertical strain within the Wombarra Claystone varies between 12 mm/m and 16 mm/m. The maximum vertical strain occurs at the longwall quarter-points with the strains reducing towards the longwall centreline, maingate and tailgate. The vertical strains within the Newport Formation and the Bald Hill Claystone are typically less than 2 mm/m.

The horizontal shear on the bedding plane partings is approximately 20 mm within the Hawkesbury Sandstone and varies between 40 mm and 120 mm within the Bulgo Sandstone. The maximum horizontal shear occurs at the quarter point within the Bulgo Sandstone.

It is noted that the magnitudes of horizontal shear are dependent on their spacings. Hence, fewer but larger horizontal shears, or more but smaller horizontal shears could develop compared with that predicted, depending on their actual spacing.

3.9. Review of the measured and predicted valley related effects at TCCO

The predicted upsidence and closure movements for the longwalls at TCCO have been obtained using the empirical method outlined in Australian Coal Association Research Program (ACARP) Research Project No. C9067 (Waddington and Kay, 2002), referred to as the 2002 ACARP method. The comparisons between the measured and predicted valley related effects for the previously extracted longwalls at the colliery have been provided in the following sections.

3.9.1. Myrtle Creek and the Skew Culvert

Detailed ground monitoring was undertaken where Myrtle Creek and a tributary to this creek (referred to as the Skew Culvert) crosses beneath the Main Southern Railway above Longwalls 26 and 27. A map showing the monitoring lines in these locations is shown in Fig. 3.26.

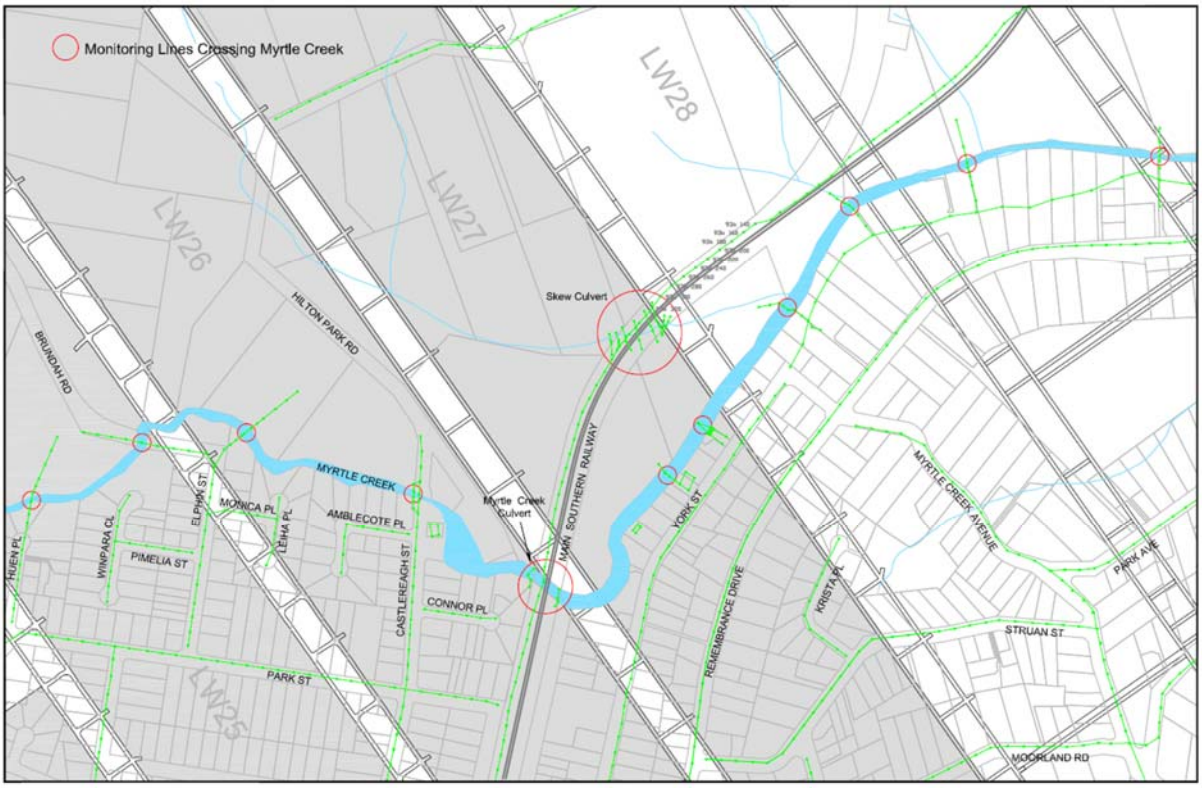

Fig. 3.26 Monitoring lines across Myrtle Creek and the Skew Culvert

The development of valley closure at each of the monitoring lines across the Myrtle Creek, during the extraction of Longwalls 24B to 27, are illustrated in Fig. 3.27.

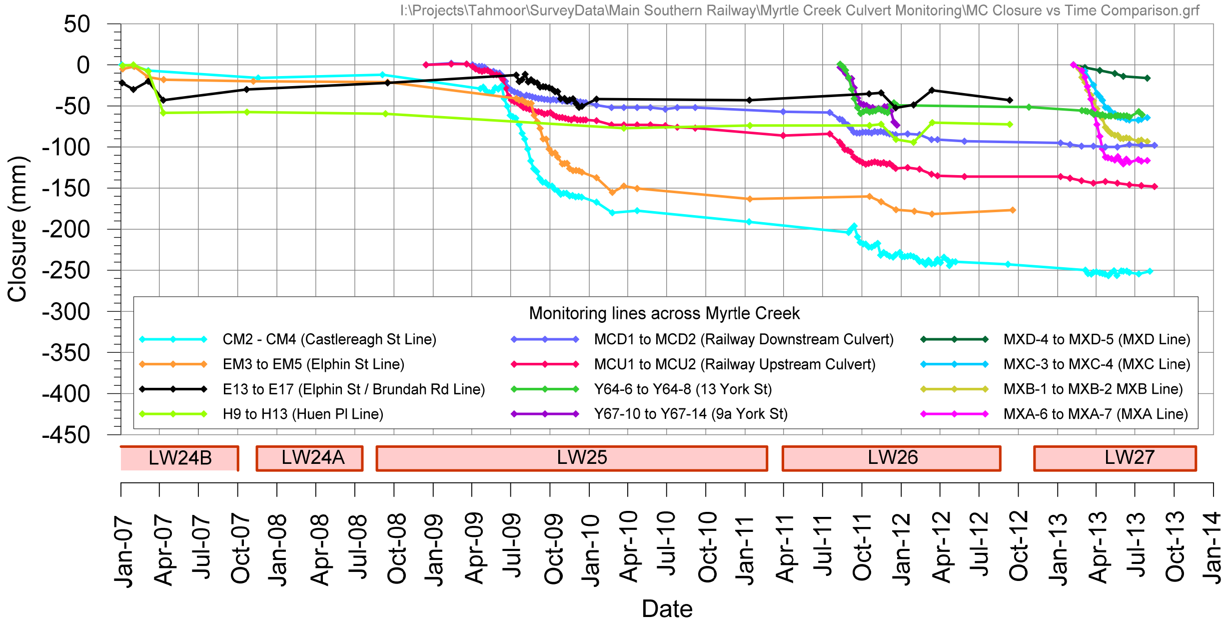

Fig. 3.27 Development of closure across Myrtle Creek during LW24B to LW27

The development of valley closure at each of the monitoring lines across the creek at the Skew Culvert, during the extraction of LW26 and LW27, are shown in Fig. 3.28.

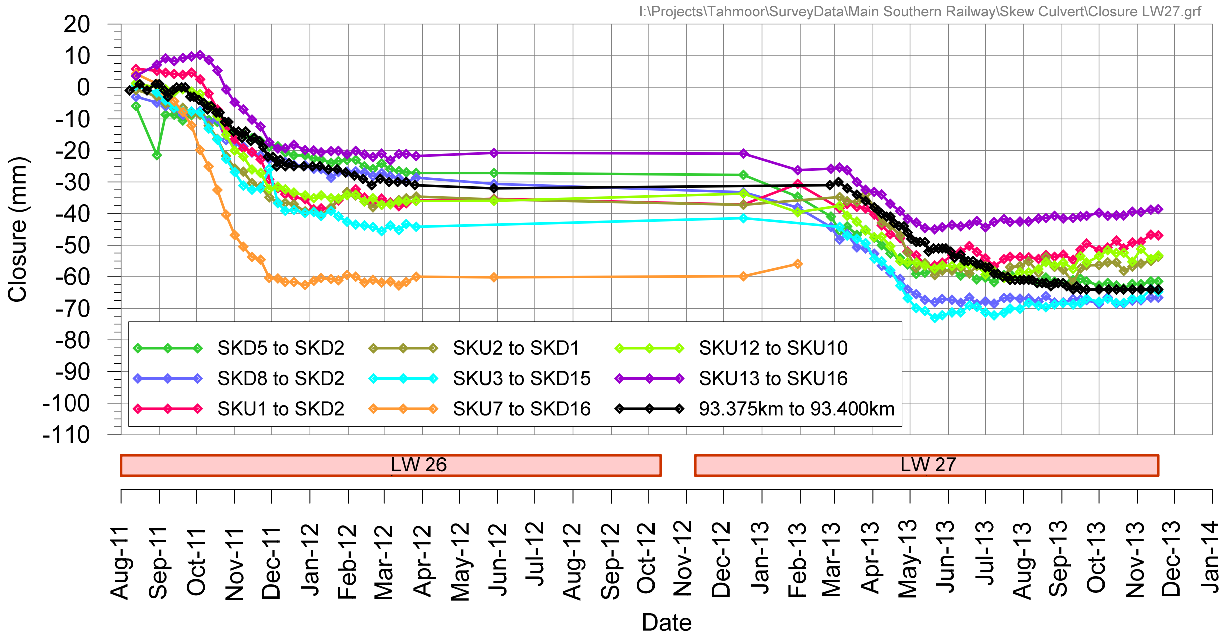

Fig. 3.28 Development of closure across the Skew Culvert during LW26 and LW27

A summary of the predicted and measured incremental closure across Myrtle Creek and the Skew Culvert is provided in Table 3.5. The predictions are consistent with those provided in Report No. MSEC355, which supported the SMP Application for Tahmoor LW27 to LW30.

Table 3.5 Predicted and measured incremental closure at the monitoring lines across Myrtle Creek and the Skew Culvert

Location	Category	Predicted and measured valley closure due to the mining of each longwall (mm)			
		Due to LW24	Due to LW25	Due to LW26	Due to LW27
Castlereagh Street (Pegs CM2 to CM4)	Predicted	30	55	45	25
	Measured	12	179	52	8
Elphin-Myrtle (Pegs EM3 to EM5)	Predicted	60	70	40	-
	Measured	21	142	22	-
Elphin St / Brundah Rd (Pegs E13 to E17)	Predicted	75	75	30	-
	Measured	0	21	6	-
Huen Place (Pegs H9 to H13)	Predicted	60	35	15	-
	Measured	58	15	20	-
Main Southern Railway Upstream (MCU1 to MCU4) Downstream (MCD1 to MCD4)	Predicted	15	30	30	15
	Measured	-	57 (d/s) to 86 (u/s)	36 (d/s) to 50 (u/s)	5 (d/s) to 12 (u/s)
Skew Culvert (8 cross-sections)	Predicted	< 5	10	25	25
	Measured	-	-	21 to 60 (average 36)	8 to 36 (average 21)
13 York Street (Pegs Y64-6 to Y64-8)	Predicted	-	-	65	50
	Measured	-	-	51	9
9a York Street (Pegs Y67-10 to Y67-14)	Predicted	-	-	85	85
	Measured	-	-	73	No access
MXA Line (Pegs MXA-6 to MXA-7)	Predicted	-	-	-	150
	Measured	-	-	-	116
MXB Line (Pegs MXB-1 to MXB-2)	Predicted	-	-	-	170
	Measured	-	-	-	93
MXC Line (Pegs MXC-3 to MXC-4)	Predicted	-	-	-	150
	Measured	-	-	-	64
MXD Line (Pegs MXD-4 to MXD-5)	Predicted	-	-	-	50
	Measured	-	-	-	16

It can be seen from the above table, that the measured valley closure has substantially exceeded predictions at the Castlereagh Street crossing, at the crossing of the Elphin-Myrtle monitoring line and, to a lesser extent, the crossing of the Main Southern Railway during the mining of LW25. It is considered that the reason for the differences in observations may be linked to the change in orientation of Myrtle Creek as the three above-mentioned monitoring lines are located along the same stretch of Myrtle Creek. It is noted, however, that substantially less closure has developed at Castlereagh Street than predicted during the mining of LW27.

The measured valley closure across the creek at the Skew Culvert has also slightly exceeded predictions, where the differences between predicted and measured closure are relatively small for most cross sections.

The measured valley closure across Myrtle Creek where it flows directly above LW27 (MXA to MXC lines) has been less than predicted, but greater in magnitude than that measured across monitoring lines upstream of LW27. This was expected because the valley is deeper compared to sections further upstream.

3.9.2. Redbank Creek

Detailed ground monitoring has been undertaken along Redbank Creek during the extraction of LWs 26 to LW31. The ability to survey valley closure across the creek was constrained as access was not provided by some landowners located adjacent to the creek. There was no access to the creek from the northern bank and limited access on the southern bank of the Redbank Creek.

Ground surveys were undertaken in relative 3D from Bridge Street to a monitoring line that is located in cleared pasture land along the top of the valley, as shown in Fig. 3.29. This has provided measurements of total valley closure. Some survey pegs have been installed along a fenceline on the southern side to a point where surveyors can sight a survey peg on Bridge Street. Despite the best efforts of the survey team, the accuracy of the survey is challenged by the lack of cross lines across Redbank Creek. Baseline monitoring indicates that the valley closure measurements were accurate to approximately 20 mm to 30 mm.

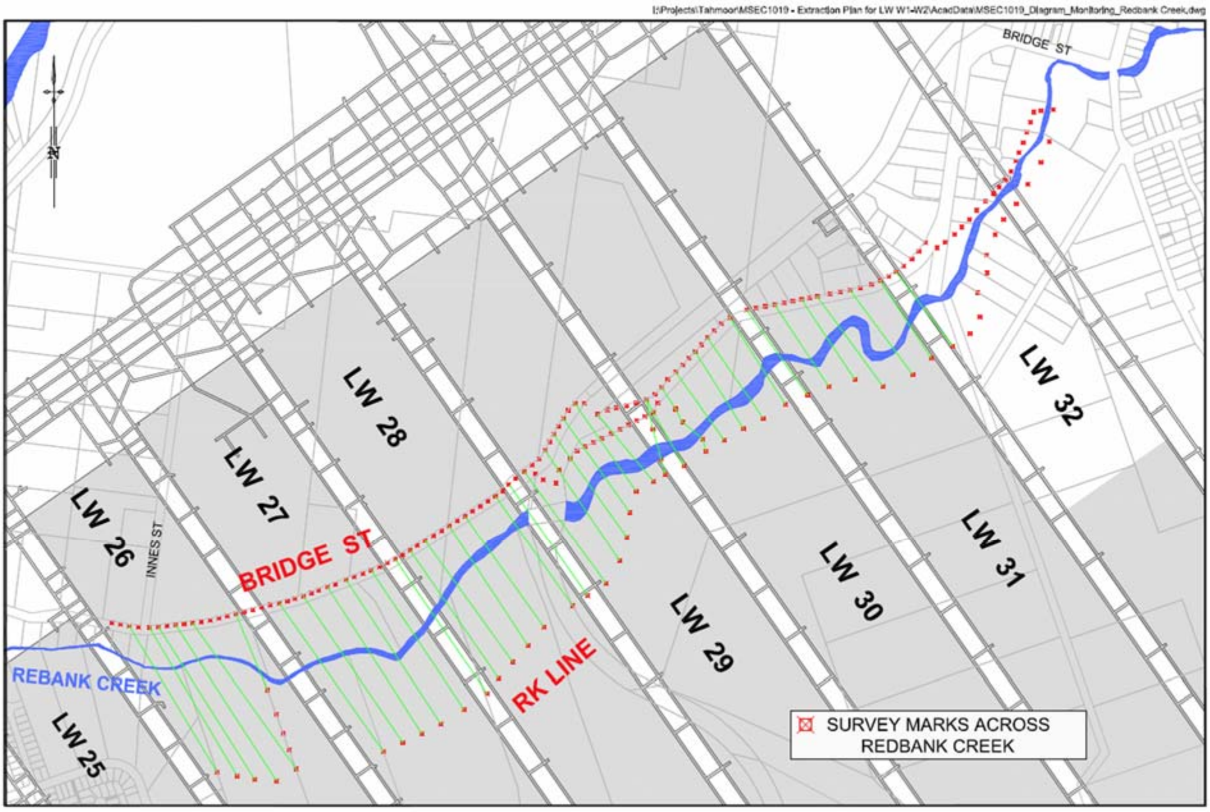

Fig. 3.29 Location of survey marks across Redbank Creek

A comparison between observed and predicted total valley closure along Redbank Creek after the mining of Longwall 31 is shown in Fig. 3.30. A comparison between observed and predicted incremental closure along Redbank Creek is also provided.

The closures are based on calculating changes in horizontal distance between pegs located across the valley in an orientation that is approximately parallel to the longwall panel. This orientation was chosen as Redbank Creek flows approximately at right angles across the panel.

Different results can be derived if the calculations were based on different pairs of pegs, though it is considered that if different pairs were chosen, such calculations would include an additional component of conventional and non-conventional ground shortening that occurs across the panel in both plateau areas or valleys. This is particularly the case if the pegs are located across the width of the longwall panel from each other. When comparing the results against predictions of valley closure, it was considered simpler to choose pegs that are approximately aligned with longwall direction so as not to make allowances for the additional effects of conventional lateral ground closure movements.

A number of observations are made from the monitoring data:

- There has been a reasonable correlation between predicted and observed incremental closure at the completion of Longwall 31. Valley closure was slightly greater for a temporary period of time, when the transient effects of the subsidence travelling wave passed through the valley.
- Observed total closure from the mining of Longwalls 26 to 31 is less than predicted.

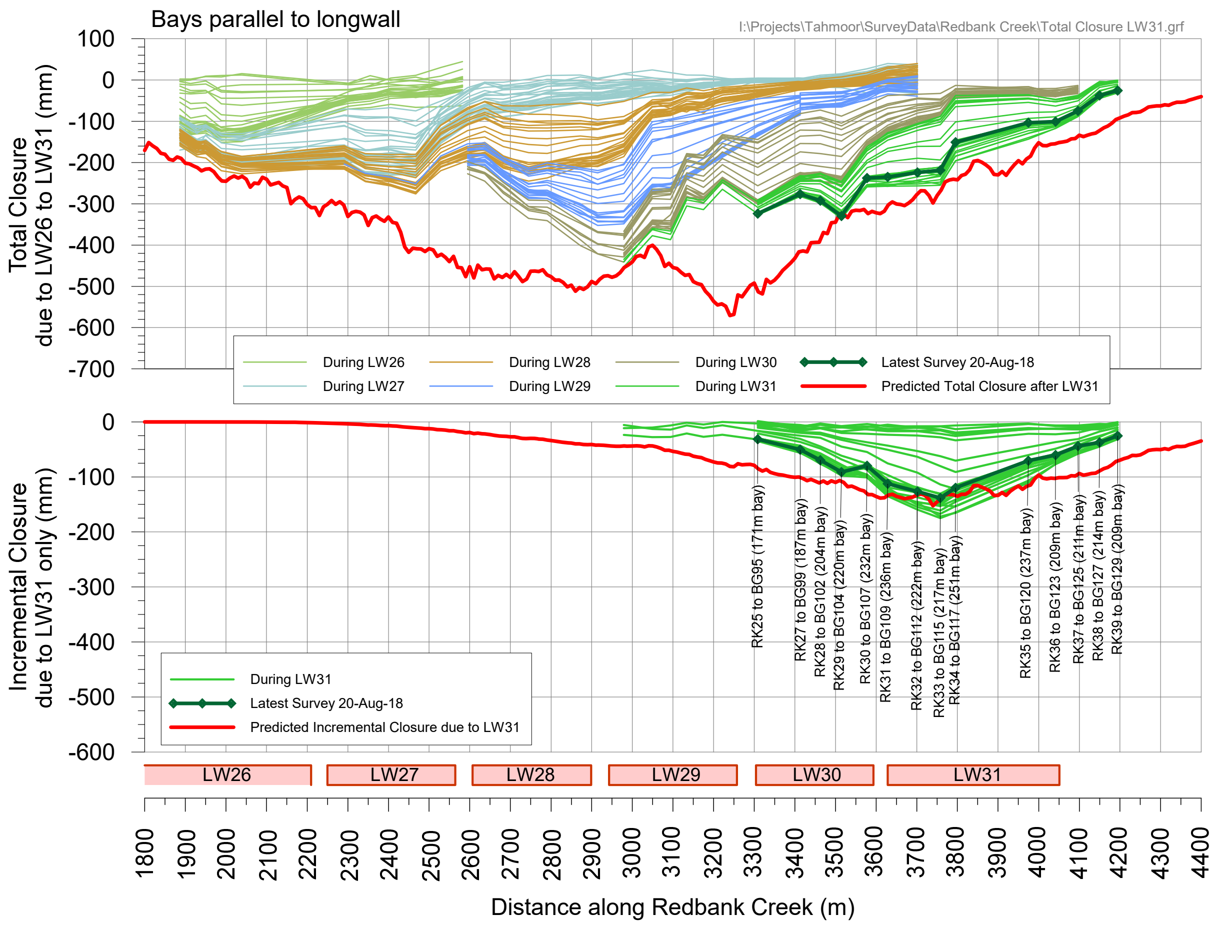

Fig. 3.30 Comparison between observed and predicted valley closure along Redbank Creek

The results show that while the prediction of valley closure is not an exact science, there is a reasonable correlation between measured and predicted subsidence when measured across the width of the valley.

3.9.3. Reliability of the predicted valley related movements

The review of the observed movements at Myrtle and Redbank Creeks indicate that the ACARP Method provides reasonable predictions for valley closure at TCCO. It is noted, however, the measured closures substantially exceeded those predicted in three locations along Myrtle Creek, due to the extraction of LW25, but these all occurred along the same section of creek. Elsewhere, the measured closures were typically similar to or less than those predicted.

Whilst the major factors that determine the levels of movement have been identified, there are some factors that are difficult to isolate. One factor that is thought to influence the upsidence and closure movements is the level of in-situ horizontal stress that exists within the strata. In-situ stresses are difficult to obtain and not regularly measured and the limited availability of data makes it impossible to be definitive about the influence of the in-situ stress on the upsidence and closure values. The methods are, however, based predominantly upon the measured data from Tower Colliery in the Southern Coalfield, where the in-situ stresses are high. The methods should, therefore, tend to over-predict the movements in areas of lower stress.

Variations in local geology can affect the way in which the near surface rocks are displaced as subsidence occurs. In the compression zone, the surface strata can buckle upwards or can fail by shearing and sliding over their neighbours. If localised cross bedding exists, this shearing can occur at relatively low values of stress. This can result in fluctuations in the local strains, which can range from tensile to compressive. In the tensile zone, existing joints can be opened up and new fractures can be formed at random, leading to localised concentrations of tensile strain.

Another factor that is thought to influence the movements is the characteristics of near surface geology, particularly in stream beds. Upsidence in particular is considered to be sensitive to the way in which the bedrock responds, since thin strata layers may respond differently to thicker ones. The location of the point of maximum upsidence is also considered to be strongly influenced by the characteristics of near surface geology.

Another factor that is thought to influence upsidence and closure movements is the presence of geomorphological features. Recent monitoring along a deeper and more incised valley has shown variable measurements around bends. There tended to be less movement at the apex of the bend than in the straight sections.

Notwithstanding the abovementioned limitations, the 2002 ACARP method is the most thoroughly used and tested prediction method for upsidence and closure movements in the Southern Coalfield. It is expected in most cases to provide reasonable, if not, slightly conservative predictions of the valley related movements for the proposed longwalls.

More recently, the empirical prediction method has been refined based on further research undertaken as part of ACARP Research Project No. 18015 (Kay and Waddington, 2014). The 2014 ACARP method only provides predictions for valley closure and not for upsidence.

The predictions based on the 2002 ACARP method can be directly compared with the predictions provided in previous MSEC subsidence reports for TCCO and with other case studies. This method has also been more widely used and tested than the more recent 2014 ACARP method. The assessments provided in this report, therefore, have been based on the predictions obtained using the 2002 ACARP method.

4.1. Introduction

The following sections provide the maximum predicted conventional subsidence parameters resulting from the extraction of the proposed LW W1-W2. The predicted subsidence parameters and the impact assessments for the natural and built features are provided in Chapters 5 and 6.

The predicted vertical subsidence, tilt and curvature have been obtained using the IPM, which has been calibrated based on the latest monitoring data from the Mine, as described in Section 3.6. The predicted strains have been determined by analysing the strains measured at other collieries within the NSW coalfields, where the longwall width-to-depth ratios and extraction heights are similar to those for the proposed longwalls.

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 incremental vertical subsidence contours resulting from the extraction of the proposed longwalls are shown in Drawings Nos. MSEC1019-25 to MSEC1019-26, in Appendix E A summary of the maximum predicted values of incremental vertical subsidence, tilt and curvature are provided in Table 4.1. The incremental parameters represent the additional movements due to the extraction of each of the proposed longwalls.

Table 4.1 Maximum predicted incremental conventional subsidence, tilt and curvature for the proposed longwalls

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})
LW W1	475	3.0	0.03	0.06
LW W2	650	5.0	0.06	0.11

The predicted total vertical subsidence contours resulting from the extraction of the proposed longwalls are shown in Drawings Nos. MSEC1019-27 to MSEC1019-29, in Appendix E. A summary of the maximum predicted values of total vertical subsidence, tilt and curvature is provided in Table 4.2. The predicted total parameters represent the accumulated movements due to the extraction of all proposed longwalls within each of the mining areas.

Table 4.2 Maximum predicted total conventional subsidence, tilt and curvature for the proposed longwalls

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})
LW W1	475	3.0	0.03	0.06
LW W2	750	5.5	0.06	0.11

The maximum predicted total vertical subsidence of 750 mm represents 36 % of the proposed mining height of 2.1 m. The maximum predicted total tilt is 5.5 mm/m (i.e. 0.55 %, or 1 in 180) and it occurs adjacent to the maingate of LW W2. The maximum predicted total curvatures are 0.06 km^{-1} hogging and 0.11 km^{-1} sagging, which represent minimum radii of curvature of 17 km and 9 km, respectively.

The predicted conventional subsidence parameters vary across the mining area. To illustrate this variation, the predicted profiles of vertical subsidence, tilt and curvature have been determined along two prediction lines. The predicted profiles of total vertical subsidence, tilt and curvature along Prediction Lines 1 and 2 are shown in Figs. C.01 and C.02, respectively, in Appendix C. The locations of these prediction lines are shown in Drawings Nos. MSEC1019-25 to MSEC1019-30.

4.3. Comparison of predictions for LW22 to LW32

A comparison of the maximum predicted total conventional subsidence parameters for LW W1-W2 with the predictions for LW22 to LW32 is provided in Table 4.3. The predictions for each of these mining areas are based on the calibrated IPM as described in Section 3.6.

Table 4.3 Comparison of maximum predicted total subsidence parameters

Location	Maximum predicted total conventional subsidence (mm)	Maximum predicted total conventional tilt (mm/m)	Maximum predicted total conventional hogging curvature (km^{-1})	Maximum predicted total conventional sagging curvature (km^{-1})
LW22 to LW32	1250	6.0	0.09	0.14
LW W1-W2	750	5.5	0.06	0.11

The maximum predicted subsidence parameters for the proposed LW W1-W2 are less than the maximum predicted values for LW22 to LW32. The predicted subsidence parameters for the proposed longwalls are less due to the higher depth of cover and since there are only two longwalls in the series.

4.4. Potential additional settlement above coal barriers between proposed and previous mine workings

The proposed LW W1-W2 will be extracted in a new series from the current series of LWs 22 to 32, separated by a barrier of unmined coal, except for development headings.

Additional vertical settlement has been observed within the following areas at Tahmoor that were located above solid intact coal between previously extracted areas, such as;

- Between Longwall 3 and Longwall 22 at Tahmoor Mine,
- Between Longwall 23A and 23B at Tahmoor Mine,
- Between Longwall 24A and the 200 Panels at Tahmoor Mine,
- Between Longwalls 22 to 24B and Longwall 24A and the 200 Panels and Longwall 25 (i.e. mining on three sides of a corridor of intact coal) at Tahmoor Mine,
- Between Longwalls 8-12, Longwall 18 and Longwall 408 at Appin Colliery, and
- Between Longwalls 14-18, 301-302 and 401 at Appin Colliery.

The amount of additional vertical settlement in these areas has been generally been between 50 and 150 mm of subsidence above what was predicted using the IPM and generally low levels of tilt and strain were measured within these areas. Increased subsidence has not always been observed in these situations. For example, it was not observed between Longwalls 3-9 and Longwall 20 at Tahmoor Mine.

While observed subsidence may exceed predictions above the coal barrier between proposed LW W1-W2 and current series of LWs 22 to 32, subsidence monitoring has shown that it is usually accompanied by relatively low conventional tilts, curvature and strains (less than 0.5 mm/m and usually within survey tolerance).

4.5. 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.

In previous MSEC subsidence reports, predictions of conventional strain were provided based on the best estimate of the average relationship between curvature and strain. Similar relationships have been proposed by other authors. The reliability of the strain predictions was highlighted in these reports, where it was stated that measured strains can vary considerably from the predicted conventional values.

Adopting a linear relationship between curvature and strain provides a reasonable prediction for the conventional tensile and compressive strains. The locations that are predicted to experience hogging or convex curvature are expected to be net tensile strain zones and locations that are predicted to experience sagging or concave curvature are expected to be net compressive strain zones. In the Southern Coalfield, it has been found that a factor of 15 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains.

The maximum predicted conventional strains resulting from the extraction of proposed longwalls, based on applying a factor of 15 to the maximum predicted curvatures, are 1 mm/m tensile and 2 mm/m compressive. These strains represent typical values when the ground subsides regularly with no localised or elevated strains due to near-surface geological structures or valley closure effects. The maximum strains can be much greater than these typical values, especially in the locations of near-surface geological structures and in the bases of valleys.

At a point, however, there can be considerable variation from the linear relationship, resulting from non-conventional movements or from the normal scatters which are observed in strain profiles. When expressed as a percentage, observed strains can be many times greater than the predicted conventional strain for low magnitudes of curvature. In this report, therefore, we have provided a statistical approach to account for the variability, instead of just providing a single predicted conventional strain.

The range of potential strains above the proposed longwalls has been determined using monitoring data from the previously extracted longwalls at the mine. The range of strains measured during the extraction of these longwalls should, therefore, provide a reasonable indication of the range of potential strains for the proposed longwalls.

The data used in the analysis of observed strains included those resulting from both conventional and non-conventional anomalous movements, but did not include those resulting from valley related effects, which are discussed separately in the impact assessments for the natural and built features provided in Chapters 5 and 6. The strains resulting from damaged or disturbed survey marks have also been excluded.

4.5.1. 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 maximum strains measured in individual survey bays.

The survey database has been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of the previous longwalls at the mine, for survey bays that were located directly above goaf or the chain pillars that are located between the extracted longwalls, which has been referred to as "*above goaf*".

A histogram of the maximum total tensile and compressive strains measured in survey bays above goaf is provided in Fig. 4.1. A number of probability distribution functions were fitted to the empirical data. It was found that a *Generalised Pareto Distribution (GPD)* provided a good fit to the raw strain data, which have also been shown in this figure.

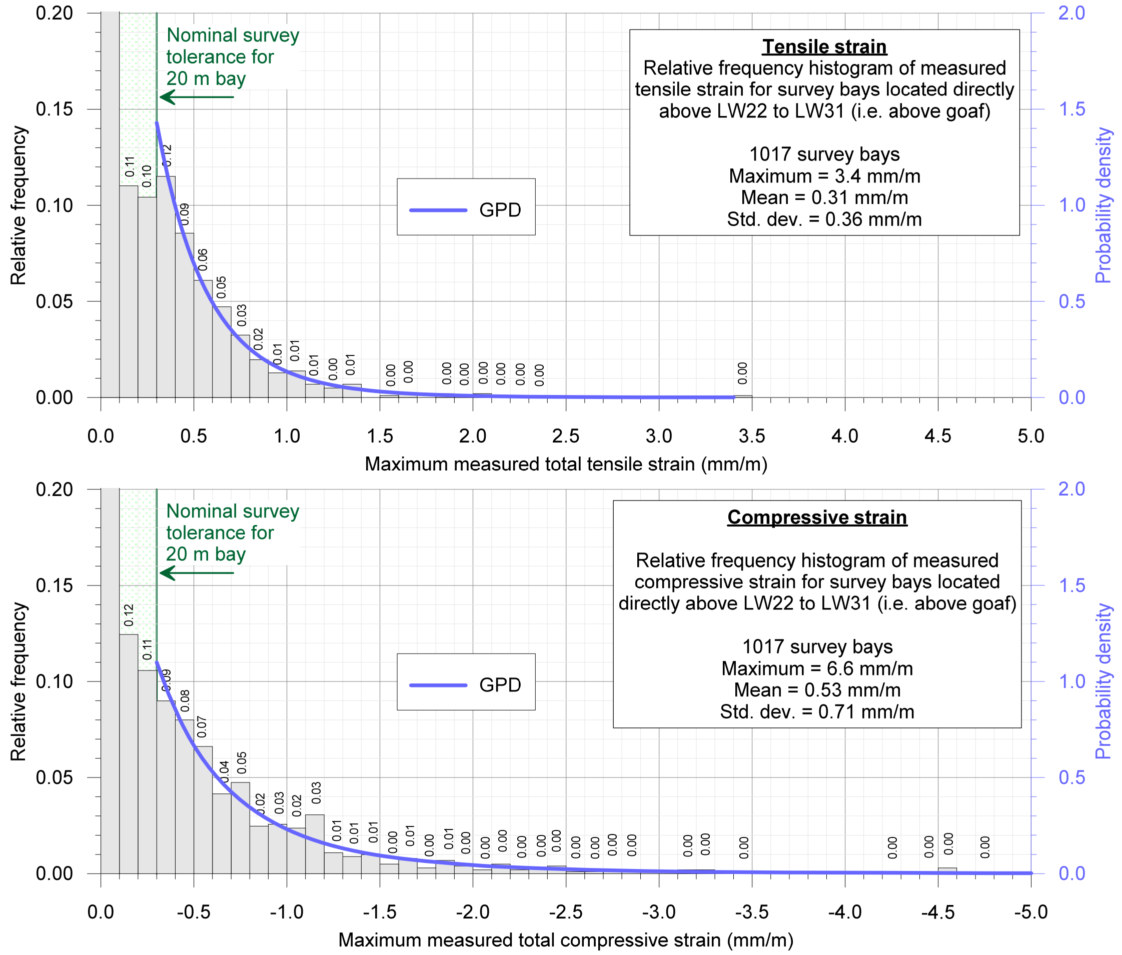

Fig. 4.1 Distributions of the maximum measured tensile and compressive strains during the extraction of previous longwalls at the mine for survey bays located directly above goaf

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 a 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 probabilities of exceedance for tensile and compressive strains for survey bays located above goaf, based on the fitted GPDs, is provided in Table 4.4. The analysis does not include the strains resulting from valley related effects, which are discussed separately in the impact assessments for the natural and built features provided in Chapters 5 and 6.

Table 4.4 Probabilities of exceedance for strain for survey bays located directly above goaf

	Strain (mm/m)	Probability of exceedance
Compression	-8.0	1 in 1700
	-6.0	1 in 610
	-4.0	1 in 170
	-2.0	1 in 25
	-1.0	1 in 7
	-0.5	1 in 3
	-0.3	1 in 2
Tension	+0.3	1 in 2
	+0.5	1 in 5
	+1.0	1 in 20
	+2.0	1 in 290
	+3.0	1 in 2500

The 95 % confidence levels for the maximum total strains that the individual survey bays above goaf experienced at any time during mining were 1.0 mm/m tensile and 1.8 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays above goaf experienced at any time during mining were 1.6 mm/m tensile and 3.4 mm/m compressive.

The probabilities for survey bays located above goaf are based on the strains measured anywhere above the previously extracted longwalls at the mine. As described previously, tensile strains are more likely to develop in the locations of hogging curvature and compressive strains are more likely to develop in the locations of sagging curvature.

The distribution of incremental strains measured above previously extracted longwalls in the Southern Coalfield is illustrated in Fig. 4.2 (after Barbato, 2017). The distances have been normalised, so that the locations of the measured strains are shown relative to the longwall maingate and tailgate sides. The approximate confidence levels for the incremental tensile and compressive strains are also shown in this figure, to help illustrate the variation in the data.

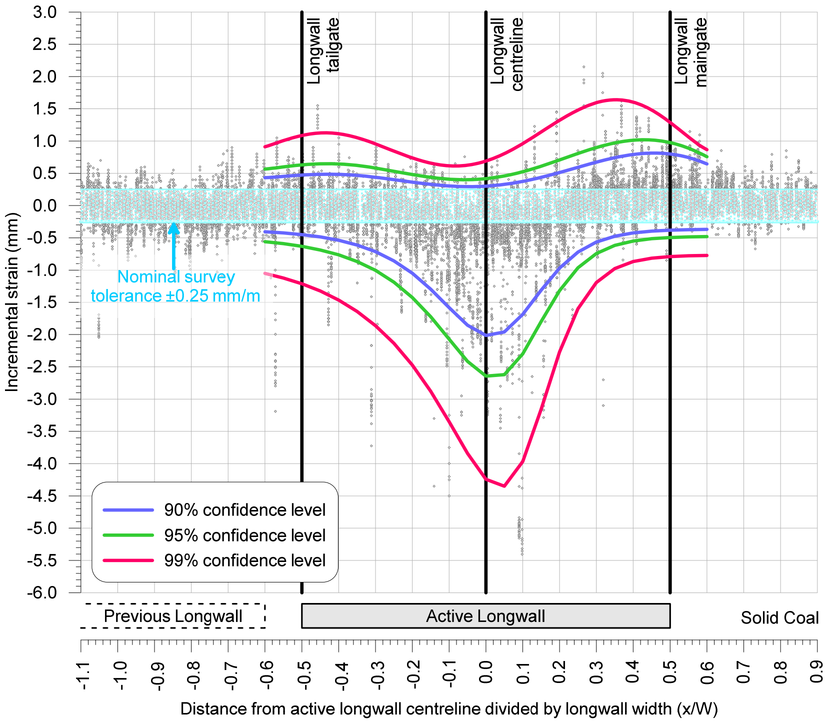

Fig. 4.2 Measured incremental strains versus normalised distance from the longwall maingate for previously extracted longwalls in the Southern Coalfield

The survey database has also been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of the previous longwalls at the mine, for survey bays that were located outside and within 250 m of the nearest longwall goaf edge, which has been referred to as "*above solid coal*".

A histogram of the maximum observed tensile and compressive strains measured in survey bays above solid coal is provided in Fig. 4.3. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

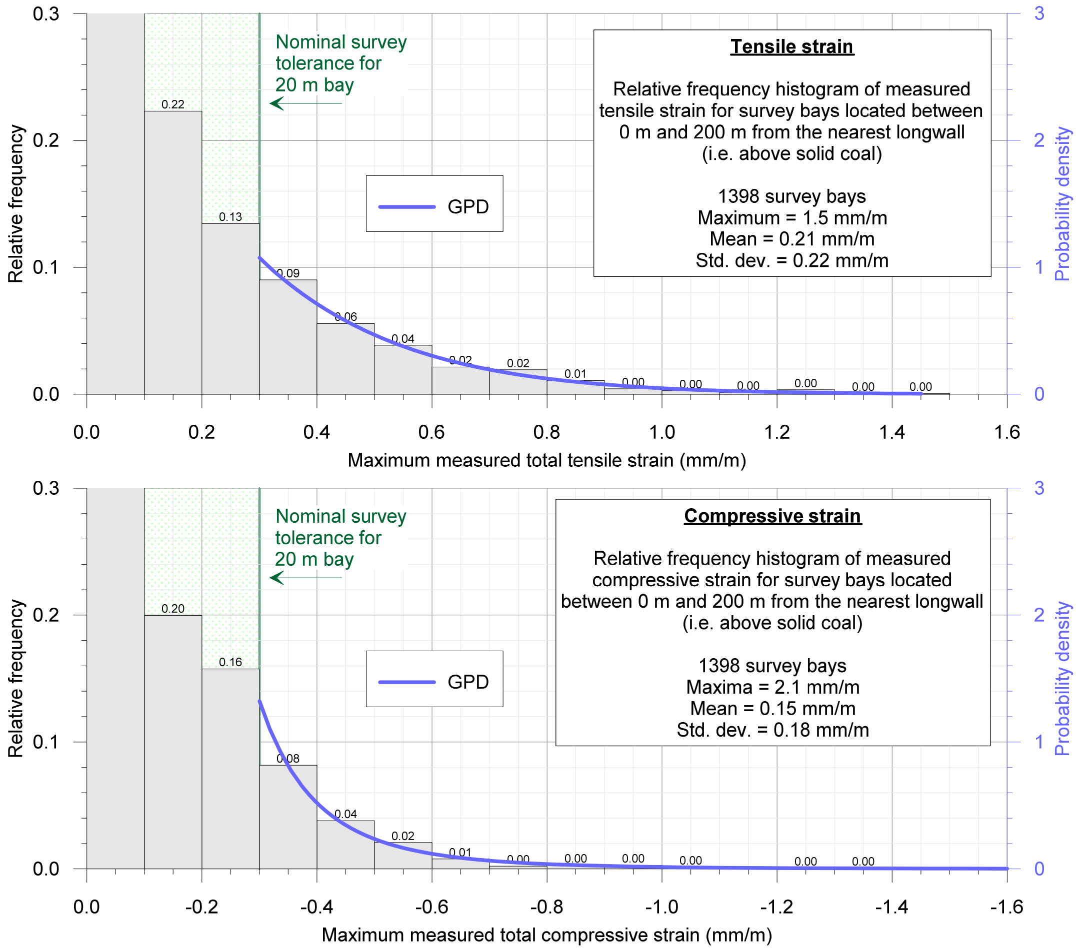

Fig. 4.3 Distributions of the maximum measured tensile and compressive strains during the extraction of previous longwalls at the mine for survey bays located directly above solid coal

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 a 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 probabilities of exceedance for tensile and compressive strains for survey bays located above solid coal, based the fitted GPDs, is provided in Table 4.5. The analysis does not include the strains resulting from valley related movements, which are discussed separately in the impact assessments for the natural and built features provided in Chapters 5 and 6.

Table 4.5 Probabilities of exceedance for strain for survey bays located above solid coal

	Strain (mm/m)	Probability of exceedance
Compression	-2.0	1 in 2900
	-1.5	1 in 1000
	-1.0	1 in 230
	-0.5	1 in 25
	-0.3	1 in 6
Tension	+0.3	1 in 4
	+0.5	1 in 10
	+1.0	1 in 110
	+1.5	1 in 1800
	+2.0	1 in 5000

The 95 % confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining were 0.7 mm/m tensile and 0.5 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining were 1.0 mm/m tensile and 0.8 mm/m compressive.

4.5.2. 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 the maximum strains measured along whole monitoring lines, rather than for individual survey bays. That is, an analysis of the maximum strains measured anywhere along the monitoring lines, regardless of where the strain occurs.

A histogram of maximum measured total tensile and compressive strains measured anywhere along the monitoring lines, at any time during or after the extraction of the previous longwalls at the mine, is provided in Fig. 4.4.

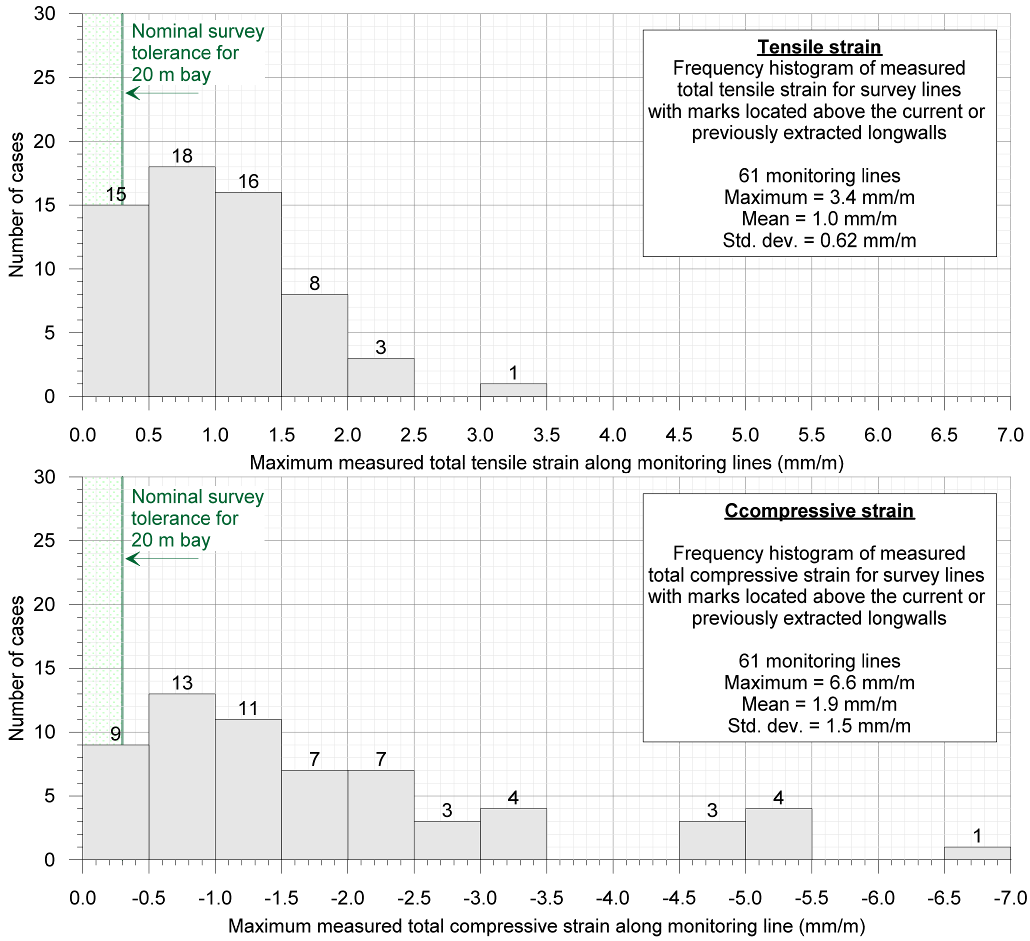

Fig. 4.4 Distributions of maximum measured tensile and compressive strains along the monitoring lines during the extraction of previous longwalls at the mine

It can be seen from the above figure, that 33 of the 61 monitoring lines (i.e. 54 %) had recorded maximum total tensile strains of 1.0 mm/m, or less, and that 57 monitoring lines (i.e. 93 %) had recorded maximum total tensile strains of 2.0 mm/m, or less. It can also be seen, that 40 of the 61 monitoring lines (i.e. 66 %) had recorded maximum compressive strains of 2.0 mm/m, or less, and that 54 of the monitoring lines (i.e. 89 %) had recorded maximum compressive strains of 4.0 mm/m, or less.

4.5.3. Analysis of shear strains

As described in Section 3.2, ground strain comprises two components, being normal strain and shear strain, which can be interrelated using Mohr's Circle. The magnitudes of the normal strain and shear strain components are, therefore, dependent on the orientation in which they are measured. The maximum normal strains (i.e. principal strains) are those in the direction where the corresponding shear strain is zero.

Normal strains along monitoring lines can be measured using 2D and 3D techniques, by taking the change in horizontal distance between two points on the ground and dividing by the original horizontal distance between them. This provides the magnitude of normal strain along the orientation of the monitoring line and, therefore, this strain may not necessarily be the maximum (i.e. principal) strain.

Shear deformations are more difficult to measure, as they are the relative horizontal movements perpendicular to the direction of measurement. However, 3D monitoring techniques provide data on the direction and the absolute displacement of survey marks and, therefore, the shear deformations perpendicular to the monitoring line can be determined. But, in accordance with rigorous definitions and the principles of continuum mechanics, (e.g. Jaeger, 1969), it is not possible to determine horizontal shear strains in any direction relative to the monitoring line using 3D monitoring data from a straight line of survey marks.

As described in Section 3.2, shear deformations perpendicular to monitoring lines can be described using various parameters, including horizontal tilt, horizontal curvature, horizontal mid-ordinate deviation, angular distortion and shear index. In this report, horizontal mid-ordinate deviation has been used as the measure for shear deformation, which is defined as the differential horizontal movement of each survey mark, perpendicular to a line drawn between two adjacent survey marks.

The frequency distribution of the maximum total horizontal mid-ordinate deviations measured at survey marks above goaf, for previously extracted longwalls in the Southern Coalfield, is provided in Fig. 4.5. As the typical survey bay length was 20 metres, the calculated mid-ordinate deviations were over a chord length of 40 metres. The probability distribution function, based on the fitted GPD, has also been shown in this figure.

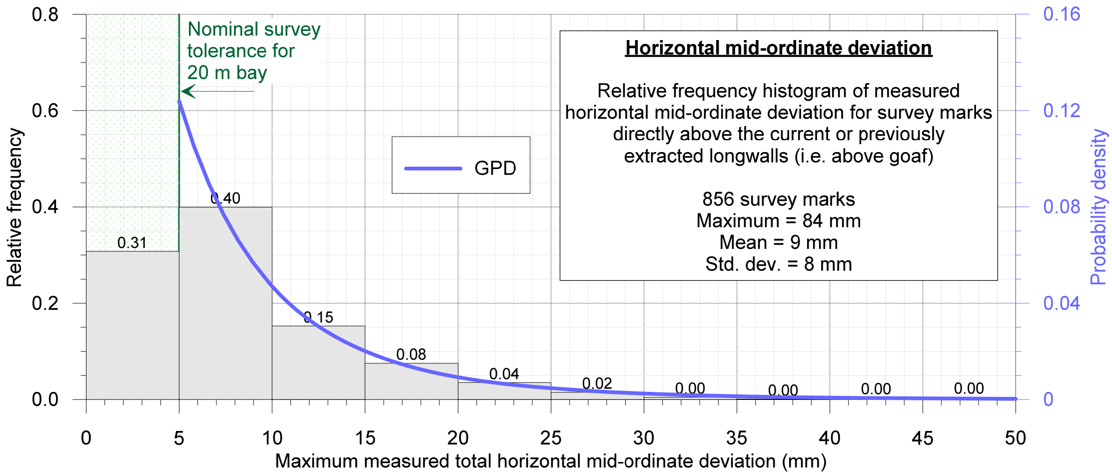

Fig. 4.5 Distribution of maximum measured mid-ordinate deviation during the extraction of previous longwalls in the Southern Coalfield for marks located above goaf

A summary of the probabilities of exceedance for total horizontal mid-ordinate deviation for survey bays located above goaf, based the fitted GPD, is provided in Table 4.6. The analysis does not include the strains resulting from valley related movements, which are discussed separately in the impact assessments for the natural and built features provided in Chapters 5 and 6.

Table 4.6 Probabilities of exceedance for mid-ordinate deviation for survey marks above goaf for monitoring lines in the Southern Coalfield

	Horizontal mid-ordinate deviation (mm)	Probability of exceedance
Mid-ordinate deviation over a 40 m chord length	10	1 in 3
	20	1 in 15
	30	1 in 40
	40	1 in 110
	50	1 in 250
	60	1 in 550
	70	1 in 1,000
	80	1 in 1,900

The 95 % and 99 % confidence levels for the maximum total horizontal mid-ordinate deviation that the individual survey marks located above goaf experienced at any time during mining were 23 mm and 39 mm, respectively.

4.6. Predicted absolute horizontal movements

The predicted conventional horizontal movements over the proposed longwalls are calculated by applying a factor to the predicted conventional tilt values. In the Southern Coalfield a factor of 15 is generally adopted, being the same factor as that used to determine the conventional strains from the conventional curvatures, and this has been found to give a reasonable correlation with measured data. This factor will vary and will be higher at low tilt values and lower at high tilt values. The application of this factor will therefore lead to over-prediction of horizontal movements where the tilts are high and under-prediction of the movements where the tilts are low.

The maximum predicted conventional tilt for the proposed longwalls is 5.5 mm/m. The maximum predicted conventional horizontal movement, therefore, is approximately 85 mm, i.e. 5.5 mm/m multiplied by a factor of 15. Greater movements can develop in incised terrain, due to the increased horizontal movements that develops in the downslope direction and due to valley related effects.

The distribution of the measured horizontal movements for the 3D survey marks located directly above the longwalls at the mine is provided in Fig. 4.6. It can be seen from this figure, that horizontal movements have been measured up to 300 mm at the mine, with an average measured value of approximately 150 mm. The greater horizontal movements have occurred due to topographic and valley related effects.

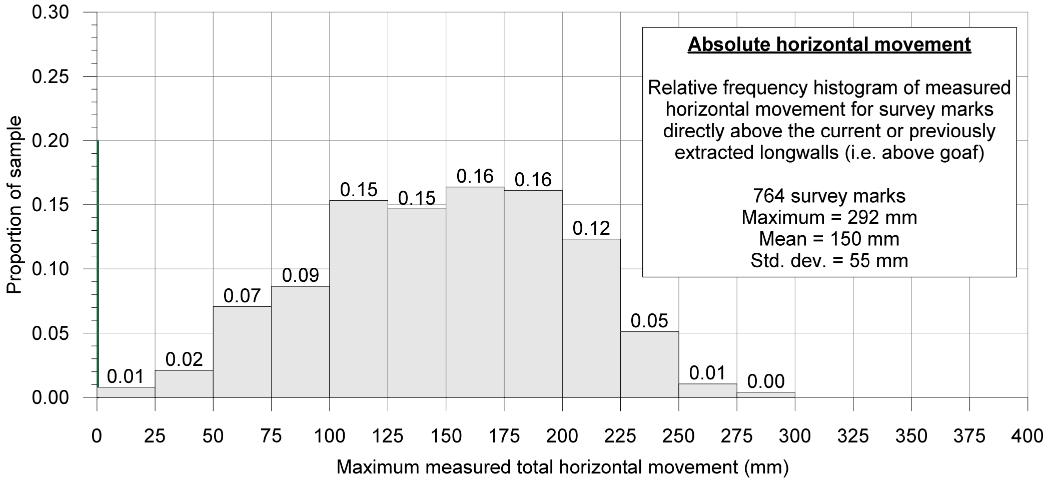

Fig. 4.6 Distribution of the measured absolute horizontal movements at the mine

Absolute 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 features and items of surface infrastructure are addressed in the impact assessments for each feature, which have been provided in Chapters 5 and 6.

4.7. Predicted far-field horizontal movements

In addition to the conventional subsidence movements that have been predicted above and adjacent to the proposed longwalls, and the predicted valley related movements along the streams, it is also likely that far-field horizontal movements will be experienced during the extraction of the proposed longwalls.

The observed incremental far-field horizontal movements resulting from the extraction of each longwall, in any location above goaf (i.e. above the currently mined or previously mined longwalls) or above solid coal (i.e. unmined areas of coal) are provided in Fig. 4.7. The observed incremental far-field horizontal movements above solid coal only, i.e. outside the extents of extracted longwalls, are provided Fig. 4.8. The confidence levels based on fitted GPDs have also been shown in these figures to illustrate the spread of the data. It can be seen from Fig. 4.7 and Fig. 4.8 that the magnitude of the observed far-field horizontal movements over solid unmined areas of coal are lower and more consistent than the observed far-field horizontal movements over previously extracted longwalls.

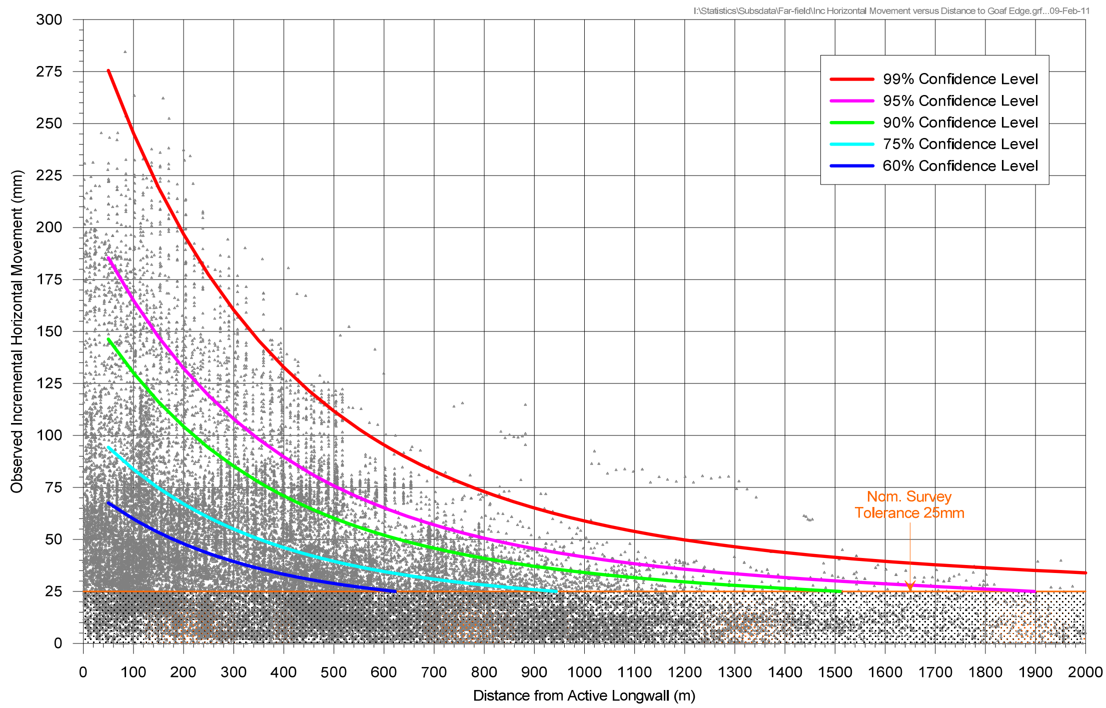

Fig. 4.7 Measured incremental far-field horizontal movements above goaf or solid coal

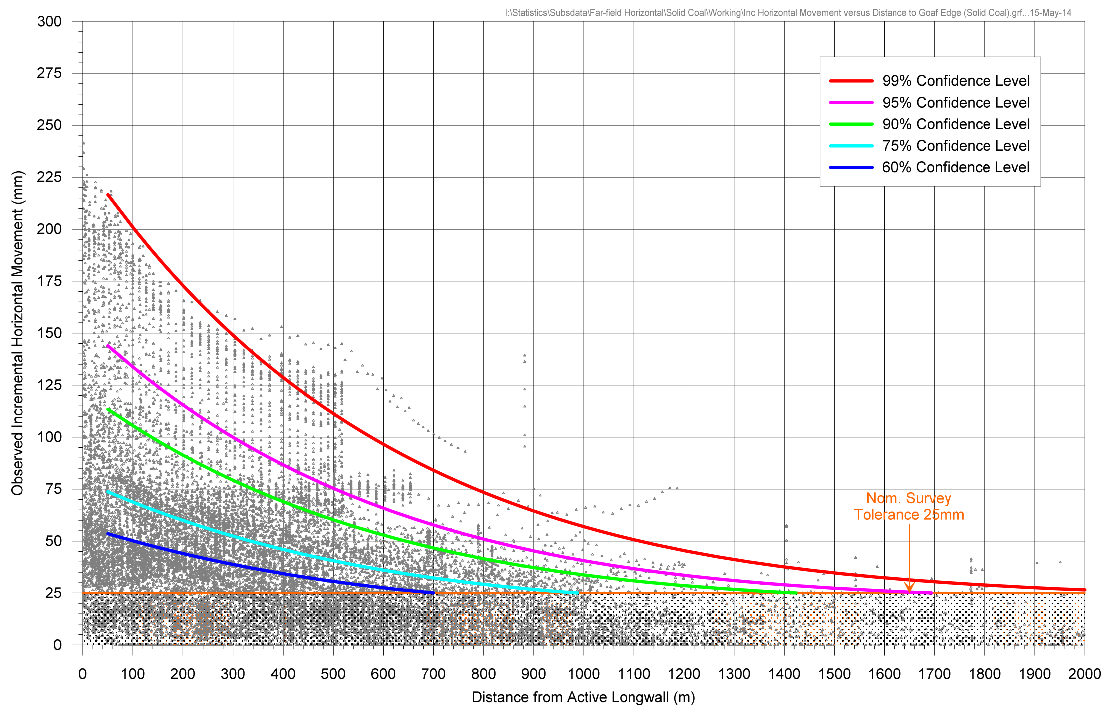

Fig. 4.8 Measured incremental far-field horizontal movements above solid coal only

As successive longwalls within a series of longwalls are mined, the magnitudes of the incremental far-field horizontal movements tend to decrease. The total far-field horizontal movement is not, therefore, the sum of the incremental far-field horizontal movements for the individual longwalls.

The predicted far-field horizontal movements resulting from the extraction of the longwalls are very small and could only be detected by precise surveys. Such movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low-levels of strain, which are generally less than survey tolerance. The impacts of far-field horizontal movements on the natural features and items of surface infrastructure within the vicinity of the Study Area are not expected to be significant, except where they occur at large structures which are sensitive to small differential movements.

4.8. Non-conventional ground movements

It is likely non-conventional ground movements will occur within the Study Area, which are discussed in Section 3.4. These non-conventional movements are often accompanied by elevated tilts and curvatures that are likely to exceed the conventional predictions.

Specific predictions of upsidence, closure and compressive strain due to the valley related movements are provided for the streams in Sections 5.3 and 0. The impact assessments for the streams are based on both the conventional and valley related movements. The potential for non-conventional movements associated with steep topography is discussed in the impact assessments for the steep slopes provided in Section 5.7.

In most cases, it is not possible to predict the exact locations or magnitudes of the non-conventional anomalous movements due to near surface geological conditions. For this reason, the strain predictions provided in this report are based on a statistical analysis of measured strains in the NSW coalfields, including both conventional and non-conventional anomalous strains, which is discussed in Section 4.5. In addition to this, the impact assessments for the natural features and items of surface infrastructure, which are provided in Chapters 5 and 6, include historical impacts resulting from previous longwall mining which have occurred as the result of both conventional and non-conventional subsidence movements.

Mining beneath urban and semi-rural areas at Tahmoor and Thirlmere by LWs 22 to 31 provides valuable "whole of panel" information. A plan showing the locations of observed non-conventional movements at Tahmoor is shown in Fig. 4.9. The locations were selected based on ground monitoring results or observed impacts that appear to have been caused by non-conventional movement. A total of approximately 55 locations (not including valleys) have been identified over the extracted Longwalls 22 to 31.

The surface area directly above the longwalls is approximately 9.1 km^2. This equates to a frequency of 6 sites per square kilometre or one site for every 16 hectares. The non-conventional movements were mainly characterised by elevated compressive ground strains that varied up to a maximum of approximately 5 mm/m.

The largest known case of non-conventional movement in the Southern Coalfield occurred above Appin Colliery Longwall 408 (Swarbrick *et al*, 2007). In this case, a low angle thrust fault was re-activated in response to mine subsidence movements, resulting in differential vertical and horizontal movements across the fault. Observations at the site showed that the non-conventional movements developed gradually and over a period of time. Regular ground monitoring across the fault indicated that the rate of differential movement was less than 0.5 mm/day at the time non-conventional movements could first be detected. Subsequently as mining progressed, the rate of differential movement increased to a maximum of 28 mm/week.

A recent example occurred at a low angle fault that intersected the Main Southern Railway in the Deviation Cutting at Tahmoor, which was located directly above Longwall 29. The site was monitored extensively during the mining of Longwalls 28 to 31. This included three monitoring lines along the railway cutting, and survey prisms along the railway track.

The results of observed changes in vertical alignment of the pegs along the railway cutting are shown in Fig. 4.10. It can be seen that the most significant changes occurred during the mining of Longwall 29. The changes, however, developed gradually over time, allowing the railway track to be adjusted such that trains could continue to travel through the site.

The observations of the gradual development of differential movements have been consistently observed during the mining of previous longwalls at TCCO. While some sites have experienced severe impacts, the subsidence movements developed gradually, allowing time to repair before they became unsafe.

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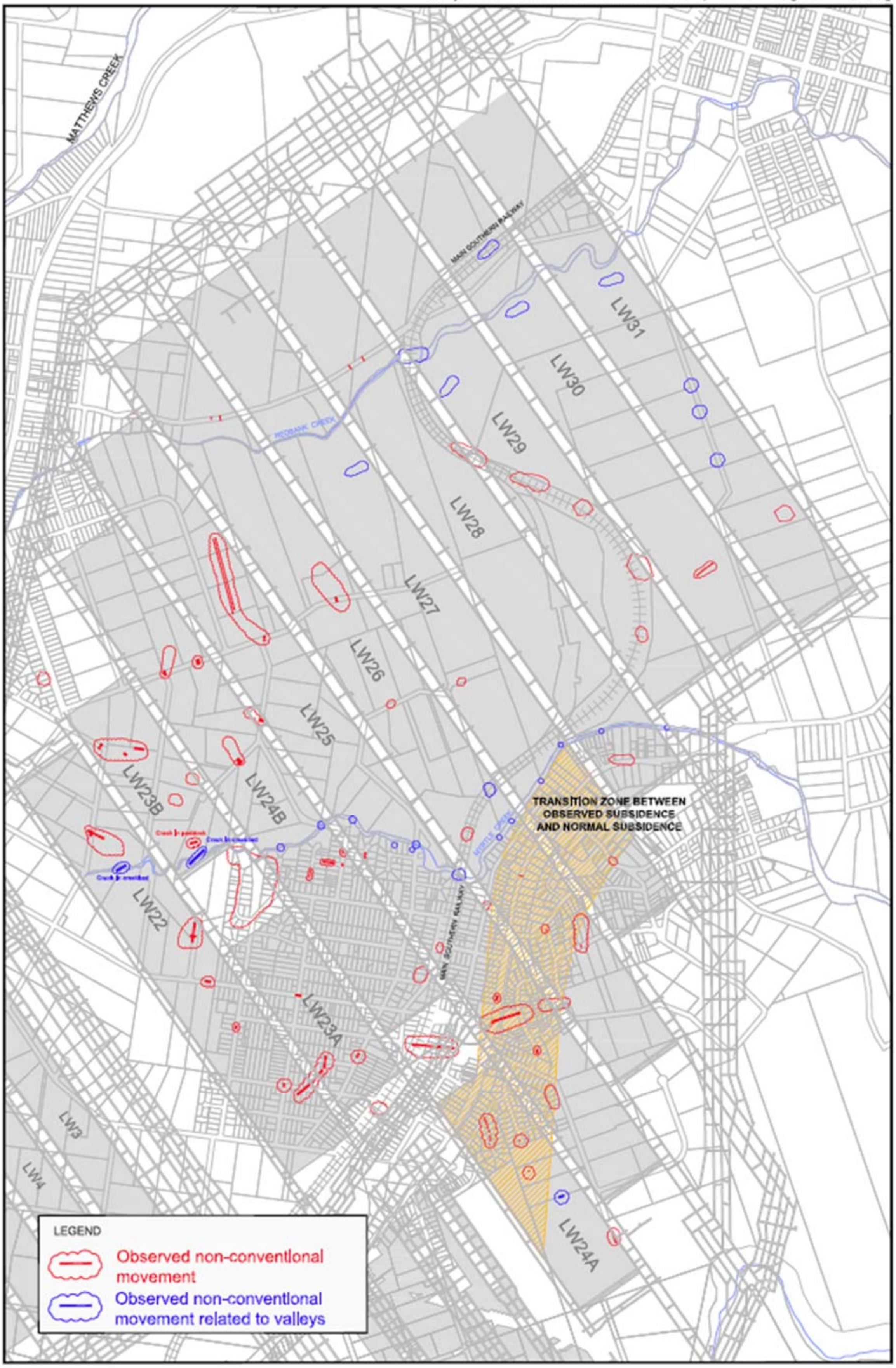

Fig. 4.9 Map of Locations of Potential Non-Conventional Movements

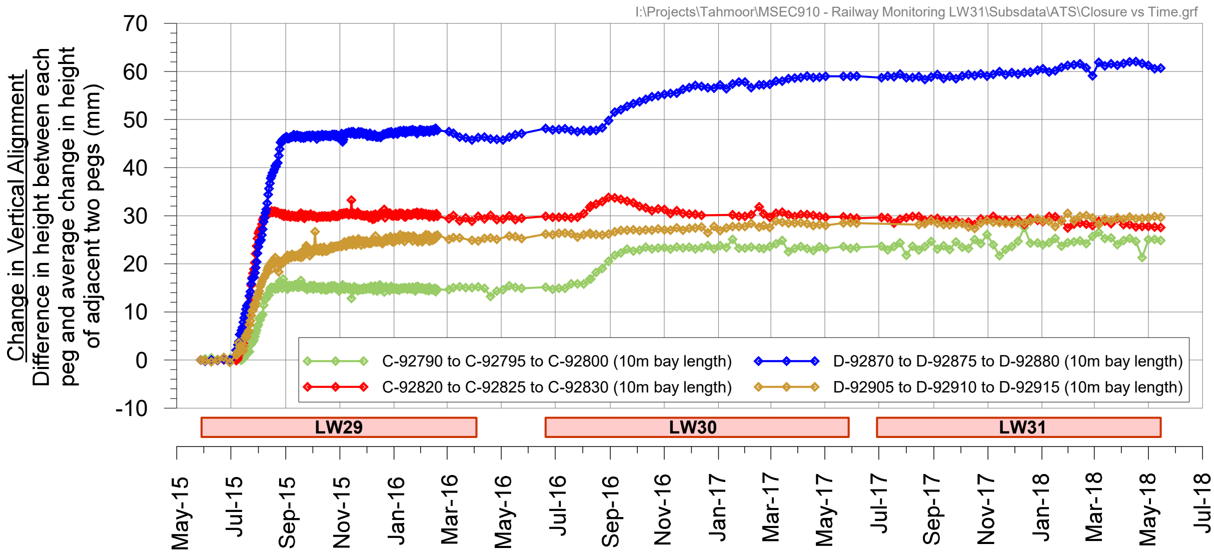

Fig. 4.10 Changes in vertical alignment across a geological fault within a railway cutting during the mining of Longwalls 29 to 31 at Tahmoor Coking Coal Operations

4.9. Surface deformations

Longwall mining can result in surface cracking, heaving, buckling, humping and stepping at the surface. The extent and severity of these mining induced ground deformations are dependent on several factors, including the mine geometry, depth of cover, overburden geology, locations of natural jointing in the bedrock and the presence of near surface geological structures.

Faults and joints in bedrock develop during the formation of the strata and from subsequent distressing associated with movement of the strata. Longwall mining can result in additional fracturing in the bedrock, which tends to occur in the tensile zones, but fractures can also occur due to buckling of the surface beds in the compressive zones. The incidence of visible cracking at the surface is dependent on the pre-existing jointing patterns in the bedrock as well as the thickness and inherent plasticity of the soils that overlie the bedrock.

The depths of cover within the Study Area are greater than 400 metres. Cracking in the surface soils as the result of conventional subsidence movements are not commonly observed at these depths of cover, in areas away from valleys and steep slopes. Surface cracking that has been observed as the result of conventional subsidence movements has generally been relatively isolated and of a minor nature.

Surface deformations can also develop as the result of downslope movements where longwalls are extracted beneath steep slopes. In these cases, the downslope movements can result in the development of tension cracks at the tops and on the sides of the steep slopes and compression ridges at the bottoms of the steep slopes. The impact assessments for downslope movements are provided in Section 5.7.

Fracturing of bedrock can also occur in the bases of stream valleys due to the compressive strains associated with valley upsidence and closure movements. The impact assessments for valley related movements are provided in Sections 5.3 and 0.

The following sections provide the descriptions, predictions and impact assessments for the natural features located within the Study Area. All significant natural features located outside the Study Area, which may be subjected to far-field movements or valley related movements and may be sensitive to these movements, have also been included as part of this review.

5.1. Catchment Areas and Declared Special Areas

There are no catchment areas or declared special areas within the Study Area. The nearest catchment area is the Warragamba Special Area, and its closest point to the proposed longwalls is at Thirlmere Lakes National Park, which is located approximately 4.5 km south-west of the proposed longwalls.

5.2. Rivers

There are no rivers within the Study Area. The closest river is the Nepean River located more than 3 km south-east of LW W1-W2. At this distance, the Nepean River will not experience measurable movements due to the extraction of the proposed longwalls. Adverse impacts are not anticipated even if the actual ground movements exceed the predictions by a factor or two times.

5.3. Creeks

5.3.1. Description of the creeks

The locations of the named creeks within the Study Area are shown in Drawing No. MSEC1019-09.

The NSW Government's Strategic Review into the Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield (DoP, 2008) recommended that risk management zones (RMZs) be applied to all streams of third order or above, in the Strahler stream classification. The stream orders, as mapped in the Strategic Review, are shown in Drawing No. MSEC1019-09.

The Matthews, Cedar and Stonequarry Creek system is partly located within the Study Area. These ephemeral creeks are located outside but adjacent to LW W1-W2. The details of Matthews, Cedar and Stonequarry Creeks are provided in Table 5.1.

Table 5.1 Creeks located within the Study Area

Location	Strahler stream order within Study Area	Total length within the Study Area (km)	Total length within 600 m of LW W1-W2 (km)	Minimum distance of the creek thalweg / centreline from LW W1-W2 (m)
Matthews Creek	Third and fourth order	1.14	1.38	110 m west of the tailgate of LW W1
Cedar Creek	Fourth and fifth order	1.30	1.46	50 m north of the commencing end of LW W1
Stonequarry Creek	Fourth and fifth order	0.93	1.51	50 m north of the commencing end of LW W2

Redbank Creek and the third order section of Tributary 1 to Redbank Creek are located outside the Study Area, both at minimum distances of 900 m from LW W1-W2, at their closest points. Rumker Gully is a third order stream located within the Study Area and it is discussed in Section 5.4.

Cross-sections through Matthews, Cedar and Stonequarry Creeks, where they are located near to LW W1-W2, are provided in Fig. 5.1, Fig. 5.2 and Fig. 5.3, respectively. The angles between the proposed longwalls and the thalwegs of the creeks are also shown in these figures.

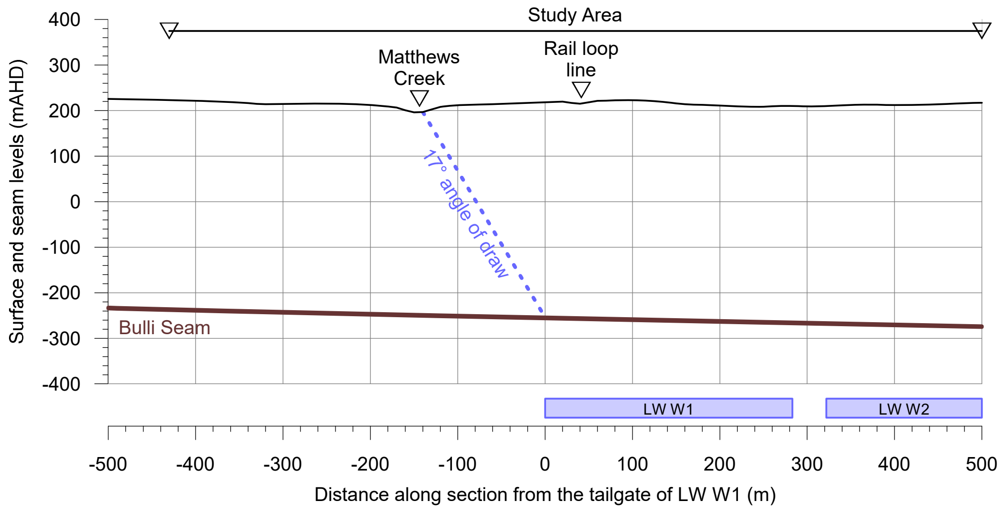

Fig. 5.1 Cross-section through Matthews Creek and LW W1-W2

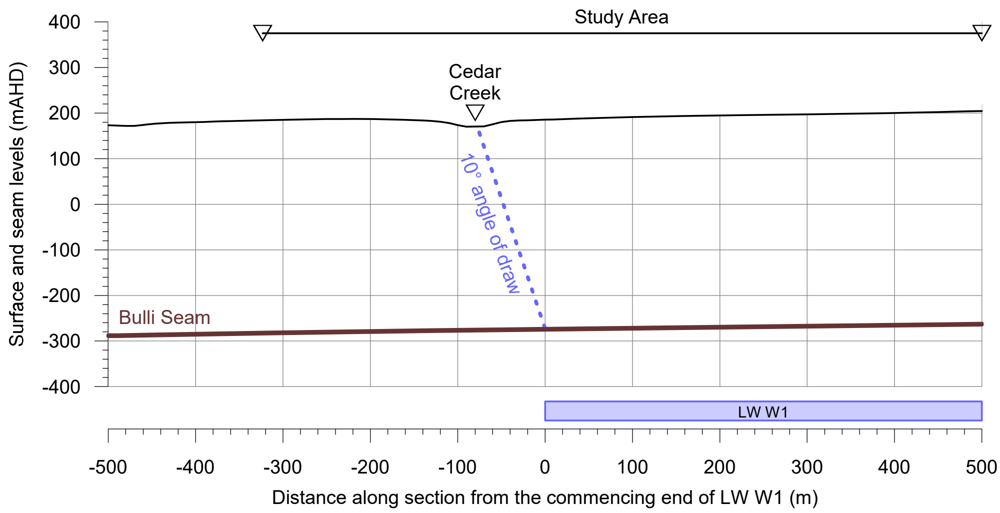

Fig. 5.2 Cross-section through Cedar Creek and LW W1

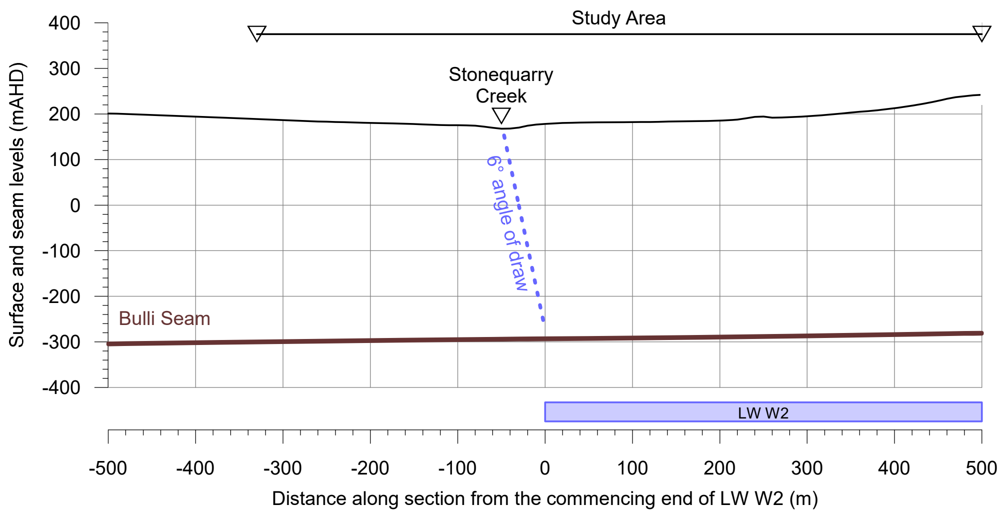

Fig. 5.3 Cross-section through Stonequarry Creek and LW W2

The sections of the creeks located within 600 m of LW W1-W2 have been mapped by the specialist surface water consultant (Geoterra, 2014). The pools along the streams have flow controlling features along their alignments that include rockbars, boulders, tree roots and gravel. The locations of pools along these streams were determined by Geoterra and are shown in Drawing No. MSEC1019-09.

The mapped stream features for Matthews, Cedar and Stonequarry Creeks are provided in Tables D.01, D.02 and D.03, respectively, in Appendix D.

Matthews Creek is located to the west of LW W1, adjacent to the tailgate side of the longwall. It generally flows in a northerly direction to where it joins Cedar Creek. The base of Matthews Creek falls approximately 34 m over the length of approximately 1.14 km within the Study Area, with an inferred average gradient of 30 mm/m (i.e. 3.0 %, or 1 in 33). The catchment of this creek mainly consists of rural properties and parts of the township of Thirlmere.

Matthews Creek flows over predominantly Hawkesbury Sandstone bedrock within the Study Area, though it can be seen that sediments are present on the banks of some pools. There are a number of channel constraints including rockbars, boulders and rock shelves, which form standing pools along the alignment of the creek. An analysis of baseline pool water level data at three sites on Matthews Creek has found that water levels regularly fell below the Cease to Flow levels, indicating that pools on Matthews Creek experience natural periods of no flow (HEC, 2019). Example photographs are shown in Fig. 5.4 to Fig. 5.6.

Photograph courtesy GeoTerra (2014)

Fig. 5.4 Pool MB23 along Matthews Creek located 245 m from the tailgate of LW W1

Photograph courtesy GeoTerra (2014)

Fig. 5.5 Pool MR39 along Matthews Creek located 155 m from the tailgate of LW W1

Photograph courtesy GeoTerra (2014)

Fig. 5.6 Rockbar MR45 along Matthews Creek located 145 m from the tailgate of LW W1

Cedar Creek is located to the west and north of LW W1 and adjacent to the tailgate side and commencing end of this longwall. This creek flows into Stonequarry Creek adjacent to the commencing end of LW W2. The base of Cedar Creek falls 15 m over the length of approximately 1.3 km within the Study Area, with an inferred average gradient of 12 mm/m (i.e. 1.2 %, or 1 in 83). The catchment of this creek mainly consists of rural properties.

Cedar Creek flows over predominantly Hawkesbury Sandstone bedrock in the Study Area, though it can be seen that sediments are present on the banks of some pools. There are a number of channel constraints including rockbars, boulders and rock shelves, which form standing pools along the alignment of the creek. An analysis of baseline pool water level data at six sites on Cedar Creek has found that water levels at upstream sites regularly fell below the Cease to Flow levels and water levels at downstream sites consistently remained above the Cease to Flow levels for the duration of the monitoring period. The results indicated that flow persistence increases with distance downstream along Cedar Creek (HEC, 2019). Example photographs are shown in Fig. 5.7 to Fig. 5.9.

Photograph courtesy GeoTerra (2014)

Fig. 5.7 Pool CR12 along Cedar Creek located 220 m from the tailgate of LW W1

Photograph courtesy GeoTerra (2014)

Fig. 5.8 Pool CB25 along Cedar Creek located 160 m from the commencing end of LW W1

Photograph courtesy GeoTerra (2014)

Fig. 5.9 Pool CR32 along Cedar Creek located at the confluence with Stonequarry Creek, approximately 130 metres from the commencing end of LW W1.

Stonequarry Creek is located to the north of LW W2, adjacent to the commencing end of this longwall. It flows in an easterly direction within the Study Area. Further downstream, the creek initially turns towards the north and then the south and south-east, to where it joins the Nepean River at a distance of more than 3 km from the proposed longwalls. The base of Stonequarry Creek falls approximately 5 m over the length of approximately 0.93 km within the Study Area, with an inferred average gradient of 5 mm/m (i.e. 0.5 %, or 1 in 2000). The catchment of this creek upstream from the Study Area mainly consists of rural properties.

Stonequarry Creek flows over predominantly Hawkesbury Sandstone bedrock within the Study Area, though it can be seen that sediments are present on the banks of some pools. There are a number of channel constraints including rockbars, boulders and rock shelves, which form standing pools along the alignment of the creek. An analysis of baseline pool water level data at two sites on Stonequarry Creek has found a variable response, where the water level consistently remained above the Cease to Flow levels for the duration of the monitoring period for the upstream site, while further downstream, water levels regularly fell below the Cease to Flow level during the monitoring period (HEC, 2019).

HEC (2019) further advise that streamflow data is available between 1990 and 2019 at a WaterNSW station that is approximately 5 kilometres downstream of the confluence with Cedar Creek. Analysis of the data has found that non-zero streamflows have been recorded 98.3% of the time, while the flow rate exceeds 2.5 ML/day approximately 50% of the time.

Example photographs are shown in Fig. 5.10 and Fig. 5.11.

Photograph courtesy GeoTerra (2014)

Fig. 5.10 Pool SR7 along Stonequarry Creek located 495 m from the commencing end of LW W1

Photograph courtesy GeoTerra (2014)

Fig. 5.11 Pool SC2 along Stonequarry Creek located 50 m from the commencing end of LW W2

Further descriptions of the Matthews, Cedar and Stonequarry Creeks are provided in the reports by Geoterra (2014) and the Surface Water Technical Report (HEC, 2019).

5.3.2. Predictions for the creeks

The predicted profiles of total vertical subsidence, upsidence and closure along the Matthews Creek, Cedar Creek and Stonequarry Creek are shown in Figs. C.03, C.04 and C.05, respectively, in Appendix C. The predicted total profiles after the extraction of each of the proposed longwalls are shown as the blue lines.

Summaries of the maximum predicted values of total vertical subsidence, upsidence and closure for the Matthews Creek, Cedar Creek and Stonequarry Creek are provided in Table 5.2, Table 5.3 and Table 5.4, respectively. These tables provide the maximum predicted values anywhere along the sections of creek within the Study Area.

The profiles of the equivalent valley heights that were used to determine the predicted valley related upsidence and closure movements along the creeks are shown in Figs. C.03 to C.05. An equivalent valley height factor of 0.85 was adopted for these creeks, which was determined based on a review of measured and predicted valley related effects above the previously extracted longwalls at the colliery.

Table 5.2 Maximum predicted total vertical subsidence, upsidence and closure for Matthews Creek

Location	Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
Matthews Creek	After LW32	< 20	< 20	< 20
	After LW W1	70	50	120
	After LW W2	90	90	170

Table 5.3 Maximum predicted total vertical subsidence, upsidence and closure for Cedar Creek

Location	Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
Cedar Creek	After LW32	< 20	< 20	< 20
	After LW W1	40	90	130
	After LW W2	60	160	180

Table 5.4 Maximum predicted total vertical subsidence, upsidence and closure for Stonequarry Creek

Location	Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
Stonequarry Creek	After LW32	< 20	< 20	< 20
	After LW W1	< 20	30	30
	After LW W2	60	90	60

Matthews, Cedar and Stonequarry Creeks are predicted to experience maximum values of total vertical subsidence between 60 mm and 90 mm. Whilst these creeks could experience low-levels of vertical subsidence, they are not expected to experience measurable conventional tilts, curvatures or strains.

The maximum predicted values of valley related closure for Matthews, Cedar and Stonequarry Creeks are 170 mm, 180 mm and 60 mm, respectively. These creeks could experience compressive strains due to these valley related effects. The predicted strains due to valley related effects have been determined from an analysis of ground monitoring lines for valleys with similar heights located at similar distances from previously extracted longwalls in the Southern Coalfield, as for these creeks.

The sections of Matthews, Cedar and Stonequarry Creeks adjacent to the proposed longwalls have effective valley heights ranging between 20 m and 30 m. These creeks are located at distances typically ranging between 100 m and 250 m from the tailgate of LW W1 and typically between 50 m and 150 m from the commencing ends of LW W1-W2. The maximum compressive strain measured at similar streams in the Southern Coalfield is 6 mm/m based on the 95 % confidence level.

5.3.3. Experience of mining adjacent to creeks in the Southern Coalfield

TCCO has mined directly beneath various streams including Myrtle Creek, Redbank Creek and their tributaries. The impacts experienced along these creeks are not representative of the potential impacts that may occur along Matthews, Cedar and Stonequarry Creeks, as the proposed longwalls do not mine directly beneath these creeks. Longwalls have mined adjacent to but not directly beneath similar streams elsewhere in the Southern Coalfield.

The most appropriate case studies are the Cataract River at Appin Area 3, the Georges River at West Cliff Area 5 and Wongawilli Creek at Dendrobium Areas 3A and 3B. These case studies are described below.

Cataract River in Area 3 at Appin Colliery

Longwalls 301 and 302 in Area 3 at Appin Colliery were mined adjacent to the Cataract River. The river is located adjacent to the tailgate of Longwall 301 and the commencing ends of Longwalls 301 and 302. The locations of the river, longwalls and monitoring lines are shown in Fig. 5.12. The closest distance of the extracted longwalls to the Cataract River was 100 m, near the E-Line.

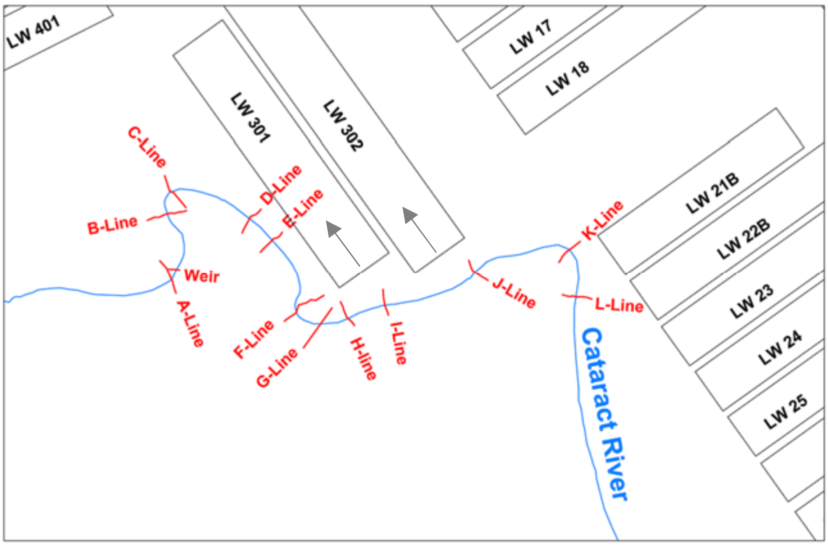

Fig. 5.12 Locations of the Cataract River, longwalls and monitoring in Area 3 at Appin Colliery

Longwalls 301 and 302 had overall void widths of 260 m and a solid chain pillar width of 40 m. The longwalls were extracted in the Bulli Seam at depths of cover ranging between 470 m and 520 m. The seam thickness within the extents of the longwalls varied between 2.7 m and 3.1 m. The longwalls were extracted towards the northwest, away from the Cataract River, as shown by the arrows in Fig. 5.12.

The equivalent valley heights of the Cataract River within the mining area vary between 60 m and 70 m. The valley sides of this river, therefore, are higher than those along Matthews, Cedar and Stonequarry Creeks.

The valley closure effects were measured across the Cataract River at a number of monitoring lines, including the Cat X A-Line to L-Line. The measured and predicted closure movements for the Cataract River at the completion of Longwall 302 are illustrated in Fig. 5.13. The maximum measured total closure was 285 mm at the E-Line, adjacent to the tailgate of Longwall 301, and the maximum predicted total closure was 460 mm near the E-Line.

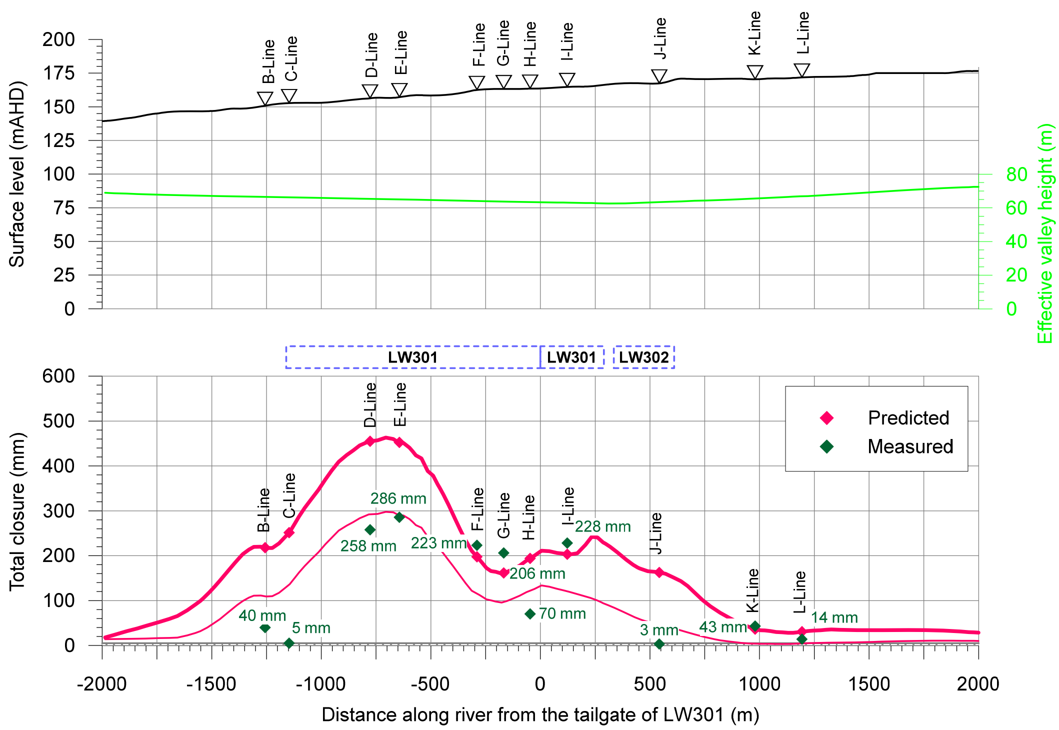

Fig. 5.13 Measured and predicted total closure along the Cataract River due to Longwalls 301 and 302

Fracturing and gas release zones were observed along the section of the Cataract River located adjacent to the tailgate of Longwall 301 and adjacent to the commencing ends of Longwalls 301 and 302. Minor and isolated fracturing were observed up to 400 m from these longwalls. No surface water flow diversions were observed due to the extraction of Longwalls 301 and 302. Water flows were controlled by releases from the Cataract Dam, which were between 35 and 250 ML/day at times.

Georges River in Area 5 at West Cliff Colliery

The longwalls in Area 5 at West Cliff Colliery were initially mined directly beneath the Georges River. However, further downstream, Longwalls 29 to 38 were mined adjacent to but not directly beneath this river. Longwalls 29 to 37 are located on the western side of the Georges River and Longwall 38 is located on the eastern side of the river. The locations of the river, longwalls and monitoring lines are shown in Fig. 5.14.

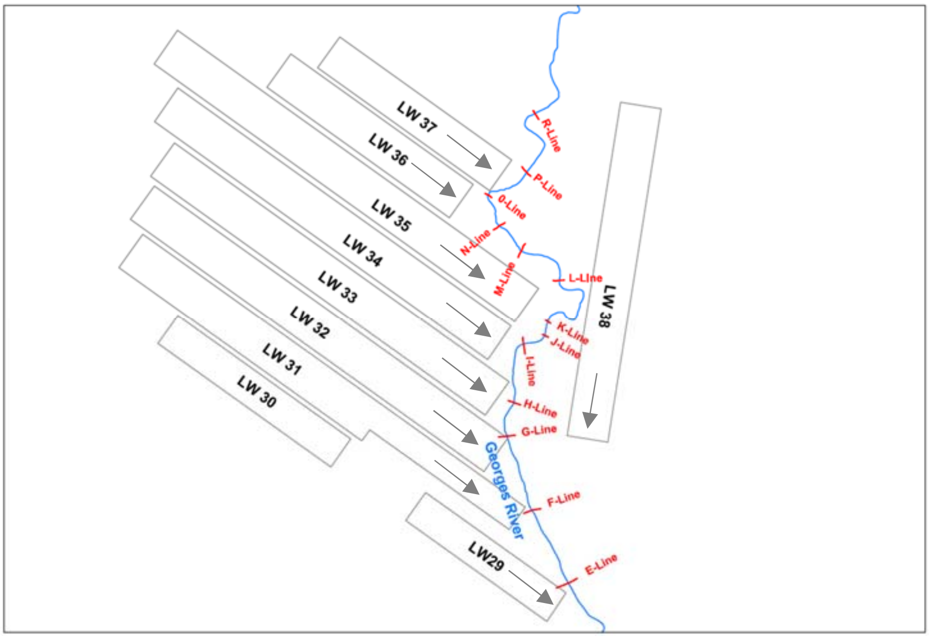

Fig. 5.14 Locations of the Georges River, longwalls and monitoring in Area 5 at West Cliff Colliery

The overall voids widths were 255 m for Longwalls 29 and 30, 205 m for the eastern part of Longwall 31, 280 m for Longwall 37 and 305 m for the remaining longwalls, including the western part of Longwall 31. The solid chain pillar widths typically varied between 35 m and 40 m, with a 135 m pillar between Longwall 29 and the eastern part of Longwall 31. The longwalls were extracted in the Bulli Seam at depths of cover ranging between 470 m and 550 m. The seam thickness within the extents of the longwalls varied between 2.2 m and 2.8 m. The longwalls were extracted towards the southeast, towards the Georges River, as shown by the arrows in Fig. 5.14.

The Georges River is located adjacent to the finishing ends of Longwalls 29, 31 and 32 to 37. Longwalls 32 and 37 were mined up to but not directly beneath the thalweg (i.e. centreline) of the river. The finishing ends of Longwalls 29, 31 and 33 are at minimum distances ranging between 30 m and 50 m from the river thalweg. The finishing ends of Longwalls 34, 35 and 36 are at minimum distances ranging between 130 m and 190 m from the river thalweg.

Sections of the Georges River are also located adjacent to the maingate of Longwall 35 and the tailgate of Longwall 38. The sides of Longwalls 35 and 38 are located at minimum distances of 150 m and 40 m, respectively, from the river thalweg.

The equivalent valley heights of the Georges River within the mining area vary between 15 m and 35 m. The valley sides of this river, therefore, are higher than those along Matthews, Cedar and Stonequarry Creeks.

The valley closure effects were measured across the Georges River at 13 monitoring lines, referred to as the Geo X E-Line to R-Line. The measured and predicted closures for the Georges River at the completion of Longwall 38 are illustrated in Fig. 5.15. The maximum measured total closure was 250 mm at the N-Line and the maximum predicted total closure was 220 mm adjacent to the maingate of Longwall 35.

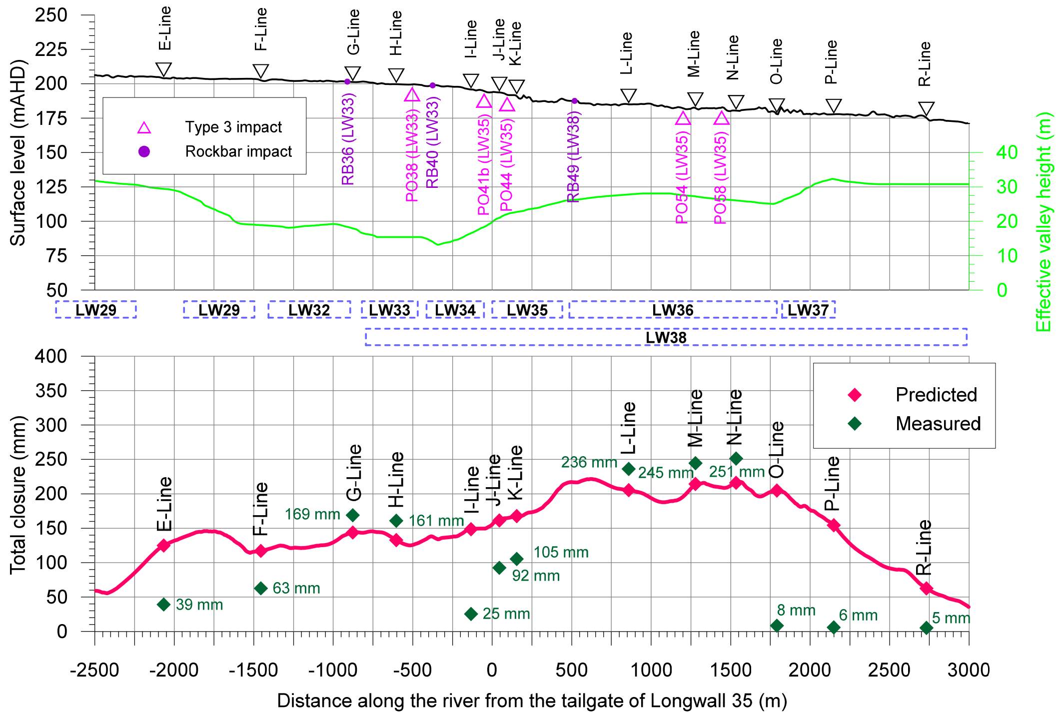

Fig. 5.15 Measured and predicted total closure along the Georges River due to Longwalls 29 to 38

Gas releases and fracturing were observed at discrete locations along the Georges River during the extraction of Longwalls 29 to 38. Pool water levels were observed to fall lower than their baseline levels (referred to as Type 3 impacts) at five locations. Whilst standing water levels were reduced, there were no pools that completely drained. Surface water flow diversions were also identified at three rockbars; however, the upstream pools were not affected.

The surface water flow impacts were observed during the mining of Longwalls 33, 35 and 38. The impacts were located near the finishing ends of Longwalls 33 and 35, along the side of Longwall 35 and at the closest pool to Longwall 38.

The total length of the Georges River located within a distance of 400 m of the as-extracted longwalls is approximately 5.6 km. There is a total of 50 pools that have been mapped over this section of river. The observed rate of Type 3 impacts (i.e. fracturing resulting in the reduction in the pool standing water levels) therefore is 10 %. The observed rate is consistent with that assessed using the rockbar impact model based on a maximum predicted closure of 220 mm, which is discussed in the following Section 5.3.4. Water flows were partially controlled by releases from Brennans Creek Dam, which were typically between 0.5 and 3 ML/day.

Wongawilli Creek in Areas 3A and 3B at Dendrobium Mine

Longwalls have been mined on two sides of Wongawilli Creek at Dendrobium Mine. Longwalls 6 to 8 in Area 3A were mined on the eastern side of the creek at a minimum distance of 110 m from the thalweg. Longwalls 9 to 13 were mined on the western side of Wongawilli Creek at a minimum distance of 290 m from the thalweg. The locations of the creek, longwalls and monitoring lines are shown in Fig. 5.16.

The overall voids widths were 250 m for Longwalls 6 and 7 and 305 m for Longwalls 8 to 13. The solid chain pillar widths varied between 40 m and 45 m. The longwalls were extracted in the Wongawilli Seam at depths of cover ranging between 280 m and 390 m in Area 3A and between 320 m and 420 m in Area 3B. The mining height was 3.9 m in Area 3A and varied between 3.9 m and 4.6 m in Area 3B. The longwalls in both series were extracted towards the southeast as shown by the arrows in Fig. 5.16.

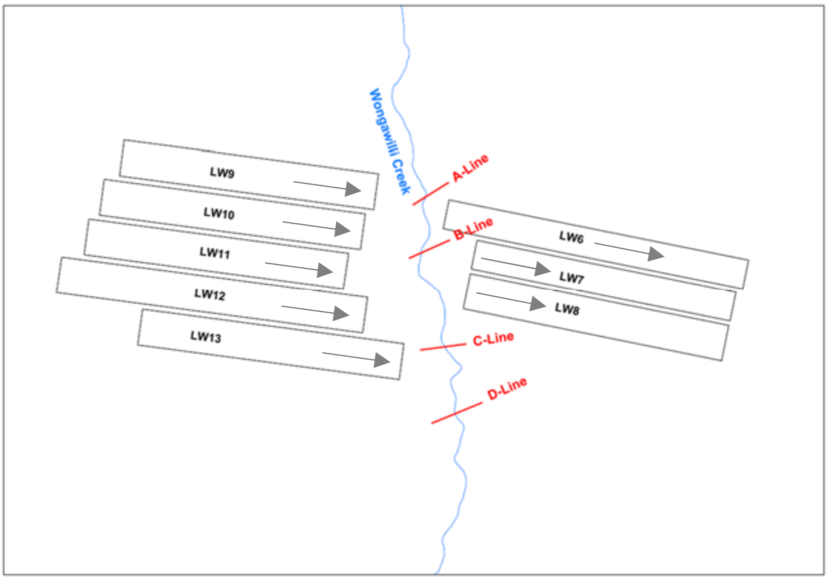

Fig. 5.16 Locations of Wongawilli Creek, the longwalls and monitoring in Areas 3A and 3B at Dendrobium Mine

The effective valley heights of Wongawilli Creek within the mining area vary between 50 m and 60 m. The valley sides of this creek, therefore, are higher than those along Matthews, Cedar and Stonequarry Creeks.

The valley closure effects were measured across Wongawilli Creek at four monitoring lines. The measured and predicted closure for Wongawilli Creek at the completion of Longwall 13 are illustrated in Fig. 5.17. The maximum measured total closure was 124 mm at the A-Line and the maximum predicted total closure was 210 mm between the A-Line and B-Line.

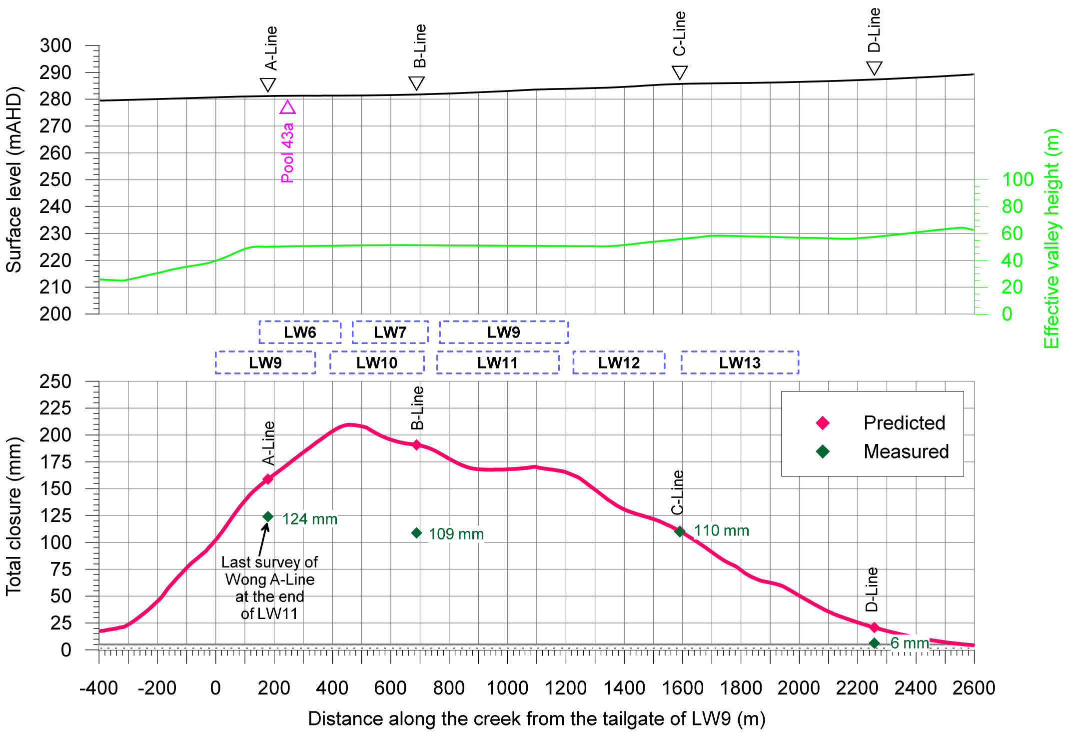

Fig. 5.17 Measured and predicted closure along Wongawilli Creek due to Longwalls 6 to 13

The extraction of Longwalls 6 to 13 has resulted in fracturing and the reduction in the standing water level in Pool 43a. This pool is located 200 m west of Longwall 6 in Area 3A and 410 m east of Longwall 9 in Area 3B. There were no other impacts observed along Wongawilli Creek at the completion of Longwall 13.

The total length of Wongawilli Creek located within a distance of 400 m of the as-extracted longwalls is 2 km. The rate of impacts along Wongawilli Creek due to the mining in Areas 3A and 3B therefore is considered to be very low.

Summary of case studies and application to Matthews, Cedar and Stonequarry Creeks

There are many factors that influence the potential for mining-induced impacts to occur on streams, including but limited to the mining geometry, direction of mining away from or towards the stream, offset distances between the longwall panels and the streams, valley shape and geology, the nature of the pools and how their water levels are controlled, and the nature of the surface water flows.

Of the three case studies presented, the Cataract River in Area 3 at Appin Colliery would be the most representative in terms of the mining geometry, direction of mining away from the stream and offset distances to the side of the longwall panels. The Georges River in Area 5 at West Cliff Colliery would be the most representative in terms of the depths of the valley and offset distances to the side and end of the longwall panels. Surface water flows are, however, greater in volume and more consistent over time, particularly in the Cataract River, compared to those that are present within Matthews, Cedar and Stonequarry Creeks.

Regardless of these similarities and differences, each of the case studies demonstrate that the outcomes were not impact free but the severity and extent of impacts on streams were substantially reduced compared to examples when longwalls are extracted directly beneath streams.

5.3.4. Impact assessments for the creeks

Matthews, Cedar and Stonequarry Creeks are predicted to experience maximum values of total vertical subsidence between 60 mm and 90 mm. Whilst these creeks could experience low-levels of vertical subsidence, they are not expected to experience measurable conventional tilts, curvatures or strains.

The mining-induced changes in grade along Matthews, Cedar and Stonequarry Creeks are predicted to be negligible. It is unlikely, therefore, that the creeks would experience adverse impacts due to increased levels of ponding, increased levels of scouring of the banks nor changes in stream alignment.

The maximum predicted values of valley related closure for Matthews, Cedar and Stonequarry Creeks are 170 mm, 180 mm and 60 mm, respectively. The maximum predicted compressive strain for these creeks due to the valley closure effects is 6 mm/m based on the 95 % confidence level.

Fracturing in bedrock has been observed due to previous longwall mining where the tensile strains are greater than 0.5 mm/m or where the compressive strains are greater than 2 mm/m. Fracturing could therefore occur along Matthews, Cedar and Stonequarry Creeks due to the valley related compressive strains. Fracturing has been observed up to approximately 400 m outside of previously extracted longwalls in the Southern Coalfield.

The potential for Type 3 impacts along Matthews, Cedar and Stonequarry Creeks has been assessed using the rockbar impact model for the Southern Coalfield (Barbato, et al., 2014). A Type 3 impact is defined as *fracturing in a rockbar or upstream pool resulting in reduction in standing water level based on current rainfall and surface water flow*.

The rockbar model relates the likelihood of impact on rockbars with the predicted total valley closure along the stream based on the previous longwall mining experience in the Southern Coalfield. The impact model is illustrated in Fig. 5.18. This model was used to determine the longwall setbacks at West Cliff Colliery from the Georges River and at Dendrobium Mine from Wongawilli Creek.

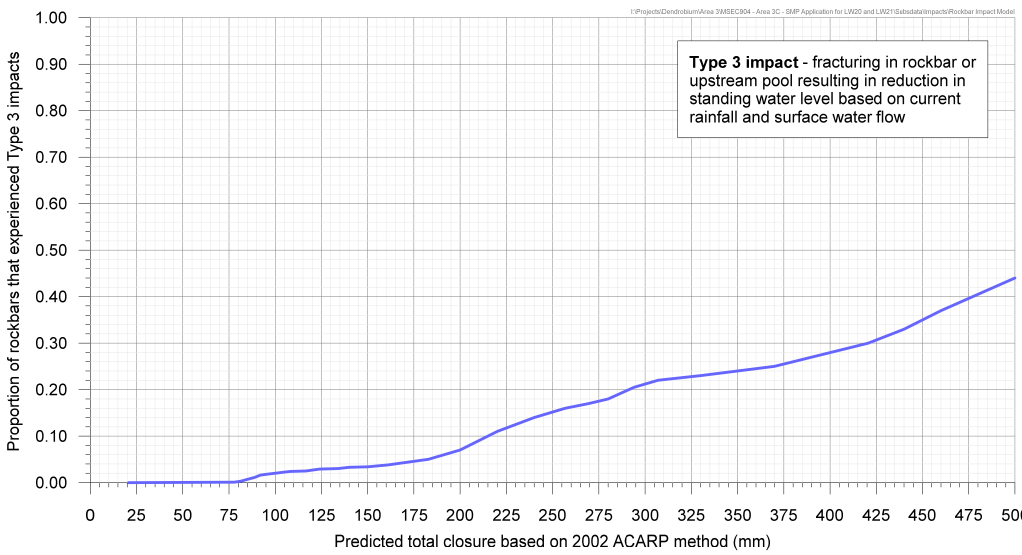

Fig. 5.18 Rockbar impact model for the Southern Coalfield

The maximum predicted total closure for Matthews, Cedar and Stonequarry Creeks due to the extraction of the proposed longwalls is 180 mm. The predicted rate of impact for the pools along these creeks due to the extraction of the proposed longwalls, therefore, is less than 10 %. Impacts are more likely to occur near the commencing ends of LW W1-W2, where Cedar and Stonequarry Creeks are located closest to these longwalls, and where Cedar and Matthews Creeks are located closest to the tailgate of LW W1.

The likelihoods of fracturing and surface flow diversions reduce with distance away from the proposed longwalls. The furthest distance of an observed fracture from longwall mining was at the base of Broughtons Pass Weir, which was located approximately 415 m from Appin Colliery Longwall 401. Another minor fracture was also recorded in the upper Cataract River, approximately 375 m from Appin Colliery Longwall 301. This fracture occurred in a large rockbar, which was formed in thinly bedded sandstone, which had experienced movements from nearby previously extracted longwalls. These are the furthest most recorded fractures from longwall mining in the NSW coalfields.

Gas emissions from the sandstone strata have been previously observed above and adjacent to mining areas in the Southern Coalfield, although never at Tahmoor Mine, and some gas emissions have also been observed in water bores. Analyses of gas compositions indicate that the Bulli Seam is not the direct and major source of the gas and that the most likely source is the Hawkesbury Sandstone (APCRC, 1997).

All recorded examples of gas emissions have occurred in collieries located to the east and to the north-east of Tahmoor Mine. No gas emissions or consequential changes in water quality have been reported over Tahmoor Mine in the Bargo River, Redbank Creek or Myrtle Creek.

Where these gas releases occur into the water column there is insufficient time for any substantial amount of gas to dissolve into the water. The majority of the gas is released into the atmosphere and is unlikely to have an adverse impact on water quality.

It is possible for substantial gas emissions at the surface to cause localised vegetation die-back. This is a rare event and has only been observed to occur previously on one occasion at Tower Colliery, over small areas in the base of the Cataract Gorge that had been directly mined beneath by Longwalls 10 and 14. These impacts were limited to small areas of vegetation, local to the points of emission, and when the gas emissions declined, the affected areas were successfully restored.

Further discussions on the potential impacts of fracturing, changes in surface water flows and water quality, and environmental consequences are provided in the Surface Water Technical Report (HEC, 2019).

5.3.5. Adaptive management of impacts on Stonequarry Creek

Following feedback received in relation to the 2014 SMP Application for Longwalls 31 to 37, TCCO has designed the layout of LW W1-W2 to avoid mining directly beneath Matthews, Cedar and Stonequarry Creeks. The purpose of the design is to substantially reduce the severity and extent of impacts on surface water flows within these creeks, compared to impacts that would occur if the longwalls were extracted directly beneath them.

TCCO has committed to implementing a detailed monitoring program to measure and record mining-induced ground movements and impacts on the streams during the mining of LW W1. A review of these observations will be undertaken after the LW W1 face has mined a sufficient distance such that the majority of mining-induced movements have occurred (after approximately 1000 m of extraction). If impacts on Cedar and Stonequarry Creek near the commencing end of LW W1 are greater than anticipated, TCCO will consider amending the commencing position of LW W2 to further reduce the potential for impacts on Stonequarry Creek. A similar review will be undertaken during the extraction of LW W2 prior to confirming the commencing position of future LW W3.

The review will be undertaken in consultation with the Department of Planning and Environment.

5.3.6. Recommendations for the creeks

TCCO has developed an Environmental Management Plan for managing the potential impacts on streams during the mining of Longwalls 22 to 32. The management plan includes ground monitoring, water quality and pool level monitoring and visual inspections. The plan also commits to remediation of aquatic ecosystems if impacts occur.

TCCO is required to develop and implement a Water Management Plan as part of the Extraction Plan for LW W1-W2.

5.4. Tributaries

5.4.1. Description of the tributaries

The locations of the tributaries within the Study Area are shown in Drawing No. MSEC1019-09.

Rumker Gully is classified as a third order stream between the rail loop line and its confluence with Matthews Creek. The length of the third order section of this tributary is approximately 0.4 km and its total length within the Study Area (i.e. first, second and third order sections) is approximately 1.12 km. Rumker Gully is located outside the LW W1-W2, at minimum distances of 80 m to the second order section and 230 m to the third order section of this tributary. The upper reaches first order section is partially located above the existing LW30.

The base of Rumker Gully falls approximately 37 m over the total length of approximately 1.12 km within the Study Area, with an inferred average gradient of 33 mm/m (i.e. 3.3 %, or 1 in 30). The upper reaches of the tributary flow through cleared grazing land. It then crosses beneath Thirlmere Way and some houses on Stonequarry Road via a concrete pipe. The tributary resurfaces after crossing beneath the road and flows beneath the Picton to Mittagong Loop Line, after which it drains to Matthews Creek.

The third order section of Rumker Gully is shown in Fig. 5.19. This section of the tributary flows over predominantly Hawkesbury Sandstone bedrock. The section of the tributary further upstream is steeply incised with isolated vertical scarps along its upper reaches. There are a number of channel constraints, including rockbars, boulders and rock shelves, which form standing pools along the alignment of the tributary.

Fig. 5.19 Rumker Gully upstream of Picton to Mittagong Loop Line

The remaining tributaries within the Study Area are first and second order. The third order section of Tributary 1 to Redbank Creek is located outside the Study Area, at minimum distance of 900 m from LW W1-W2.

The first and second order tributaries are located directly above LW W1-W2. These tributaries generally flow into Matthews, Cedar and Stonequarry Creeks. The tributaries in the eastern and southern parts of the Study Area flow into Redbank Creek.

5.4.2. Predictions for the tributaries

The predicted profiles of total vertical subsidence, upsidence and closure along Rumker Gully are shown in Fig. C.06, in Appendix C. The predicted total profiles at the completion of LW22 to LW32 are shown as the cyan lines. The predicted total profiles after the extraction of each of the proposed longwalls are shown as the blue lines.

The upper reaches of Rumker Gully is partially located above the existing LW30. The maximum predicted subsidence parameters for this first order section of the tributary, due to the extraction of LW22 to LW32, are 300 mm vertical subsidence, 350 mm upsidence and 200 mm closure. Only low-level additional movements (i.e. less than 20 mm subsidence, upsidence and closure) are predicted along this section of the tributary due to the extraction of LW W1-W2.

A summary of the maximum predicted values of total vertical subsidence, upsidence and closure for the third order section of Rumker Gully is provided in Table 5.5. This table provides the maximum predicted values for the section of the tributary from just upstream of the rail loop line to the confluence with Matthews Creek.

Table 5.5 Maximum predicted total vertical subsidence, upsidence and closure for the third order section of Rumker Gully

Location	Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
Third order section of Rumker Gully	After LW32	< 20	< 20	< 20
	After LW W1	30	30	60
	After LW W2	40	40	80

The third order section of Rumker Gully is predicted to experience vertical subsidence of less than 20 mm. Whilst this section of the tributary could experience very low-levels of vertical subsidence, it is not expected to experience measurable conventional tilts, curvatures or strains. The maximum predicted closure for the third order section of the tributary is 80 mm closure and the associated maximum predicted compressive strain is 6 mm/m based on the 95 % confidence level.

The first and second order tributaries are located directly above LW W1-W2 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.

5.4.3. Impact assessments for the tributaries

The third order section of Rumker Gully is predicted to experience vertical subsidence of less than 20 mm. The mining-induced changes in grade along this section of the tributary are predicted to be negligible.

The maximum predicted tilt for the first and second order tributaries located directly above LW W1-W2 is 5.5 mm/m (i.e. 0.55 %, or 1 in 180). The natural grades of these tributaries typically vary between 20 mm/m (i.e. 2 %, or 1 in 50) and 150 mm/m (15 %, or 1 in 7), with an average value of approximately 50 mm/m (i.e. 5 %, or 1 in 20).

The predicted mining-induced changes in grade are small when compared with the natural grades of the tributaries. It is unlikely, therefore, that the tributaries would experience adverse impacts due to increased levels of ponding, increased levels of scouring of the banks nor changes in stream alignment.

The maximum predicted total compressive strain along the third order section of Rumker Gully, due to the valley closure effects, is 6 mm/m based on the 95 % confidence level. The first and second order tributaries located directly above LW W1-W2 could experience compressive strains of 10 mm/m, or greater, due to valley closure effects.

Fracturing in bedrock has been observed due to previous longwall mining where the tensile strains are greater than 0.5 mm/m or where the compressive strains are greater than 2 mm/m. Fracturing could therefore develop along the tributaries located within the Study Area. The fracturing will predominately occur where the tributaries are located directly above LW W1-W2, but it can also occur at distances up to approximately 400 m outside the longwalls.

The mining-induced compression due to valley closure effects can also result in dilation and the development of bed separation in the topmost bedrock, as it is less confined. This additional dilation due to valley closure is expected to develop predominately within the top 10 m to 20 m of the bedrock. Compression can also result in buckling of the topmost bedrock resulting in heaving in the overlying surface soils.

Surface water flow diversions could occur along the tributaries that are located directly above LW W1-W2. In times of heavy rainfall, the majority of the runoff would flow over the fractured bedrock and soil beds and would not be diverted into the dilated strata below. In times of low flow, however, surface water flows can be diverted into the dilated strata below the beds. The tributaries are ephemeral and, therefore, surface water flows only occur during and for short periods after rain events.

Further discussions on the environmental consequences for the drainage lines are provided in the Surface Water Technical Report (HEC, 2019).

5.4.4. Recommendations for the tributaries

TCCO has developed an Environmental Management Plan for managing the potential impacts to streams during the mining of Longwalls 22 to 32. The management plan includes ground monitoring, water quality and pool level monitoring and visual inspections. The plan also commits to remediation of aquatic ecosystems if impacts occur.

TCCO is required to develop and implement a Water Management Plan as part of the Extraction Plan for LW W1-W2.

5.5. Aquifers and known groundwater resources

The potential for adverse impacts on groundwater and seeps as a result of mine subsidence is provided in Groundwater Technical Report (HydroSimulations, 2019) and the Baseline Private Bore Assessment (GeoTerra, 2019).

GeoTerra advise that it is possible that groundwater seepage may discharge in the streams in addition to the non-mining induced springs observed in Redbank Creek, Matthews Creek and Cedar Creek. If an adverse change in stream water quality occurs through development of an isolated new, or change to an existing, ferruginous spring occurs, it is anticipated that due to the ephemeral nature of the streams and the generally low flow volumes in the creeks, the effect will be localised around the point of discharge and will not adversely affect the overall water quality discharging out of the Study Area.

In relation to aquifer / aquitard interconnection, GeoTerra advise that, from past experience in NSW coalfields, it has been assessed that hydraulic connection of surface water or alluvial groundwater systems is not likely at mining depths of cover greater than 150 m.

A temporary lowering of the regional piezometric surface over the subsidence area due to horizontal dilation of strata may occur due to the increase in secondary porosity and permeability. This effect will be more notable directly over the area of greatest subsidence and dilation, and will dissipate laterally out to the edge of the subsidence zone.

Based on observations within the LW22 to LW31 mining area and similar observations in other areas in the Southern Coalfield, GeoTerra advise that groundwater levels may reduce by up to 15 m, and may stay at that reduced level until maximum subsidence develops at a specific location. The duration of the reduced levels depends on the time required to develop maximum subsidence, the time for subsidence effects to migrate away from a location as mining advances to subsequent panels, and the length of time required to recharge the secondary voids.

On the basis that the pre-mining circumstances of rainfall recharge and bore pumping remain the same, and based on observation of groundwater levels over LW22 to LW31, it is anticipated that groundwater levels generally recover over a few months to a year or so as the secondary void space is recharged by rainfall infiltration.

TCCO has developed an Environmental Management Plan for managing the potential impacts to groundwater bores during the mining of Longwalls 22 to 32. The management plan includes ground monitoring, water quality and pool level monitoring and visual inspections. The plan also commits to remediation of groundwater bores if impacts occur.

TCCO is required to develop and implement a Water Management Plan as part of the Extraction Plan for LW W1-W2.

5.6. Cliffs, minor cliffs and rock outcrops

5.6.1. Descriptions of the cliffs, minor cliffs and rock outcrops

The definitions of cliffs and minor cliffs provided in the NSW DP&E *Standard and Model Conditions for Underground Mining* (DP&E, 2012) are:

"Cliff	*Continuous rock face, including overhangs, having a minimum length of 20 metres, a minimum height of 10 metres and a minimum slope of 2 to 1 (>63.4°)*
Minor Cliff	*A continuous rock face, including overhangs, having a minimum length of 20 metres, heights between 5 metres and 10 metres and a minimum slope of 2 to 1 (>63.4°); or a rock face having a maximum length of 20 metres and a minimum height of 10 metres"*

Rock outcrops have been defined in this report as a rockface with a minimum slope of 2 to 1 (> 63.4°) irrespective of its length and height.

The cliffs, minor cliffs and rock outcrops have been identified from the LiDAR surface level contours and from field investigations. The locations of these rock features located within the Study Area are shown in Drawing No. MSEC1019-11.

There are 11 cliffs within the Study Area and two additional cliffs within the Study Area for natural features based on the 600 m boundary. These cliffs are located along Matthews and Cedar Creeks to the west of LW W1-W2. A summary of the cliffs within the Study Area is provided in Table 5.6.

Table 5.6 Cliffs located within the Study Area

Valley	Reference	Distance from LW W1-W2 (m)	Maximum height (m)	Overall length (m)
Matthews Creek	C_M01	100	10	21
	C_M02	145	10	23
Cedar Creek	C_C01	535	13	57
	C_C02	515	16	33
	C_C03	315	11	35
	C_C04	335	15	73
	C_C05	260	11	24
	C_C06	205	12	49
	C_C07	250	11	24
	C_C08	260	12	29
	C_C09	210	12	55

Minor cliffs and rock outcrops have also been identified along the valleys of Matthews and Cedar Creeks. These features are located outside the extents of LW W1-W2 at a minimum distance of 100 m from the proposed longwalls.

Photographs of typical cliffs and rock outcrops located within the Study Area are shown in Fig. 5.20 to Fig. 5.22 (Source: GeoTerra, 2014).

Fig. 5.20 Cliffs along Matthews Creek (Source: GeoTerra, 2014)

Fig. 5.21 Overhang along Matthews Creek (Source: GeoTerra, 2014)

Fig. 5.22 Overhang along Cedar Creek (Source: GeoTerra, 2014)

The cliffs and rock outcrops have predominantly developed in the Hawkesbury Sandstone group. The exposed rock faces demonstrate various stages of weathering or erosion, with many overhangs and undercuts.

5.6.2. Predictions for the cliffs, minor cliffs and rock outcrops

The predicted profiles of total vertical subsidence along the Matthews Creek and Cedar Creek are shown in Figs. C.03 and C.04, respectively, in Appendix C. The locations of the cliffs along these creeks are indicated in these figures.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvatures for the cliffs within the Study Area is provided in Table 5.7. The table provides the maximum predicted values within 20 m of the mapped extents of each of the cliffs.

Table 5.7 Maximum predicted total vertical subsidence, tilt and curvatures for the cliffs

Reference	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})
C_M01	100	0.5	< 0.01	< 0.01
C_M02	80	0.5	< 0.01	< 0.01
C_C01	< 20	< 0.5	< 0.01	< 0.01
C_C02	< 20	< 0.5	< 0.01	< 0.01
C_C03	40	< 0.5	< 0.01	< 0.01
C_C04	30	< 0.5	< 0.01	< 0.01
C_C05	40	< 0.5	< 0.01	< 0.01
C_C06	50	< 0.5	< 0.01	< 0.01
C_C07	30	< 0.5	< 0.01	< 0.01
C_C08	30	< 0.5	< 0.01	< 0.01
C_C09	< 20	< 0.5	< 0.01	< 0.01

The cliffs and minor cliffs along Matthews Creek are predicted to experience vertical subsidence up to 100 mm and tilts up to 0.5 mm/m (i.e. 0.05 %, or 1 in 2000). The cliffs and minor cliffs along Cedar Creek are predicted to experience vertical subsidence up to 50 mm and tilts of less than 0.5 mm/m. Whilst the cliffs and minor cliffs within the Study Area could experience low-level vertical subsidence and tilt, they are not expected to experience measurable curvatures or conventional strains.

Matthews and Cedar Creeks are predicted to experience valley related effects. However, the cliffs and minor cliffs are located on the valley sides and, therefore, they are not expected to experience the upsidence or compressive strains that occur near the bases of the valleys.

5.6.3. Impact assessments for the cliffs

The cliffs and minor cliffs within the Study Area are located outside the extents of LW W1-W2. These rock features are predicted to experience only low-levels of vertical subsidence. The likelihood of cliff instabilities has been assessed using case studies where previous longwall mining has occurred close to but not directly beneath cliffs. These case studies are based on cliffs and valleys that are considerably larger than those within the Study Area.

- *Appin Longwalls 301 and 302 near the Cataract River*

  Appin Longwalls 301 and 302 mined adjacent to a number of cliff lines located along the Cataract River valley. A total of 68 cliffs were identified within a 35°angle of draw from the longwalls. The cliffs had continuous lengths ranging between 5 m and 230 m, overall heights ranging between 10 m and 37 m and had been formed within the Hawkesbury Sandstone.

  Appin Longwalls 301 and 302 have void widths of 260 m, solid chain pillar widths of 40 m and were extracted from the Bulli Seam at a depth of cover of 500 m. These longwalls mined to within 50 m of the identified locations of the cliffs along the Cataract River valley.

  There were no large cliff instabilities observed as a result of the extraction of Appin Longwalls 301 and 302. There were, however, five minor rock falls or disturbances which occurred during the mining period, of which, three were considered likely to have occurred due to a significant rainfall event and natural instability of the cliff overhang. The length of cliff line disturbed as a result of the extraction of Appin Longwalls 301 and 302 was, therefore, estimated to be less than 0.5 % of the total face area of the cliff lines within the mining domain.

- *Tower Longwalls 18 to 20 and Appin Longwalls 701 to 707 near the Nepean River*

  Tower Longwalls 18 to 20 and Appin Longwalls 701 to 707 mined adjacent to many cliff lines located along the Nepean River valley. More than 50 cliffs were identified within a 35°angle of draw from these longwalls. The cliffs had continuous lengths ranging between 5 m and 225 m, overall heights ranging between 10 m and 40 m and had been formed within the Hawkesbury Sandstone.

  Tower Longwalls 18 to 20 have void widths of 235 m, solid chain pillar widths of 40 m and were extracted from the Bulli Seam at a depth of cover of 500 m. Appin Longwalls 701 to 707 have void widths of 320 m, solid chain pillar widths of 40 m and were extracted from the Bulli Seam at a depth of cover of 500 m.

  Tower Longwall 20 mined directly beneath some cliffs located at the confluence of Elladale Creek and the Nepean River. Appin Longwalls 701 to 707 mined to within 75 m of the identified locations of the cliffs along the Nepean River valley.

  There were no cliff instabilities observed as a result of the extraction of Tower Longwalls 18 to 20 and Appin Longwalls 701 to 707.

Based on the previous experience of mining at Appin and Tower Collieries, it is possible that isolated rock falls could occur at the cliffs within the Study Area due to the extraction of LW W1-W2. It is unlikely that large-scale cliff instabilities would occur based on the experience of mining adjacent to but not directly beneath cliffs in the Southern Coalfield.

While the risk of large cliff instabilities is considered to be extremely low, some risk remains and attention must therefore be paid to any structures and roads that are located in the vicinity of the cliffs. The cliffs within the Study Area are located on privately owned land that is thick with vegetation. The likelihood that a person or persons would be present if and when a rock fall occurred is considered to be extremely low. It is recommended, however, that management strategies are developed with the land owners to minimise the potential risks resulting from rock falls.

5.6.4. Recommendations for the cliffs and minor cliffs

TCCO has developed an Environmental Management Plan for managing the potential impacts on the cliffs and minor cliffs during the mining of Longwalls 22 to 32. It is recommended that TCCO continue to develop these management plans during the mining of the proposed longwalls.

TCCO is required to develop and implement a Land Management Plan as part of the Extraction Plan for LW W1-W2.

It is recommended that TCCO include measures to manage the potential consequences of rock falls at the cliffs and minor cliffs due to LW W1-W2. This would include consultation with the landowner and visual inspections before and after the completion of each longwall.

5.7. Steep slopes

5.7.1. Descriptions of the steep slopes

The definition of a steep slope provided in the NSW DP&E *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 the steep slopes were identified from the 1 m surface level contours that were generated from the LiDAR survey of the area.

The areas identified as having steep slopes are shown in Drawing No. MSEC1019-11.

Natural steep slopes have been identified along the banks of Matthews, Cedar and Stonequarry Creeks, where the near surface lithology is part of the Hawkesbury Sandstone group. Natural steep slopes are also located on the sides of ridges above the proposed longwalls, where the near surface lithology is part of the Wianamatta Shale group.

An analysis of the LiDAR survey has also identified steep slopes that have been constructed, such as dam walls, embankments and cutting faces. In some cases, retaining walls have been cut into the side of a natural slope with a gradient that is less than 1 in 3 but the analysis has identified a "steep slope" due to the presence of the retaining walls. Potential impacts on built features that are located on or near natural steep slopes are addressed in Chapter 6 of this report. A total of 46 structures within the Study Area have been built on or near steep slopes. A summary of these structures is provided in Table 5.8.

Table 5.8 Structures and dams within the Study Area that are located on or near steep slopes

Structure Type	Description	No.
H	Houses	11
P	Pool	1
R	Rural structures	21
PU	Public Utilities	13
	Total	**46**

The structures and dams within the Study Area that are located on or near steep slopes are shown in Drawing No. MSEC1019-11. Driveways have also been identified from an aerial photograph that traverse along or near steep slopes and these are shown in Drawing No. MSEC1019-11.

5.7.2. Predictions, impact assessments and recommendations for the steep slopes

The steep slopes are located directly above LW W1-W2 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 maximum predicted tilt for the steep slopes within the Study Area is 5.5 mm/m (i.e. 0.55 %, or 1 in 180). The predicted changes in grade are very small when compared to the natural surface grades, which are greater than 1 in 3. It is unlikely, therefore, that the mining-induced tilts would result in an adverse impact on the stability of the steep slopes.

The steep slopes are more likely to be affected by curvature and strain, rather than tilt. The potential impacts generally occur from the increased horizontal movements in the downslope direction, resulting in tension cracks appearing at the tops and on the sides of the steep slopes and compression ridges forming at the bottoms of the steep slopes.

There has been extensive experience of mining directly beneath the steep slopes along the banks of Myrtle Creek and Redbank Creek during the previous extraction of LW22 to LW31. No slope instabilities have been observed during this mining. Soil cracking up to 65 mm wide was observed on both the upper banks and flanks of Myrtle Creek at one location above Longwall 23B. The cracks extended into the soil to depths of approximately 1.5 m to 2.0 m and over a length of approximately 40 m.

There is extensive experience of mining beneath steep slopes elsewhere in the Southern Coalfield, including the mining of Longwalls 14 to 19 at Tahmoor Mine. The majority of the steepest slopes above previous mining within the Southern Coalfield were within the Hawkesbury Sandstone group, along the Cataract, Nepean, Bargo and Georges Rivers, and no slope instabilities have been observed.

There is some experience of mining beneath slopes in the Wianamatta Shale group at Tahmoor Mine, during the mining of Longwalls 27 and 28 directly beneath the ridge that runs along Tickle Drive. No slope instabilities have been observed during mining.

It is possible, therefore, that some remediation might be required to ensure that mining-induced cracking does not result in the formation of soil erosion channels. In some cases, erosion protection measures may be needed, such as the planting of additional vegetation in order to stabilise the slopes in the longer term.

While any impacts on slopes are likely to consist of surface cracking, there remains a possibility of slope slippage on the ridges. Localised natural slope slippage has been observed at TCCO, such as on Redbank Range and, therefore, it is possible that localised slope slippages could develop along the ridges within the Study Area that may be attributable to either natural causes, mine subsidence, or both.

Experience indicates that the likelihood of slope slippages due to mining is extremely low due to the significant depth of cover beneath the ridges. No large scale mining-induced slope failures have been observed in the Southern Coalfield at depths of cover exceeding 400 m. While the risk is extremely low, some risk remains and attention must therefore be paid to any structures or roads that may be located in the vicinity of steep slopes.

A total of 36 structures have been identified on or near to natural steep slopes within the Study Area. There are also a number of privately owned driveways or tracks that are located on or near these steep slopes.

TCCO has developed a subsidence management plan for managing the potential impacts on steep slopes during the mining of Longwalls 22 to 32. The management plan includes:

- identification of structures, dams and roads that lie in close proximity to steep slopes;
- site investigation and landslide risk assessment of structures near slopes by a qualified geotechnical engineer. This has been conducted previously by GHD Geotechnics for all structures near steep slopes that may experience subsidence during the mining of Longwalls 22 to 32;
- site investigation and structural assessment of structures where recommended by the geotechnical engineer. This may include recommendations to mitigate against potential impacts;
- monitoring, including ground survey and visual inspections; and
- remediation if cracking or slippage occurs.

While no impacts have been observed on structures or dams due to mining-induced slope instabilities during the mining of Longwalls 22 to 31, it is recommended that TCCO continue to develop strategies to manage potential impacts on slopes during the mining of the proposed longwalls.

Thirlmere Way runs along the side of a ridge near the southern (i.e. finishing) end of LW W1. Steep slopes are located above and below the road, as shown in Drawing No. MSEC1019-11. A cross-section through Thirlmere Way and the ridgeline above the finishing end of LW W1 is provided in Fig. 5.23.

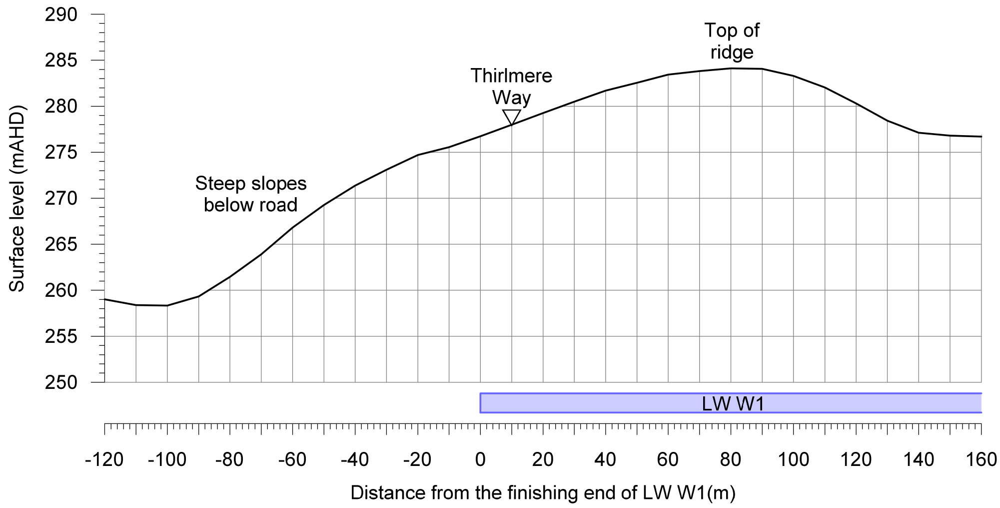

Fig. 5.23 Cross-section through Thirlmere Way and the ridgeline above LW W1

It is possible that surface cracking or slippage could develop on the side of the ridge due to the extraction of LW W1 and that these may intersect with Thirlmere Way. Thirlmere Way narrows in this section, with no shoulders on either side of the pavement, limiting the access for monitoring and undertaking repairs. The traffic along this section of road, therefore, will need to be managed to allow surveys and inspections to be undertaken and undertake any required remediation works.

Management strategies have already been developed for another section of Thirlmere Way located on a ridgeline adjacent to the finishing ends of LW31 and LW32, in consultation with Wollondilly Shire Council. These management strategies include site investigation by a geotechnical engineer, visual and ground monitoring during active subsidence and remediation methods in accordance with safe working procedures. It is recommended that TCCO continue to develop strategies to manage potential impacts on Thirlmere Way during the mining of the proposed longwalls, in consultation with Wollondilly Shire Council.

In addition to the above, TCCO is required to develop and implement a Land Management Plan and a Built Features Management Plan as part of the Extraction Plan for LW W1-W2 and measures to manage potential impacts on steep slopes are included in these Plans.

5.8. Escarpments

There are no escarpments located within the Study Area.

5.9. Land prone to flooding and inundation

Flood modelling has been undertaken by WRM based on the existing topography as surveyed by LiDAR and predicted subsidence movements due to the extraction of the proposed longwalls *WRM* (2019).

The study found that flows are generally contained within the channels of Matthews Creek, Cedar Creek and Stonequarry Creek within the Study Area. The crest of Barkers Lodge Road may be overtopped during a Probable Maximum Flood (PMF) event. The subsidence resulting from the mining of the proposed LW W1-W2 results in a negligible change in flood levels, flow velocities and flood extent within the catchment area (WRM, 2019

5.10. Water-related ecosystems

The potential impacts on the water-related ecosystems within the Study Area are discussed in the Aquatic Biodiversity Technical Report (*Niche* 2019a).

5.11. Threatened, protected species, other fauna and natural vegetation

Impact assessments for threatened and protected species, other fauna and natural vegetation within the Study Area are provided in the Terrestrial Biodiversity Technical Report (Niche, 2019b).

5.12. Natural Vegetation

The majority of the natural vegetation in the Study Area has previously been cleared for residential, agricultural and commercial land uses. Remnant natural vegetation has been identified along the alignments of the streams and along the ridges. A survey of the natural vegetation within the Study Area has been undertaken by Niche Environment and Heritage and included in Terrestrial Biodiversity Technical Report (Niche, 2019b).

The following sections provide descriptions, predictions and impact assessments for the built features within the Study Area. All significant features located outside the Study Area, which may be subjected to far-field movements or valley related movements and may be sensitive to these movements, have also been included as part of these assessments.

6.1. The Main Southern Railway

The Main Southern Railway is located outside the Study Area. The railway is located 600 m east of the proposed LW W2 at its closest point to the proposed longwalls. At this distance, it is unlikely that the railway would experience adverse impacts, even if the predictions were exceeded by a factor of two times.

The nearest rail bridge to LW W1 is the Bridge Street Overbridge (91.000 km), which is shown in Drawing No. MSEC1019-12. This rail bridge is located 1.1 km south of the proposed LW W1 and it is directly above the completed LW29. The nearest rail bridges to LW W2 are the Thirlmere Way Underbridge (89.826 km) and the Connellan Crescent Overbridge (89.080 km), which are shown in Drawing No. MSEC1019-12. These rail bridges are located 850 metres and 1.0 km east of the proposed LW W2, respectively. At these distances, the three rail bridges are predicted to experience negligible vertical subsidence.

The rail bridges could experience small far-field horizontal movements, in the order of 25 mm to 50 mm, as illustrated in Fig. 4.8. The absolute horizontal movements are not expected to be associated with measurable strains. It is unlikely that the rail bridges outside the Study Area would experience adverse impacts, due to the extraction of the proposed LW W1-W2, even if the predictions were exceeded by a factor of two times.

The Picton Rail Tunnel and Mushroom Tunnel are located outside and to the east of the Study Area. These tunnels are discussed in Section 6.6.

The Picton Viaduct (85.42 km) is located outside the Study Area, as shown in Drawing No. MSEC1019-12. The Viaduct is located 1.5 km east of the proposed LW W2. At this distance, the Viaduct is predicted to experience negligible vertical subsidence.

The Picton Viaduct could experience small far-field horizontal movements, in the order of 10 mm to 30 mm, as illustrated in Fig. 4.8. The absolute horizontal movements are not expected to be associated with measurable strains. It is unlikely that the Picton Viaduct would experience adverse impacts, due to the extraction of the proposed LW W1-W2, even if the predictions were exceeded by a factor of two times.

The Viaduct crosses Stonequarry Creek and while the valley related effects at the Viaduct are also predicted to be negligible, it is noted that this section of Stonequarry Creek follows alignments of geological structures associated with the Nepean Fault. Prior to the commencement of Longwall 32, TCCO has installed survey marks and GNSS monitoring units in the ground beyond the abutments at each end of the Viaduct. TCCO has also installed marks at the bases of the piers and abutments and completed a baseline dilapidation study of the Viaduct. TCCO monitors changes in the positions of the survey marks and GNSS units on a monthly basis during the mining of Longwall 32. Monitoring will continue during the proposed extraction of LW W1-W2.

6.2. Picton to Mittagong Loop Line

6.2.1. Description of the Picton to Mittagong Loop Line

The location of the Picton to Mittagong Loop Line is shown in Drawing No. MSEC1019-12.

The Picton to Mittagong Loop Line is located directly above the northern ends of LW W1-W2. The total length of the loop line located directly above the proposed longwalls is 0.83 km. The total length located within the Study Area is 2.2 km.

The Picton to Mittagong Loop Line is part of the former alignment of the Main South Line. It was built in 1867. The loop line was bypassed in 1919 following the construction of a new double track deviation, which is the current alignment of the Main Southern Railway.

The original alignment of the Picton to Mittagong Loop Line passed through the Mushroom Tunnel and along an old disused embankment, which can still be found near 87.500 km on the Main Southern Railway, forming a triangular wedge of land that is bounded by three embankments. An old brick culvert is located in the old embankment.

Transport Heritage NSW, operating the Trainworks Railway Museum at Thirlmere, holds a licence to use the track. The majority of tourist trains run between Thirlmere and Buxton to the south of the Study Area.

Approximately 4 to 5 trains typically travel through the Study Area per week as part of tours or arriving or leaving the Museum for maintenance.

The Picton to Mittagong Loop Line junction to the Main Southern Railway is located at approximately 85.5 km, just north of the Picton Viaduct. The loop line runs as a “triple track” adjacent to the dual tracks of the Main Southern Railway until it swings away towards Thirlmere near the Up Branch Landmark at 87.152 km, which is located east of the Study Area.

The Picton to Mittagong Loop Line is a single line jointed track, which is defined by ARTC as rails that can move through the rail/sleeper fastenings and which have standard joints with a 6 mm gap installed at neutral temperature. The rails are generally fixed to steel or timber sleepers (but not concrete).

The 83 lb rails on the loop line are jointed at approximately 12 m (40 foot) lengths, staggered between the Up and Down rail. Some rails are 9 m (30 foot) long. The rails are generally supported by steel sleepers within the Study Area, except at the joints, which are supported by timber sleepers. The rails are fixed to the sleepers using a wedge fastening system.

A photograph of a section of the Picton to Mittagong Loop Line within the Study Area is provided in Fig. 6.1.

Fig. 6.1 Picton to Mittagong Loop Line at 88.980 km (looking north)

There are five drainage culverts associated with the Picton to Mittagong Loop Line that are located within the Study Area and two additional culverts that are located just outside the Study Area. The locations of these culverts are shown in Drawing No. MSEC1019-12 and the details are provided in Table 6.1.

Table 6.1 Loop line culverts located within the Study Area

Kilometrage (km)	Width (mm)	Height (mm)	Description	Location relative to proposed longwalls
87.330 km	1200 dia.		Brick arch culvert (circa 1919, part of section built to join onto Main Southern Railway)	550 m east of LW W2
87.630 km	1200 dia.		Brick arch culvert (circa 1919, part of section built to join onto Main Southern Railway)	280 m east of LW W2
87.850 km	1500 dia.		Brick arch culvert (circa 1919, part of section built to join onto Main Southern Railway)	70 m east of LW W2
88.400 km	2500 dia.		Stone arch culvert (circa 1867)	Directly above LW W1
88.980 km	2500 dia.		Stone arch culvert (circa 1867, restored as part of Stonequarry Estate development)	60 m west of LW W1
89.629 km	3200	3000	Stone arch culvert (circa 1867) with brick wingwalls (circa 1919) on the upstream side to support vehicular track	250 m west of LW W1
87.300 km (old loop line)	1200 dia.		Brick arch culvert (circa 1919, part of section built to join onto Main Southern Railway)	480 m east of LW W2

Photographs of the loop line culverts located within the Study Area are shown in Fig. 6.2 to Fig. 6.6.

Fig. 6.2 Loop line culvert at 87.330 km

Fig. 6.3 Loop line culvert at 87.850 km

Fig. 6.4 Loop line culvert at 88.400 km

Fig. 6.5 Loop line culvert at 88.980 km

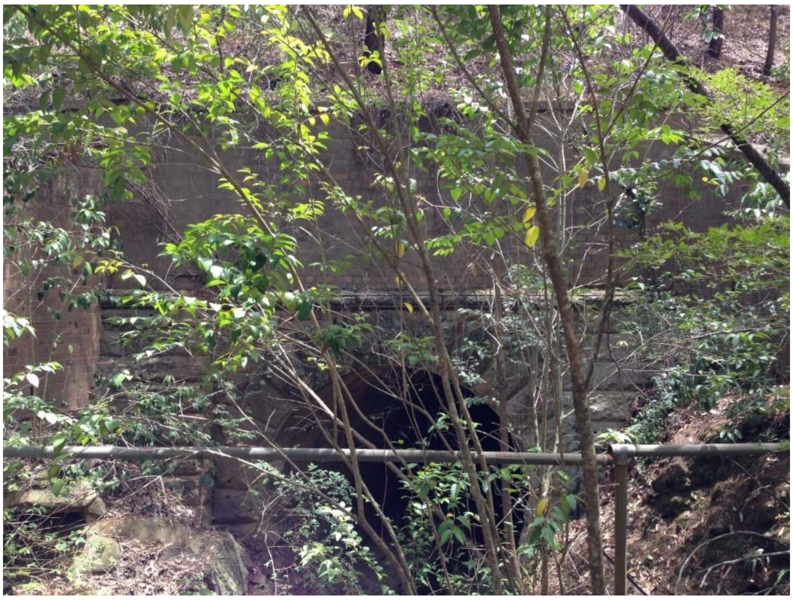

Fig. 6.6 Loop line culvert with wingwalls at 89.629 km

There are four embankments associated with the Picton to Mittagong Loop Line that are located within the Study Area and one additional embankment just outside the Study Area. The locations of these embankments are shown in Drawing No. MSEC1019-12 and the details are provided in Table 6.2.

Table 6.2 Loop line embankments located within the Study Area

Kilometrage (km)	Length (mm)	Height (mm)	Description	Location relative to proposed longwalls
Embankment at 87.331km	360	14	Earth embankment	420 m east of LW W2
Embankment at 87.850km	260	11	Earth embankment	Partially above the maingate of LW W2
Embankment at 88.400km	200	8	Earth embankment	Directly above LW W1
Embankment at 88.980km	80	8	Earth embankment	40 m west of LW W1
Embankment at 89.629km	280	12	Earth embankment	210 m west of LW W1

The embankments are typically constructed with local fill material and contain relatively steep batters.

There are three cuttings associated with the Picton to Mittagong Loop Line that are located within the Study Area. The locations of these cuttings are shown in Drawing No. MSEC1019-12 and the details are provided in Table 6.3.

Table 6.3 Loop line cuttings within the Study Area

Kilometrage (km)	Length (mm)	Height (mm)	Description	Location relative to proposed longwalls
Cutting at 88.1 km	150	15	Battered, weathered shale	Above LW32
Cutting at 88.7 km	220	8	Battered, weathered shale	Above LW35 & LW36
Cutting at 89.3 km	300	4	Battered, weathered shale	Above LW37

A photograph of the low height cutting at 88.7 km is shown in the background in Fig. 6.1.

6.2.2. Predictions for the Picton to Mittagong Loop Line

The predicted profiles of total vertical subsidence and change in grade along the alignment of the Picton to Mittagong Loop Line are shown in Fig. C.07, in Appendix C. The predicted total profiles after the extraction of each of the proposed longwalls are shown as the blue lines. The transient movements during active subsidence are shown by the yellow shading for LW W1 and the green shading for LW W2.

A summary of the maximum predicted values of total vertical subsidence, change in grade and curvatures for the Picton to Mittagong Loop Line is provided in Table 6.4. The table provides the maximum predicted values for the section of track located within the Study Area at any time during or after the extraction of each of the proposed longwalls.

Table 6.4 Maximum predicted total vertical subsidence, change in grade and curvatures for the Picton to Mittagong Loop Line

Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total change in grade (%)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
After LW W1	450	0.20	0.02	0.03
After LW W2	750	0.50	0.03	0.06

The maximum predicted total change in grade along the alignment of the Picton to Mittagong Loop Line is 0.5 % (i.e. 5 mm/m, 1 in 200). The maximum predicted total curvatures are 0.03 km^{-1} hogging and 0.06 km^{-1} sagging, which represent minimum radii of curvature of 33 km and 17 km, respectively.

The maximum predicted conventional strains along the Picton to Mittagong Loop Line, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 0.5 mm/m tensile and 1 mm/m compressive. Higher strains could develop along the loop line due to irregular ground movements or topographic effects.

The predicted strains for the Picton to Mittagong Loop Line have been based on the statistical analyses of strain provided in Chapter 4. The loop line is a linear feature and, therefore, the most relevant distribution of strain is the maximum measured values anywhere along whole monitoring lines above the previously extracted longwalls, as discussed in Section 4.5.2. The maximum measured total tensile strains were less than 2 mm/m in 93 % of cases and the maximum measured total compressive strains were less than 4 mm/m in 89 % of cases.

Higher compressive strains could develop where the Picton to Mittagong Loop Line crosses the tributaries due to valley closure effects. The predicted ground movements in the tributary crossings are discussed in Section 6.2.3.

The predicted profiles of total horizontal movement, change in cant and long twist across the alignment of the Picton to Mittagong Loop Line are shown in Fig. C.08, in Appendix C. The predicted total profiles after the extraction of each of the proposed longwalls are shown as the blue lines. The transient movements during active subsidence are shown by the yellow shading for LW W1 and the green shading for LW W2.

A summary of the maximum predicted values of total horizontal movement, change in cant and long twist for the Picton to Mittagong Loop Line is provided in Table 6.5. The table provides the maximum predicted values for the section of track located within the Study Area at any time during or after the extraction of each of the proposed longwalls.

Table 6.5 Maximum predicted total horizontal movement, change in cant and long twist for the Picton to Mittagong Loop Line

Longwall	Maximum predicted total horizontal movement across the track (mm)	Maximum predicted total change in cant (mm)	Maximum predicted total long twist over a 13.2 m bay length (m)
After LW W1	40	4	< 1
After LW W2	40	4	< 1

The maximum predicted total change in cant along the Picton to Mittagong Loop Line is 4 mm. The greatest changes in cant occur directly above LW W1, adjacent to the longwall maingate and tailgate. Lesser values occur directly above LW W2 as the track is less oblique to this longwall. The maximum predicted total long twist over a 13.2 m bay length is less than 1 mm.

A summary of the maximum predicted conventional subsidence and valley related effects for the loop line culverts is provided in Table 6.6. The table provides the maximum total values within a 20 m radius of each culvert due to the extraction of LW22 to LW32 and LW W1-W2.

Table 6.6 Maximum Predicted total vertical subsidence, tilt, curvature, upsidence and closure for the loop line drainage culverts within the Study Area

Label	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})	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
87.330 km	< 20	< 0.5	< 0.01	< 0.01	< 20	< 20
87.630 km	40	< 0.5	< 0.01	< 0.01	20	30
87.850 km	150	1.0	< 0.01	< 0.01	125	250
88.400 km	725	1.5	0.02	0.02	80	125
88.980 km	125	1.0	0.01	< 0.01	50	80
89.629 km	40	< 0.5	< 0.01	< 0.01	40	60
87.300 km (old loop line)	< 20	< 0.5	< 0.01	< 0.01	< 20	< 20

6.2.3. Impact assessments for the Mittagong to Picton Loop Line

The potential impacts on the Picton to Mittagong Loop Line comprise changes in track geometry and changes in rail stress.

Changes in track geometry

The changes in track geometry are described using the following parameters:

- Vertical misalignment (top) - vertical deviation of the track from design;
- Horizontal misalignment (line) - horizontal deviation of the track from design;
- Changes in track cant - changes in superelevation across the rails from design; and
- Track Twist - changes in superelevation over a length of track from design.

The Australian Rail Track Corporation's (ARTC) National Code of Practice provide allowable deviations in track geometry. The predicted total changes in track geometry for the Picton to Mittagong Loop Line have been determined using the predicted conventional mine subsidence movements provided in Section 6.2.2. A summary of the maximum allowable and maximum predicted changes in track geometry are provided in Table 6.7.

Table 6.7 Allowable and predicted maximum changes in track geometry for the Picton to Mittagong Loop Line based on conventional subsidence movements for LW W1-W2

Track geometry parameter	Description	Maximum allowable (mm)		Maximum predicted due to conventional movements (mm)	
		Speed limit is first applied	Trains are stopped	LW W1	LW W2
Top	Vertical mid-ordinate deviation over a 10 m chord	38	46	< 1	2
Line	Horizontal mid-ordinate deviation over an 8 m chord	35	53	1	2
Change in cant	Deviation from design superelevation across rails spaced 1.435 m apart	41	75	4	4
Long twist	Changes in cant over a 14 m chord	43	65	< 1	< 1

The predicted changes in track geometry are an order of magnitude less than the maximum allowable deviations specified in the National Code of Practice, if conventional subsidence occurs. For example, the maximum allowable changes in cant across the rails are 41 mm and 75 mm before the trains are respectively slowed and then stopped. In mining terminology, this represents tilts of approximately 30 mm/m to 50 mm/m (i.e. 3 % to 5 %), which are substantially greater than the maximum predicted conventional tilt of 5 mm/m due to the extraction of LW W1-W2.

The changes in track geometry could be greater than those presented in Table 6.7 if non-conventional movements develop along the Picton to Mittagong Loop Line. The potential rates of development of non-conventional movements have been assessed using the ground monitoring data from the previously extracted longwalls at TCCO and elsewhere in the Southern Coalfield.

An example of substantial non-conventional movement in the Southern Coalfield occurred above Appin Longwall 408. In this case, a low angle thrust fault was re-activated in response to mine subsidence movements, resulting in differential vertical and horizontal movements across the fault. Observations at the site showed that the non-conventional movements developed gradually and over a long period of time.

Regular ground monitoring across the low angle thrust fault indicated that the rate of differential movement was less than 0.5 mm/day at the time non-conventional movements could first be detected. Subsequently as mining progressed, the rate of differential movement increased to a maximum of 28 mm/week. In comparison with the National Code of Practice, the maximum allowable deviations in track geometry are much larger than the measured daily rates of change due to mining.

Two localised non-conventional subsidence events have adversely impacted on track geometry. Differential subsidence movements developed gradually at each site, such that visual inspections could detect small changes at an early stage. This allows time to resurface the track in between the passing of trains and return track geometry parameters to within safety limits. In the case of the Picton to Mittagong Loop Line, there is ample time between trains, which generally run only on weekends.

It is therefore considered that while non-conventional movements may potentially result in adverse changes to track geometry, the potential risk to track safety can be managed through early detection via monitoring and early response through the implementation of triggered response plans. A number of management measures are proposed to manage changes in track geometry:

- assess pre-mining track condition and adjust track (if necessary) so that pre-mining track geometry is within normal operating standards for the loop line prior to the development of subsidence;
- identify potential sites of non-conventional movement, such as creeks and geological structures;
- install a monitoring system, which includes, among other things, the monitoring of ground movements along the loop line;
- regularly review and assess the monitoring data;
- conduct regular visual inspections of the track prior to the operation of the loop line; and
- adjust the track in response to monitoring results during mining if required to keep the track well within safety limits.

With an appropriate management plan in place, it is considered that potential impacts on track geometry can be managed during the mining of LW W1-W2, even if actual subsidence movements are greater than the predictions or substantial non-conventional movements occur.

Changes in track grade

The Picton to Mittagong Loop Line climbs steadily in a southbound direction through the Study Area from Picton to Thirlmere. The maximum gradient along the loop line within the Study Area is 1 in 34 near 88.5 km (i.e. approximately 1.45 km from the Main Southern Railway) directly above LW W1.

The predicted changes in track gradient along the Picton to Mittagong Loop Line and the predicted gradients along the track after the completion of LW W1-W2 are shown in Fig. C.07, in Appendix C. It should be noted, however, that the locations of steeper grades exist over relatively short lengths (a couple of hundred metres), which is of less concern to trains than steep grades over longer lengths (kilometres).

The maximum predicted gradient along the Picton to Mittagong Loop Line after the completion of the proposed longwalls is 1 in 31 near 88.5 km (i.e. approximately 1.45 km from the Main Southern Railway) directly above LW W1.

Changes in rail stress

The Picton to Mittagong Loop Line is a single line jointed track, which is defined by ARTC as rails that can move through the rail/sleeper fastenings and which have standard joints with a 6 mm gap installed at neutral temperature. Mine subsidence will result in changes in the distances between the sleepers, transferring ground strain into rail stress. The amount of transfer, however, will be limited by the short 9 m to 12 m lengths of rail, separated by 6 mm wide joints, and the types of fastenings used to secure rails to the sleepers.

It is possible that mining-induced tensile ground strains could result in opening of joints. Mining-induced compressive ground strains could result in closing of joints. The gaps between rails at the joints can, however, be reset prior to the passage of trains. In the case of the Picton to Mittagong Loop Line, there is ample time between trains, which generally run only on weekends.

It is therefore considered that while the extraction of LW W1-W2 may potentially result in adverse changes to the rail joints, the potential risk to track safety can be managed through early detection via monitoring and early response through the implementation of triggered response plans. A number of management measures are proposed to manage potential impacts on rail joints:

- assess pre-mining track condition and adjust track (if necessary) so that pre-mining rail joints are within normal operating standards for the loop line prior to the development of subsidence;
- identify potential sites of non-conventional movement, such as tributaries and geological structures;
- install a monitoring system, which includes, among other things, the monitoring of ground movements along the loop line;
- regularly review and assess the monitoring data;
- conduct regular visual inspections of the track, including rail joints and fittings, prior to the operation of the loop line; and
- adjust the track in response to monitoring results during mining if required to keep the track, including rail joints and fittings, well within safety limits.

With an appropriate management plan in place, it is considered that potential impacts on the track can be managed during the mining of LW W1-W2, even if actual subsidence movements are greater than the predictions or substantial non-conventional movements occur.

Loop line culverts

The maximum predicted total tilt at the loop line culverts is 1.5 mm/m (i.e. 0.15 %, or 1 in 670). It is not expected that mining-induced conventional tilts would have adverse impacts on the drainage flows in the culverts, as the changes in grade are predicted to be less than 1 %. It is recommended, however, that the culverts are cleared of vegetation and debris prior to mining.

The main risk identified with all the brick arch and stone culverts is the potential for physical impacts to occur. It is possible that these culverts will experience some cracking and spalling of the masonry as a result of the extraction of LW W1-W2. Cracking may occur in the masonry arch or in the headwalls. These can be reinforced prior to mining or subsequently repaired as required. In the case of the loop line, there is ample time between trains.

It is therefore considered that while the extraction of LW W1-W2 may potentially result in impacts on the culverts, the potential risk to track safety can be managed through early detection via monitoring and early response through the implementation of triggered response plans. A number of management measures are proposed to manage potential impacts on culverts:

- assess pre-mining culvert condition prior to the development of subsidence;
- consider and implement mitigation measures, if required, which may include measures such as:
    - installation of steel reinforcement structures within the culvert opening;
    - installation of steel reinforcement within the masonry itself (as undertaken at Redbank Creek culvert); or
    - installation of a steel or reinforced concrete sleeve within the culvert opening (as undertaken at the skew culvert);
- install a monitoring system, which includes, among other things, the monitoring of ground movements on and around the culvert, and track geometry above the culvert;
- regularly review and assess the monitoring data;
- conduct regular visual inspections of the culvert; and
- repair the culvert if required.

With an appropriate management plan in place, it is considered that potential impacts on the loop line culverts can be managed during the extraction of LW W1-W2, even if actual subsidence movements are greater than the predictions or substantial non-conventional movements occur.

Loop line embankments

The embankments are typically constructed with local fill material and contain relatively steep batters. The likelihood of impacts on the embankments is considered to be relatively low provided that the culverts remain serviceable and do not become blocked.

The embankments may experience cracking during mining, however, these can be readily treated before they develop into a safety hazard. TCCO will consider mitigation measures before each embankment experiences subsidence movements. Mitigation works could include, for example, cleaning out of the culverts and drainage lines beneath the embankments, or the stabilisation of the batters.

Potential impacts on the loop line embankments can be managed using measures including:

- management of potential impacts on the culvert within the embankment, which is the key element of the management strategy. This is discussed in the previous section;
- assess pre-mining condition of the embankment;
- consider and implement mitigation measures, such as cleaning out of the culverts and drainage lines beneath the embankments;
- install a monitoring system, which includes, among other things, the monitoring of ground movements on and around the embankment;
- regularly review and assess the monitoring data;
- conduct regular visual inspections of the embankment; and
- seal cracks that develop on the embankment if required.

With an appropriate management plan in place, it is considered that potential impacts on loop line embankments can be managed during the mining of LW W1-W2, even if actual subsidence movements are greater than the predictions or substantial non-conventional movements occur.

Loop line cuttings

The loop line cuttings within the Study Area are relatively small in size. The cuttings could experience the full range of subsidence movements during the extraction of LW W1-W2. It is considered unlikely that the cuttings would experience adverse impacts during the mining of the longwalls.

The potential impacts on the low height cuttings will be managed primarily by visual inspections and maintaining clear access for inspections in the cess. Ground surveys along the loop line corridor monitoring line will also be undertaken.

With an appropriate management plan in place, it is considered that potential impacts on loop line cuttings can be managed during the mining of LW W1-W2, even if actual subsidence movements are greater than the predictions or substantial non-conventional movements occur.

6.2.4. Recommendations for the Picton to Mittagong Loop Line

TCCO and Transport Heritage NSW (THNSW), operating the Trainworks Railway Museum at Thirlmere, have previously managed potential mine subsidence impacts on the Picton to Mittagong Loop Line during the extraction of LW21, when a corner of this longwall extracted directly beneath the loop line. A subsidence management plan was also developed in consultation and agreement with the then NSW Rail Transport Museum to manage the low likelihood risks associated with the mining of LW24 to LW26 at a remote distance from the loop line.

It is recommended that TCCO and THNSW develop a new plan to manage potential impacts during the mining of LW W1-W2. In the case of the loop line, there is ample time between trains, which generally run only on weekends. It is therefore possible to undertake monitoring and contingent response measures during weekdays prior to trains running.

With an appropriate management plan in place, it is considered that potential impacts on Picton to Mittagong Loop Line can be managed during the mining of LW W1-W2, even if actual subsidence movements are greater than the predictions or substantial non-conventional movements occur.

6.3. Local roads

6.3.1. Description of the local roads

The locations of the local roads within the Study Area are shown in Drawing No. MSEC1019-13.

The main road within the Study Area is Thirlmere Way which connects Thirlmere and Picton. It crosses directly above the finishing (i.e. southern) end of LW W1. The total length of Thirlmere Way located above directly above LW W1 is 0.25 km and the total length located within the Study Area is 1.2 km.

The local roads within the Study Area include Stonequarry Creek Road, Carramar Close, Attunga Close and Booyong Close, which are partially located above the southern end of LW W1. Barkers Lodge Road is located outside the mining area to the north of the proposed longwalls.

The local roads are maintained by Wollondilly Shire Council.

6.3.2. Predictions for the local roads

The predicted profiles of total vertical subsidence, tilt and curvature along Thirlmere Way and Stonequarry Road are shown in Figs. C.09 and C.10, respectively, in Appendix C. The predicted total profiles at the completion of LW22 to LW32 are shown as the cyan lines. The predicted total profiles after the extraction of each of the proposed longwalls are shown as the blue lines.

Summaries of the maximum predicted values of total vertical subsidence, tilt and curvatures for Thirlmere Way and Stonequarry Creek Road are provided in Table 6.8 and Table 6.9, respectively. The tables provide the maximum predicted values for the sections of the roads within the Study Area.

Table 6.8 Maximum predicted total vertical subsidence, tilt and curvatures for Thirlmere Way

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})
After LW32	80	< 0.5	0.01	< 0.01
After LW W1	80	< 0.5	0.01	< 0.01
After LW W2	100	< 0.5	0.02	< 0.01

Table 6.9 Maximum predicted total vertical subsidence, tilt and curvatures for Stonequarry Road

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})
After LW W1	425	2.0	0.02	0.05
After LW W2	700	3.0	0.03	0.05

The remaining roads are located directly above LW W1 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 maximum predicted conventional strains for the roads, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1 mm/m tensile and 2 mm/m compressive. Higher strains can develop along the roads due to irregular ground movements or topographic effects.

The predicted strains for the local roads have been based on the statistical analyses of strain provided in Chapter 4. The roads are linear features and, therefore, the most relevant distribution of strain is the maximum measured values anywhere along whole monitoring lines above the previously extracted longwalls, as discussed in Section 4.5.2. The maximum measured total tensile strains were less than 2 mm/m in 93 % of cases and the maximum measured total compressive strains were less than 4 mm/m in 89 % of cases.

6.3.3. Impact assessments for the local roads

There is extensive experience of mining directly beneath local roads in the Southern Coalfield which indicates that impacts can be managed with the implementation of suitable management strategies. In all cases the local roads have remained in safe and serviceable condition and have been remediated using normal road maintenance techniques.

LW22 to LW31 at TCCO have mined directly beneath more than 28 km of local roads and a total of 52 impact sites have been observed. The observed rate of impact on the local roads equates to an average of one impact for every 540 m of pavement. In most cases, the impacts were relatively minor and were remediated by locally resurfacing the pavements.

The most severe impacts were located where substantial non-conventional movements had developed. These impact sites were identified using visual and ground monitoring and remediation was undertaken during active subsidence to maintain these roads in safe and serviceable conditions.

Photographs of typical impacts observed on local roads at TCCO are provided in Fig. 6.7.

Fig. 6.7 Previously observed impacts on local loads at TCCO

Impacts have also been observed to concrete kerbs, gutters and drainage pits. The impacts are most commonly focussed around driveway laybacks and involve cracking, spalling or buckling. A typical buckling impact is shown at the bottom-right of Fig. 6.7.

TCCO and Wollondilly Shire Council have developed and acted in accordance with an agreed risk management plan to manage potential impacts to local roads during the mining of LW22 to LW32. The management plan provides for ground and visual monitoring of road pavements. If impacts occur to the road network, Wollondilly Shire Council is able to quickly repair the pavement, if required.

6.3.4. Recommendations for the local roads

TCCO and Wollondilly Shire Council have developed and acted in accordance with an agreed risk management plan to manage potential impacts to local roads during the mining of LW22 to LW32. It is recommended that this management plan is reviewed and updated to incorporate LW W1-W2.

6.4. Road drainage culverts

6.4.1. Descriptions of the road drainage culverts

The locations of the road drainage culverts are shown in Drawing No. MSEC1019-14.

There are four road drainage culverts that are located within the Study Area. A summary of these culverts is provided in Table 6.10.

Table 6.10 Road drainage culverts located within the Study Area

Road	Culvert ref.	Location	Size and type
Stonequarry Creek Road	SC-C1	190 m west of LW W1	Single RCP 600 mm dia.
	SC-C2	Directly above LW W1	Single RCP 600 mm dia.
	SC-C3	Directly above LW W1	Single RCP 900 mm dia.
Thirlmere Way	TH-C2	130 m west of LW W1	Single RCP 800 mm dia.

There are also likely to be other drainage culverts beneath private driveways with the Study Area.

6.4.2. Predictions for the road drainage culverts

A summary of the maximum predicted values of total vertical subsidence, tilt and curvatures for road drainage culverts is provided in Table 6.11. This table provides the maximum predicted values within 20 m of each of the culverts at any time during or after the extraction of LW W1-W2.

Table 6.11 Maximum predicted total vertical subsidence, tilt and curvatures for the road drainage culverts

Culvert	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})
SC-C1	40	< 0.5	< 0.01	< 0.01
SC-C2	625	3.5	0.05	0.05
SC-C3	700	2.5	0.02	0.05
TH-C2	30	< 0.5	< 0.01	< 0.01

The remaining drainage culverts beneath private driveways are located across the Study Area and, therefore, could experience the full range of predicted subsidence parameters, which are summarised in Chapter 4.

The maximum predicted conventional strains for the road drainage culverts, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 0.5 mm/m tensile and 1 mm/m compressive. Higher strains could develop at the houses due to irregular ground movements or topographic effects.

The predicted distributions of strain due to the extraction of LW W1-W2 are described in Chapter 4. The culverts are at discrete locations and, therefore, the most relevant distribution of strain is the maximum strains measured in individual survey bays above previous longwall mining, which is summarised in Section 4.5.1. The maximum predicted total strains directly above the proposed longwalls are 1.0 mm/m tensile and 1.8 mm/m compressive based on the 95 % confidence level.

The road drainage culverts are located within tributaries and therefore could experience valley related effects.

Culverts SC-C1 and TH-C2 are located on Rumker Gully. The predicted upsidence and closure along this tributary are illustrated in Fig. C.06, in Appendix C. The locations of the road crossings are indicated in this figure. The maximum predicted valley related effects for Culverts SC-C1 and TH-C2 are 50 mm upsidence and 80 mm closure.

Culverts SC-C2 and SC-C3 are located on small tributaries directly above LW W1. The maximum predicted valley related effects for these culverts are 25 mm upsidence and 50 mm closure.

6.4.3. Impact assessments for the road drainage culverts

The maximum predicted tilt for Culverts SC-C1 to SC-C3 and TH-C2 is 3.5 mm/m (i.e. 0.35 %, or 1 in 285). The other road drainage culverts beneath the private driveways could experience tilts up to 5.5 mm/m (i.e. 0.55 %, or 1 in 180). It is unlikely that the mining-induced tilts would result in adverse impacts on the serviceability of these culverts, as the changes in grade are less than 1 %. If the flow of waters through any of the culverts were adversely affected, due LW W1-W2, these could be remediated by re-levelling the affected culverts.

The predicted curvatures and strains could be of sufficient magnitudes to result in cracking in the culverts or the headwalls. It is unlikely, however, that these movements would adversely impact on the stabilities or structural integrities of the culverts. The potential impacts on the drainage culverts could be managed by visual inspection and, where required, any affected culverts can be repaired or replaced.

The drainage culverts are located along the tributaries and therefore could experience valley related effects. The drainage culverts are orientated along the alignments of the tributaries and, therefore, the upsidence and closure movements are orientated perpendicular the main axes of the culverts and unlikely to result in adverse impacts.

Previous experience of mining beneath culverts in the NSW coalfields, at similar depths of cover, indicates that the incidence of impacts is low. Impacts have generally been limited to cracking in the concrete headwalls which can be readily remediated. In some cases, however, cracking in the culvert pipes occurred which required the culverts to be replaced.

TCCO and Wollondilly Shire Council have developed and acted in accordance with an agreed risk management plan to manage potential impacts to roads drainage culverts during the mining of LW22 to LW32. The management plan provides for visual monitoring of the culverts.

6.4.4. Recommendations for the road drainage culverts

TCCO and Wollondilly Shire Council have developed and acted in accordance with an agreed risk management plan to manage potential impacts to the road drainage culverts during the mining of LW22 to LW32. It is recommended that this management plan is reviewed and updated to incorporate LW W1-W2.

6.5. Road bridges

There are no road bridges within the Study Area.

The nearest bridges are located where Remembrance Drive crosses Redbank Creek (RE-B1) and the Abbotsford Bridge, Argyle Street Bridge and Victoria Bridge across Stonequarry Creek. These road bridges are shown in Drawing No. MSEC1019-14.

The road bridges are located at distances between 1 km and 1.4 km from LW W1-W2. At these distances, the bridges are predicted to experience negligible vertical subsidence. The bridges could experience small far-field horizontal movements, in the order of 25 mm to 50 mm, as illustrated in Fig. 4.8. The absolute horizontal movements are not expected to be associated with measurable strains.

It is unlikely that the road bridges outside the Study Area would experience adverse impacts, due to the extraction of LW W1-W2, even if the predictions were exceeded by a factor of two times.

6.6. Tunnels

There are no tunnels within the Study Area.

The brick arch Picton Rail Tunnel and the stone arch Mushroom Tunnel are located outside of the Study Area at minimum distances of 750 m and 825 m, respectively, to the east of LW W2. The locations of these tunnels are shown in Drawing No. MSEC1019-14. Photographs of the tunnels are provided in Fig. 6.8 and Fig. 6.9.

Fig. 6.8 Picton Rail Tunnel

Fig. 6.9 Mushroom Tunnel

The Mushroom Tunnel is used as part of the vehicular access road along the Main Southern Railway. It is also occasionally used for heritage tours.

The Picton Rail Tunnel and Mushroom Tunnel are predicted to experience negligible vertical subsidence. However, the tunnels could experience small far-field horizontal movements and could be sensitive to these movements. It can be seen from Fig. 4.8, that incremental far-field horizontal movements around 75 mm have been measured at distances of 800 m from previously extracted longwalls in the Southern Coalfield.

The potential for impacts on the tunnels does not result from absolute far-field horizontal movements, but rather from differential horizontal movements over the lengths of the structures. The potential for differential horizontal movements at the Picton Rail and Mushroom Tunnels has been assessed by statistically analysing the available 3D monitoring data from the Southern Coalfield.

Histograms of the maximum observed incremental opening and closing movements for survey marks spaced at 200 m ±10 m, at distances between 600 m and 900 m from active longwalls, are shown in Fig. 6.10. The *Generalised Pareto Distributions (GPDs)* which have been fitted to this data have also been shown in these figures.

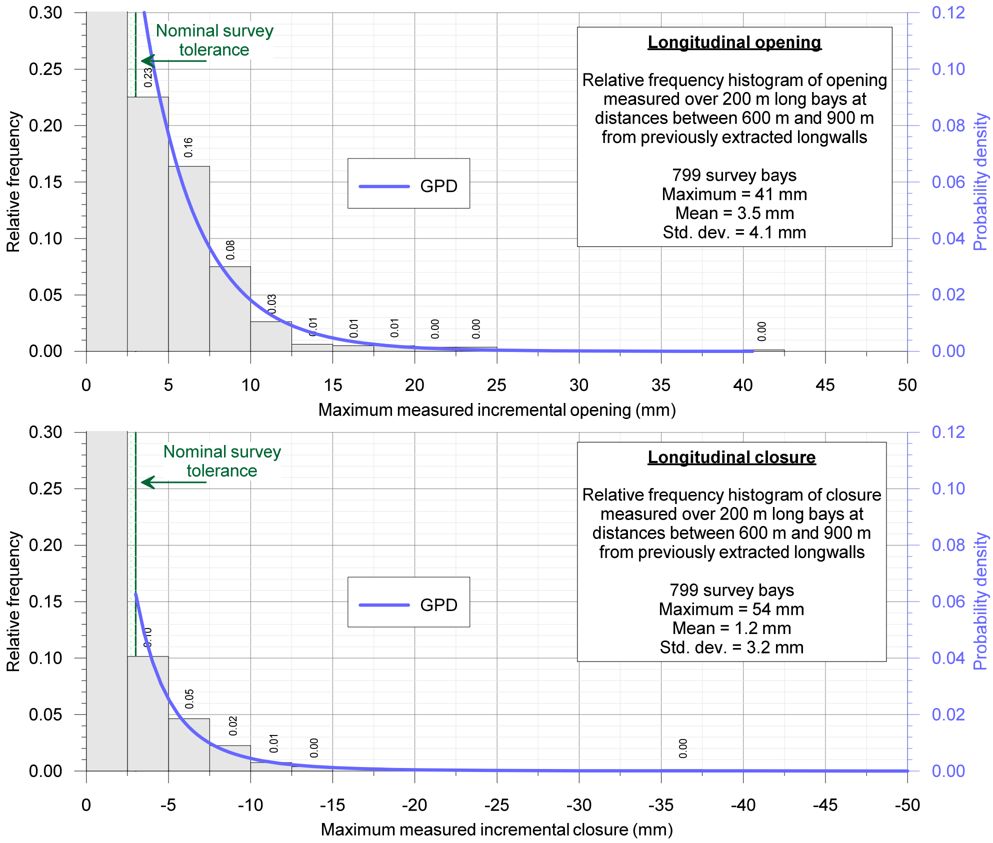

Fig. 6.10 Distributions of maximum measured incremental opening and closure for survey marks spaced at 200 m ±10 m at distances between 600 m and 900 m from active longwalls

The maximum incremental longitudinal movements over the lengths of the tunnels, based on the fitted GPDs to the available ground monitoring data, are 11 mm opening and 6 mm closure, based on the 95 % confidence levels.

Mid-ordinate deviation is a measure of differential lateral movement, which is the change in perpendicular horizontal distance from a point to a chord formed by joining points on either side. A histogram of the maximum measured incremental horizontal mid-ordinate deviation for three survey marks spaced a total of 200 m ±10 m, at distances between 600 m and 900 m from active longwalls, is shown in Fig. 6.11.

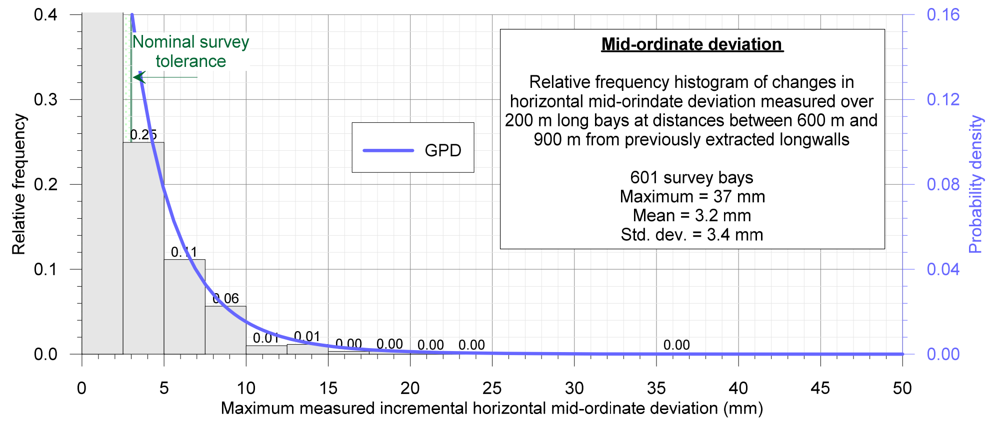

Fig. 6.11 Distribution of maximum measured incremental horizontal mid-ordinate deviation for spaced at 200 m ±10 m at distances between 600 m and 900 m from active longwalls

The maximum incremental horizontal mid-ordinate deviation over the lengths of the tunnels, based on the fitted GPD to the available ground monitoring data, is 10 mm, based on the 95 % confidence level.

TCCO is currently monitoring the position of the Picton Tunnel as part of its far field monitoring program, which is reviewed regularly. This includes a GNSS monitoring unit. Monitoring will continue during the mining of LW W1-W2.

6.7. Potable water infrastructure

6.7.1. Descriptions of the potable water infrastructure

The locations of the potable water infrastructure within the Study Area are shown in Drawing No. MSEC1019-15.

The potable water infrastructure comprises buried 100 mm and 180 mm uPVC pipelines along Thirlmere Way, Stonequarry Creek Road, Attunga Close, Booyong Close and Carramar Close. These pipelines are partly located above the southern end of LW W1. The total length of potable water pipelines located above the longwall is approximately 0.5 km. The total length of potable water pipelines within the Study Area is approximately 1.6 km.

The potable water infrastructure is owned by Sydney Water.

6.7.2. Predictions for the potable water infrastructure

The predicted profiles of total vertical subsidence, tilt and curvature for the 180 mm potable water pipeline along Stonequarry Creek Road are similar to those predicted for this road as shown in Fig. C.10, in Appendix C. The predicted total profiles after the extraction of each of the proposed longwalls are shown in blue. The sections of the 100 mm potable water pipelines located directly above LW W1 are expected to experience ground movements similar to those for the 180 mm potable water pipeline.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvatures for the potable water pipelines is provided in Table 6.12. The table provides the maximum predicted values along the alignments of the pipelines at any time during or after the extraction of each longwall.

Table 6.12 Maximum predicted total vertical subsidence, tilt and curvatures for the potable water pipelines

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})
After LW W1	425	2.0	0.02	0.05
After LW W2	700	3.0	0.03	0.05

The maximum predicted conventional strains for the potable water pipelines, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 0.5 mm/m tensile and 1 mm/m compressive. Higher strains can develop along the pipelines due to irregular ground movements or topographic effects.

The predicted strains for the potable water pipelines have been based on the statistical analyses of strain provided in Chapter 4. The pipelines are linear features and, therefore, the most relevant distribution of strain is the maximum measured values anywhere along whole monitoring lines above the previously extracted longwalls, as discussed in Section 4.5.2. The maximum measured total tensile strains were less than 2 mm/m in 93 % of cases and the maximum measured total compressive strains were less than 4 mm/m in 89 % of cases.

The potable water pipelines cross small tributaries directly above LW W1 and therefore could experience valley related effects. The maximum predicted valley related effects for these pipelines are 25 mm upsidence and 50 mm closure.

6.7.3. Impact assessments for the potable water infrastructure

LW22 to LW31 at TCCO have directly mined beneath approximately 25 km of potable water pipelines. These pipelines comprise older Ductile Iron Concrete Lined (DICL) and Cast Iron Concrete Lined (CICL) pipelines. The extraction of longwalls beneath these pipelines at TCCO has only resulted in minor impacts. Water leaks were repaired by Sydney Water using normal response procedures.

There is other experience of mining directly beneath potable water pipelines elsewhere in the Southern Coalfield, where the ground movements were similar to those predicted for LW W1-W2. Examples of the previous experience of mining beneath potable water pipelines at TCCO and elsewhere in the Southern Coalfield are provided in Table 6.13.

Table 6.13 Examples of previous experience of mining beneath water pipelines in the Southern Coalfield

Colliery and longwalls	Pipelines	Measured movements	Observed impacts
Appin LW301 and LW302	0.6 km of 150 dia. DICL 0.6 km of 300 dia. CICL 0.6 km of 1200 dia. SCL	650 mm Subsidence 4.5 mm/m Tilt 1 mm/m Tensile Strain 3 mm/m Comp. Strain (Measured M & N-Lines)	Leakage of the 150 mm and 300 mm CICL pipelines at a creek crossing, elsewhere no other reported impacts
Tahmoor LW22 to LW31	5.4 km DICL pipes 19 km CICL pipes	1200 mm Subsidence 6 to 10 mm/m Tilt 1.5 mm Tensile Strain 2 mm (typ.) and up to 5 mm/m Comp. Strain (Extensive street monitoring)	Impacts occurred to the distribution network at 5 locations and a very small number of minor leaks in the consumer connection pipes
West Cliff LW5A3, LW5A4 & LW29 to LW34	2.8 km of 100 dia. CICL pipe directly mined beneath	1100 mm Subsidence 10 mm/m Tilt 1 mm/m Tensile Strain 5.5 mm/m Comp. Strain (Measured B-Line)	No reported impacts

The newer uPVC pipelines located within the Study Area are expected to be less susceptible to impacts from mine subsidence than the DICL and CICL pipelines located above the previously extracted longwalls.

Based on this experience, it is possible that some minor leakages of the potable water pipelines could occur, in isolated locations, due to the extraction of LW W1-W2. The incidence of these impacts is expected to be very low. Impacts are more likely to occur in the locations of non-conventional ground movements and at the tributary crossings due to the valley related effects. Any impacts are expected to be of a minor nature that could be readily repaired.

6.7.4. Recommendations for the potable water infrastructure

TCCO and Sydney Water have developed and acted in accordance with an agreed risk management plan to manage potential impacts to potable water infrastructure during the mining of LW22 to LW32. It is recommended that the management plan is reviewed and updated to incorporate LW W1-W2.

6.8. Sewerage infrastructure

6.8.1. Descriptions of the sewerage infrastructure

There are sewerage pipelines located within the Study Area, which are managed by Stonequarry Estate.

A Wastewater Treatment Plant (WTP) on the Stonequarry Estate is located within the Study Area, as shown in Drawing No. MSEC1019-15. The property is located outside the proposed mining area at a minimum distance of 90 m east of LW W2.

An aerial photograph of the Stonequarry Estate WTP is shown in Fig. 6.12. The plant includes an assortment of tanks, structures and a dam, which are connected by a network of pipes.

The design of the WTP was approved by Subsidence Advisory NSW.

Fig. 6.12 WTP on Stonequarry Estate

6.8.2. Predictions for the sewerage infrastructure

Summaries of the maximum predicted values of total vertical subsidence, tilt and curvature for each of the houses within the Study Area are provided in Table D.05, in Appendix D. The predicted tilts represent the maximum values in any direction after the completion of each of LW W1-W2. The predicted curvatures represent the maximum values in any direction at any time during or after the extraction of each of the proposed longwalls.

The maximum predicted values of total vertical subsidence, tilt and curvature for each of the structures associated with the WTP are included in Table D.05, in Appendix D. The structures on this property are Refs. PSC-90-pu01 to PSC_90_pu13. The maximum predicted subsidence effects for the dam associated with the WTP (Ref. PSC_090_d01) are provided in Table D.06, in Appendix D.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvatures for structures and dam associated with the WTP is provided in Table 6.14. This table provides the maximum predicted values within 20 m of each of the structures at any time during or after the extraction of LW W1-W2.

Table 6.14 Maximum predicted total vertical subsidence, tilt and curvatures for the structures and dam associated with the WTP on Stonequarry Estate

Reference	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})
Structures (PSC 90 pu01 to PSC_90_pu13)	80	0.5	< 0.01	< 0.01
Dam (PSC_090_d01)	125	0.5	< 0.01	< 0.01

The maximum predicted conventional strains for the structures and dam, based on applying a factor of 15 to the maximum predicted conventional curvatures, are less than 0.5 mm/m tensile and compressive. Higher strains could develop at these features due to irregular ground movements or topographic effects.

The predicted distributions of strain due to the extraction of LW W1-W2 are described in Chapter 4. The structures and dam are at discrete locations and, therefore, the most relevant distribution of strain is the maximum strains measured in individual survey bays outside of previous longwall mining (i.e. above solid coal), which is summarised in Section 4.5.1. The maximum predicted total strains outside the proposed longwalls are 0.7 mm/m tensile and 0.5 mm/m compressive based on the 95 % confidence level.

6.8.3. Impact assessments and recommendations for the sewerage infrastructure

As the design of the WTP has been approved by Subsidence Advisory NSW, it is expected that the structures, dam and connecting services pipes will be able to accommodate the predicted ground movements due to LW W1-W2. It is possible, however, that the WTP could experience non-conventional movements during the extraction of the proposed longwalls.

It is recommended that TCCO and Stonequarry Estate develop a subsidence management plan to manage potential impacts on the WTP during the extraction of LW W1-W2. It is recommended that measures be developed to manage potential impacts on the WTP to ensure that the plant remains safe and serviceable during mining. These include:

- engineering assessment of potential impacts on the Picton WRP infrastructure;
- surveys and visual inspections of the WTP during mining; and
- response plan to repair the WTP if required.

6.9. Gas infrastructure

6.9.1. Descriptions of the gas infrastructure

The locations of the gas infrastructure within the Study Area are shown in Drawing No. MSEC1019-16.

The gas infrastructure comprises buried 32 mm, 50 mm and 75 mm nylon (NY) pipelines along Thirlmere Way, Stonequarry Creek Road, Attunga Close, Booyong Close and Carramar Close. These pipelines are partly located above the southern end of LW W1. The total length of gas pipelines located above the longwall is approximately 0.65 km. The total length of gas pipelines within the Study Area is approximately 1.9 km.

The gas infrastructure is owned by Jemena.

6.9.2. Predictions for the gas infrastructure

The predicted profiles of total vertical subsidence, tilt and curvature for the 50 mm gas pipeline along Stonequarry Road are similar to those predicted for this road as shown in Fig. C.10, in Appendix C. The predicted total profiles after the extraction of each of the proposed longwalls are shown in blue. The sections of the other gas pipelines located directly above LW W1 are expected to experience ground movements similar to those for the 50 mm gas pipeline.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvatures for the gas pipelines is provided in Table 6.15. The table provides the maximum predicted values along the alignments of the pipelines at any time during or after the extraction of each longwall.

Table 6.15 Maximum predicted total vertical subsidence, tilt and curvatures for the gas pipelines

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})
After LW W1	425	2.0	0.02	0.05
After LW W2	700	3.0	0.03	0.05

The maximum predicted conventional strains for the gas pipelines, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 0.5 mm/m tensile and 1 mm/m compressive. Higher strains can develop along the pipelines due to irregular ground movements or topographic effects.

The predicted strains for the gas pipelines have been based on the statistical analyses of strain provided in Chapter 4. The pipelines are linear features and, therefore, the most relevant distribution of strain is the maximum measured values anywhere along whole monitoring lines above the previously extracted longwalls, as discussed in Section 4.5.2. The maximum measured total tensile strains were less than 2 mm/m in 93 % of cases and the maximum measured total compressive strains were less than 4 mm/m in 89 % of cases.

The gas pipelines cross small tributaries directly above LW W1 and therefore could experience valley related effects. The maximum predicted valley related effects for these pipelines are 25 mm upsidence and 50 mm closure.

6.9.3. Impact assessments for the gas infrastructure

LW22 to LW31 at TCCO have directly mined beneath approximately 18 km of gas pipelines and no adverse impacts have been recorded to date. The nylon pipelines are very flexible and have demonstrated that they are able to withstand the full range of subsidence experienced during longwall extraction at TCCO. While no impacts have been experienced to date, it is acknowledged that the most vulnerable element of the system is the rigid copper pipe connections between the gas mains and the houses, which can be readily repaired.

For example, the 160 mm diameter polyethylene main along Remembrance Drive experienced no adverse impacts during the mining of LW25. This includes a ground strain of approximately 2.5 mm/m over a 37 m bay along Remembrance Drive. If all of the compressive strain is concentrated at one location, this would equate to a strain of approximately 4 mm/m over a 20 m bay. This experience provides some comfort that the gas pipelines will be able to withstand upsidence, closure and elevated compressive strains as a result of valley related effects due to the extraction of LW W1-W2.

Based on experience during the mining of LW22 to LW31, it is considered that the extraction of LW W1-W2 is unlikely to result in adverse impacts on the gas infrastructure within the Study Area. The range of predicted subsidence effects is less than that experienced during the mining of LW22 to LW31.

TCCO and Jemena have developed and acted in accordance with an agreed risk management plan to manage potential impacts to gas infrastructure during the mining of LW22 to LW31. The management plan includes ground and visual monitoring including the use of hand-held gas detection devices, and planned responses if triggered by observations of increased ground strains, ground curvature or localised surface deformations. Jemena inspectors have also conducted targeted regular inspections if triggered by monitoring results during the mining of LW24A, LW25 and LW31.

If the conditions are considered sufficient to potentially damage a section of pipe, Jemena is able to quickly uncover the pipe section, inspect the pipe for signs of stress and, if required, isolate the pipe section at short notice and repair, as documented in the management plan. The management plan is reviewed periodically by TCCO and Jemena.

6.9.4. Recommendations for the gas infrastructure

TCCO and Jemena have developed and acted in accordance with an agreed risk management plan to manage potential impacts to gas infrastructure during the mining of LW22 to LW32. It is recommended that this management plan is reviewed and updated to incorporate LW W1-W2.

6.10. Electrical infrastructure

6.10.1. Descriptions of the electrical infrastructure

The locations of the electrical infrastructure within the Study Area are shown in Drawing No. MSEC1019-17.

The electrical infrastructure comprises 11 kilovolt (kV) and low voltage powerlines that generally follow the local roads. The powerlines are partly located above the southern ends of LW W1-W2. The total length of powerlines located above the longwalls is approximately 2.4 km. The total length of powerlines within the Study Area is approximately 10.3 km.

The 11 kV powerline along Thirlmere Way and the section of the low voltage powerline above the southern end of LW W2 comprise aerial conductors supported by timber poles. The powerlines along Stonequarry Creek Road, Attunga Close, Booyong Close and Carramar Close are buried.

The electrical infrastructure is owned by Endeavour Energy.

6.10.2. Predictions for the electrical infrastructure

The predicted profiles of total vertical subsidence, tilt and curvature for the 11 kV powerlines along Thirlmere Way and Stonequarry Road are similar to those predicted for these roads as shown in Figs. C.09 and C.10, respectively, in Appendix C. The predicted total profiles after the extraction of each of the proposed longwalls are shown as the blue lines.

The other powerlines are located directly above the southern ends of LW W1-W2 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.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvatures for the powerlines is provided in Table 6.16. This table provides the maximum predicted values for the powerlines at any time during or after the extraction of each longwall.

Table 6.16 Maximum predicted total vertical subsidence, tilt and curvatures for the powerlines

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})
After LW W1	475	3.0	0.03	0.06
After LW W2	750	5.5	0.06	0.11

The maximum predicted conventional strains for the powerlines, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1 mm/m tensile and 2 mm/m compressive. Higher strains can develop along the powerlines due to irregular ground movements or topographic effects.

The predicted strains for the powerlines have been based on the statistical analyses of strain provided in Chapter 4. The powerlines are linear features and, therefore, the most relevant distribution of strain is the maximum measured values anywhere along whole monitoring lines above the previously extracted longwalls, as discussed in Section 4.5.2. The maximum measured total tensile strains were less than 2 mm/m in 93 % of cases and the maximum measured total compressive strains were less than 4 mm/m in 89 % of cases.

The powerlines cross small tributaries directly above LW W1-W2 and therefore could experience valley related effects. The maximum predicted valley related effects for these powerlines are 25 mm upsidence and 50 mm closure.

6.10.3. Impact assessments for the electrical infrastructure

The aerial powerlines will not be directly affected by the ground strains, as the cables are supported by poles above ground level. However, the cables 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 conventional tilt, and by changes in the catenary profiles of the cables.

The underground powerlines could be affected by the mining-induced curvatures and strains. These cables could also be affected by the localised ground movements at the tributary crossings due to the valley related effects.

There is extensive experience of mining directly beneath powerlines in the Southern Coalfield and this shows that incidences of impacts are very low and that these are readily repairable. The majority of these experience is for mining directly beneath aerial powerlines. Examples of the previous experience of mining beneath powerlines in the Southern Coalfield is provided in Table 6.17.

Table 6.17 Previous experience of mining beneath powerlines in the Southern Coalfield

Colliery and longwalls	Length of powerline directly mined beneath (km)	Maximum measured movements at the powerlines	Observed impacts
Appin LW1 to LW12	5.2 km of 11 kV 104 power poles	850 mm Subsidence 6 mm/m Tilt (Measured WX-Line)	No significant impacts
Appin LW14 to LW29	1.0 km of 66 kV 4.6 km of 11 kV 76 power poles	1200 mm Subsidence 7 mm/m Tilt (Measured A-Line)	No significant impacts
Appin LW301 and LW302	0.6 km of 66 kV 0.2 km of 11 kV 14 power poles	650 mm Subsidence 4.5 mm/m Tilt (Measured M & N-Lines)	No significant impacts
Appin LW401 to LW408	3.4 km of 66 kV 0.6 km of 33 kV 2.9 km of 11 kV 96 power poles	700 mm Subsidence 5 mm/m Tilt (Measured A-Line)	No significant impacts
Appin LW702	1.5 km of 11 kV 19 power poles	550 mm Subsidence 3.5 mm/m Tilt (Measured MPR-Line)	No significant impacts
Dendrobium LW3 and LW4	0.8 km of 33 kV	1100 mm Subsidence 40 mm/m Tilt (Measured 2000-Line)	No significant impacts
Tahmoor LW22 to LW31	Approx. 41 km of electrical cables and 1060 power poles	1200 mm Subsidence 12 mm/m Tilt (Extensive street monitoring, surveys of critical power poles)	Some minor adjustments to cable catenaries, pole tilts and consumer cables required.
Tower LW1 to LW10	6.0 km of 66 kV 4.3 km of 11 kV 112 power poles	400 mm Subsidence 3 mm/m Tilt (Measured T & TE-Lines)	No significant impacts
West Cliff LW5A3 to LW5A4 & LW29 to LW33	0.8 km of a 66 kV 3.7 km of 11 kV 113 power poles	950 mm Subsidence 5 mm/m Tilt (Measured B-Line)	No significant impacts

LW22 to LW31 at TCCO have directly mined beneath approximately 41 km of electrical cables and 1060 power poles and no significant impacts have been recorded. and there were no significant adverse impacts. However, tension adjustments have been made by Endeavour Energy to some aerial services connections to houses. This is understandable as the overhead cables are typically pulled tight between each house and power pole.

While the experience at TCCO has been relatively benign, Endeavour Energy has been required to adjust power pole tilts and catenaries as a result of mine subsidence at other locations within the Southern Coalfield. This repair work is more substantial but the frequency of such impacts is very low.

The past experiences demonstrate that there have only been minor impacts on aerial powerlines that have been directly mined beneath by previously extracted longwalls in the Southern Coalfield. Some remedial measures were required, which included adjustments to cable catenaries, pole tilts and to consumer cables which connect between the powerlines and houses. The incidence of these impacts was very low.

There is less experience of mining beneath buried powerlines in the Southern Coalfield. However, there is extensive experience of mining beneath buried copper telecommunications cables, as discussed in Section 6.11. This experience indicates that the likelihood of impacts on buried copper cables is also low.

Based on this experience at TCCO and elsewhere in the Southern Coalfield, it is considered unlikely that the extraction of LW W1-W2 would result in adverse impacts on the aerial and buried powerlines within the Study Area. The range of predicted subsidence effects is less than that experienced during the mining of LW22 to LW31.

It is possible, however, that a small number of adjustments of the aerial powerline connections would be required. There is also a low probability that adjustment for power pole tilt or catenaries will be required as a result of mining based on experience of mining elsewhere in the Southern Coalfield.

6.10.4. Recommendations for the electrical infrastructure

TCCO and Endeavour Energy have developed and acted in accordance with an agreed risk management plan to manage potential impacts to electrical infrastructure during the mining of LW22 to LW32. The management plan provides for ground and visual monitoring including specific surveys of critical power poles that have been identified within the network by Endeavour Energy and their consultants.

The management plan also provides for planned responses if triggered by observations of impacts. If impacts occur to the network, Endeavour Energy is able to quickly make adjustments and restore power, where required.

The management plan is reviewed periodically by TCCO and Endeavour Energy. It is recommended that TCCO and Endeavour Energy continue to develop this plan to manage the potential impacts due to the extraction of LW W1-W2.

6.11. Telecommunication services

6.11.1. Descriptions of the telecommunications infrastructure

The locations of the telecommunications infrastructure within the Study Area are shown in Drawing No. MSEC1019-18.

The telecommunications infrastructure comprises buried optical fibre cables and copper telecommunications cables that generally follow the local roads. The optical fibre cables are partly located above the southern ends of LW W1-W2. The copper telecommunications cables are located above the finishing (i.e. southern) end of LW W1.

The total length of cables located above the longwalls is approximately 2.2 km for the optical fibre cables and approximately 0.1 km for the copper cables. The optical fibre cables are owned by Telstra and NBN Co. and the copper telecommunications cables are owned by Telstra.

6.11.2. Predictions for the telecommunications infrastructure

The predicted profiles of total vertical subsidence, tilt and curvature for the optical fibre cables adjacent to Thirlmere Way and Stonequarry Creek Road are similar to those predicted for these roads as shown in Figs. C.09 and C.10, respectively, in Appendix C. The predicted total profiles after the extraction of each of the proposed longwalls are shown in blue.

The other optical fibre cables are located directly above the southern ends of LW W1-W2 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.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvatures for the optical fibre and copper cables is provided in Table 6.18. The table provides the maximum predicted values for the cables at any time during or after the extraction of each longwall.

Table 6.18 Maximum predicted total vertical subsidence, tilt and curvatures for the optical fibre and copper telecommunications cables

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})
After LW W1	475	3.0	0.03	0.06
After LW W2	750	5.5	0.06	0.11

The maximum predicted conventional strains for the telecommunications cables, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1 mm/m tensile and 2 mm/m compressive. Higher strains can develop along the cables due to irregular ground movements or topographic effects.

The predicted strains for the optical fibre and copper telecommunications cables have been based on the statistical analyses of strain provided in Chapter 4. The powerlines are linear features and, therefore, the most relevant distribution of strain is the maximum measured values anywhere along whole monitoring lines above the previously extracted longwalls, as discussed in Section 4.5.2. The maximum measured total tensile strains were less than 2 mm/m in 93 % of cases and the maximum measured total compressive strains were less than 4 mm/m in 89 % of cases.

The optical fibre and copper telecommunications cables cross small tributaries directly above LW W1-W2 and therefore could experience valley related effects. The maximum predicted valley related effects for these powerlines are 25 mm upsidence and 50 mm closure.

6.11.3. Impact assessments for the telecommunications infrastructure

The optical fibre cables are direct buried and therefore could potentially be impacted by ground strains. The greatest potential for impacts will occur as the result of localised ground strains due to non-conventional movements or valley related effects.

The tensile strains in the optical fibre cables could be higher than predicted, where the cables connect to the support structures, which may act as anchor points, preventing any differential movements that may have been allowed to occur with the ground. Tree roots have also been known to anchor cables to the ground. The extent to which the anchor points affect the ability of the cables to tolerate the mine subsidence movements depends on the cable size, type, age, installation method and ground conditions.

In addition to this, optical fibre cables contain additional fibre lengths over the sheath lengths, where the individual fibres are loosely contained within tubes. Compression of the sheaths can transfer to the loose tubes and fibres and result in "micro-bending" of the fibres constrained within the tubes, leading to higher attenuation of the transmitted signal. If the maximum predicted compressive strains were to be fully transferred into the optical fibre cables, the strains could be of sufficient magnitude to result in the reduction in capacities of the cables or transmission loss.

The strains transferred into the optical fibre cables can be monitored using Optical Time Domain Reflectometry (OTDR), which can be used to notify the infrastructure owners of strain concentrations due to non-conventional ground movements or valley related effects.

There is other experience of mining directly beneath optical fibre cables at TCCO and elsewhere in the Southern Coalfield, where the ground movements were similar to those predicted for LW W1-W2. Examples of the previous experience of mining beneath optical fibre cables is provided in Table 6.19.

Table 6.19 Examples of mining beneath optical fibre cables

Colliery and longwalls	Length of optical fibre cable directly mined beneath (km)	Maximum measured movements at the optical fibre cables	Pre-mining mitigation, monitoring and observed impacts
Appin LW301 and LW302	0.8	650 mm Subsidence 1 mm/m Tensile Strain 3 mm/m Comp. Strain (Measured M & N-Lines)	600 metre aerial cable on standby. Ground survey, visual, OTDR. No reported impacts.
Appin LW703 to LW705	10.0 total for five cables	1200 mm Subsidence 2.1 mm/m Tensile Strain 4.5 mm/m Comp. Strain (Measured HW2, ARTC and MPR Lines)	New cable redirection to avoid potential impacts to old optical fibre cable. Ground survey, visual, OTDR. Strain concentrations detected in three cables, attenuation losses were relieved by locally exposing the cables or by building a bypass cable.
Tahmoor LW22 to LW31	3.2	775 mm Subsidence 0.8 mm/m Tensile Strain 1.9 mm/m Comp. Strain	Ground survey, visual, OTDR, SBS. No reported impacts.
Tower LW1 to LW10	1.7	400 mm Subsidence 3 mm/m Tilt 0.5 mm/m Tensile Strain 1 mm/m Comp. Strain	No reported impacts
West Cliff LW5A3, LW5A4 and LW29 to LW36	3.4	1300 mm Subsidence 1.3 mm/m Tensile Strain 5.5 mm/m Comp. Strain (Measured B-Line)	Survey, visual, OTDR, SBS. No reported impacts.

Note: SBS is a method of monitoring optical fibres and means Stimulated Brillouin Scattering

The previous experience of mining beneath optical fibre cables at TCCO and elsewhere in the Southern Coalfield indicates that the potential impacts can be managed with the implementation of suitable management and monitoring strategies. With an appropriate management plan in place, it is considered that potential impacts on the optical fibre cables within the Study Area can be managed during the extraction of LW W1-W2, even if actual subsidence movements are greater than the predictions or substantial non-conventional movements occur.

The copper telecommunications cables are located above the finishing (i.e. southern) end of LW W1 and outside of the proposed longwalls. These cables are predicted to experience only low levels of vertical subsidence.

There is extensive experience of mining beneath copper telecommunications cables at TCCO and elsewhere in the Southern Coalfield. There has been no reported impacts on the direct buried copper telecommunications cables in these cases.

For example, the buried optical fibre cable along Remembrance Drive experienced no adverse impacts during the mining of LW22 to LW28. This includes a ground strain of approximately 2.5 mm/m over a 37 m bay along Remembrance Drive. If all of the compressive strain is concentrated at one location, this would equate to a strain of approximately 4 mm/m over a 20 m bay. This experience provides some comfort that the optical fibre cables will be able to withstand upsidence, closure and elevated compressive strains as a result of valley related effects due to the extraction of LW W1-W2.

6.11.4. Recommendations for the telecommunications infrastructure

TCCO and Telstra have developed and acted in accordance with an agreed risk management plan to manage potential impacts to telecommunications infrastructure during the mining of LW22 to LW32. The management plan provides for ground and visual monitoring, which includes detailed inspections of pits and cables prior to, during and after mining, and recording of cable pressures for main copper cables.

The management plan also provides for planned responses if triggered by observations of impacts. If impacts occur to the network, Telstra is able to quickly make adjustments and restore communications, if required. It is recommended that this management plan is reviewed and updated to incorporate LW W1-W2.

6.12. Public amenities

The locations of the public amenities within the Study Area are shown in Drawing No. MSEC1019-21.

There is one public amenity within the Study Area, being the Queen Victoria Memorial Home (Property Ref. V04). The property is located above the southern boundary of the Study Area, to the south-west of LW W1.

The Queen Victoria Memorial Home is on Thirlmere Way and comprises a total of 46 buildings, one pool and 12 dams. However, the majority of these structures are located outside of the Study Area, at a minimum distance of 310 m from LW W1.

The main three-storey buildings, one heritage listed building constructed in 1886 and one modern building, are both located just inside the Study Area. The proposed longwalls are approximately 320 m from the original old main building and 310 m from the new main building at their closest points. Photographs of the buildings are provided in Fig. 6.13 and Fig. 6.14. The old three-storey building is currently vacant.

Fig. 6.13 Queen Victoria Memorial Home (Source: Niche, 2014c)

Fig. 6.14 Queen Victoria Memorial Home

The maximum predicted values of total vertical subsidence, tilt and curvature for the structures associated with the Queen Victoria Memorial Home are included in Table D.05, in Appendix D. The structures on the property located within the Study Area are Refs. V04a (Nursing Home), V04b(Goodlet House), and two small buildings Refs. V04ag and V04bh.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvatures for structures associated with the Queen Victoria Memorial Home is provided in Table 6.20. This table provides the maximum predicted values within 20 m of each of the structures at any time during or after the extraction of LW W1-W2.

Table 6.20 Maximum predicted total vertical subsidence, tilt and curvatures for the structures associated with the Queen Victoria Memorial Home

Reference	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})
V04a, V04b, V04ag and V04bh	20	< 0.5	< 0.01	< 0.01

The structures are predicted to experience up to 20 mm vertical subsidence due to LW W1-W2. Whilst the structures could experience low-level vertical subsidence, they are not expected to experience measurable tilts, curvatures or conventional strains.

The predictions of vertical subsidence at the Queen Victoria Memorial home are relatively small and may be exceeded. The property is located between two series of longwall panels, Longwall series 22 to 32 and Longwall series W1-W2. As discussed in Section 4.4, additional vertical settlement has previously been observed during mining around other barriers of unmined coal, elsewhere in the Southern Coalfield. It is expected that additional vertical subsidence could develop above the barrier pillar, up to 150 mm greater than that predicted using the IPM. Whilst the observed vertical subsidence could exceed the predictions in this location, previous experience has found that this is not accompanied by any significant tilts, curvatures or strains, i.e. less than 0.5 mm/m which is in the order of survey tolerance.

The building structures are located at distances of approximately 310 m from the proposed longwalls. A histogram of the maximum observed tensile and compressive strains measured at these distances from longwalls at Tahmoor is provided in Fig. 6.15. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

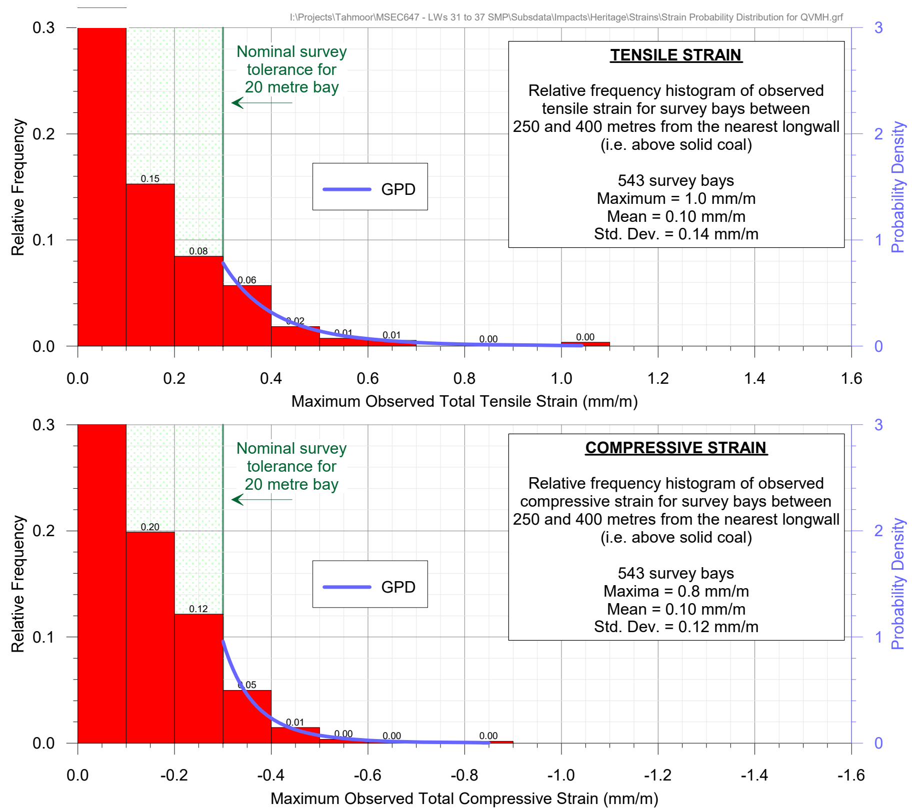

Fig. 6.15 Distributions of the measured maximum tensile and compressive strains for bays located between 250 m and 400 m from previous longwalls at TCCO

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 a 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).

The predicted strains based on the 95 % confidence levels are 0.4 mm/m tensile and 0.3 mm/m compressive, which are similar to the order of survey tolerance, i.e. not measurable.

The building structures are predicted to experience vertical subsidence of approximately 20 mm after the completion of the proposed longwalls. Whilst the structures could experience very low levels of vertical subsidence, they are not expected to experience any measurable tilts, curvatures or strains, even if the predictions were exceeded by a factor of 2 times.

There are a total of 430 structures located adjacent to but within the 26.5 degree angle of draw line for Longwalls 22 to 27. To date, impacts have been reported to 10 structures, which represents an impact rate of approximately 2 %. Nine of the 10 structures experienced very slight to slight impacts, with only one structure experiencing substantial impacts, which is discussed below.

The furthest reported impact beyond the end of a longwall at Tahmoor Mine occurred at a house located approximately 175 metres beyond the end of Longwall 23B. The impacts were unusual as they were substantial (cracking to walls) but no impacts were observed to any other structures within a 400 metre radius of it and no impacts were observed to pavements near it. The impacts have been treated as mining related as they were observed during the mining of Longwall 24B and a geological disturbed zone has been identified in the coal seam directly beneath it. The furthest impact of the side of a longwall at Tahmoor occurred at a house located approximately 200 metres from the tailgate of Longwall 24A, which comprised cracked tiles in the bathroom.

Based on the experience at Tahmoor Mine, it is considered that there is a very low probability of adverse impacts to the building structures associated with the Queen Victoria Memorial Home as a result of the mining of the proposed longwalls. All structures are expected to remain in safe and serviceable condition at all times.

TCCO and QVMH have developed and acted in accordance with an agreed risk management plan to manage potential impacts to the QVMH property during the mining of LW30 and LW31. It is recommended that this management plan is reviewed and updated to incorporate LW W1-W2.

6.13. Farm land and facilities

6.13.1. Agriculture utilisation and agriculture improvements

The rural areas within the Study Area have been cleared and are used mainly for light agricultural and residential purposes and, to a lesser extent, for commercial purposes. The land uses include the following:-

- Grassland – not grazed; and
- Grassland – light grazing for cattle, horses and poultry.

6.14. Rural structures

6.14.1. Descriptions of the rural structures

The locations of the rural structures are shown in Drawing No. MSEC1019-21.

There are 145 rural structures that have been identified within the Study Area. These structures include farm sheds, garages and other non-residential building structures. Details of the rural structures are included in Table D.04, in Appendix D.

There are 20 rural structures located directly above LW W1 and 5 structures located directly above LW W2. The remaining rural structures are located outside the proposed mining area.

6.14.2. Predictions for the rural structures

Predictions of conventional vertical subsidence, tilt and curvature have been made at the centroid and at the vertices of each structure, as well as 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 maximum predicted values of total vertical subsidence, tilt and curvature for each of the rural structures within the Study Area are included in Table D.05, in Appendix D. The predicted tilts represent the maximum values in any direction after the completion of each of LW W1-W2. The predicted curvatures represent the maximum values in any direction at any time during or after the extraction of each of the proposed longwalls.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvatures for the rural structures is provided in Table 6.21. The table provides the maximum predicted values for the structures at any time during or after the extraction of each longwall.

Table 6.21 Maximum predicted total vertical subsidence, tilt and curvatures for the rural structures

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})
After LW W1	425	2.5	0.02	0.05
After LW W2	700	5.5	0.06	0.05

The maximum predicted tilt for the rural structures is 5.5 mm/m (i.e. 0.55 %, or 1 in 180). The maximum predicted curvatures are 0.06 km^{-1} hogging and 0.05 km^{-1} sagging, which represent minimum radii of curvature of 17 km and 20 km, respectively.

Distributions of the predicted vertical subsidence, tilt and curvatures for the rural structures within the Study Area are illustrated in Fig. 6.16 and Fig. 6.17.

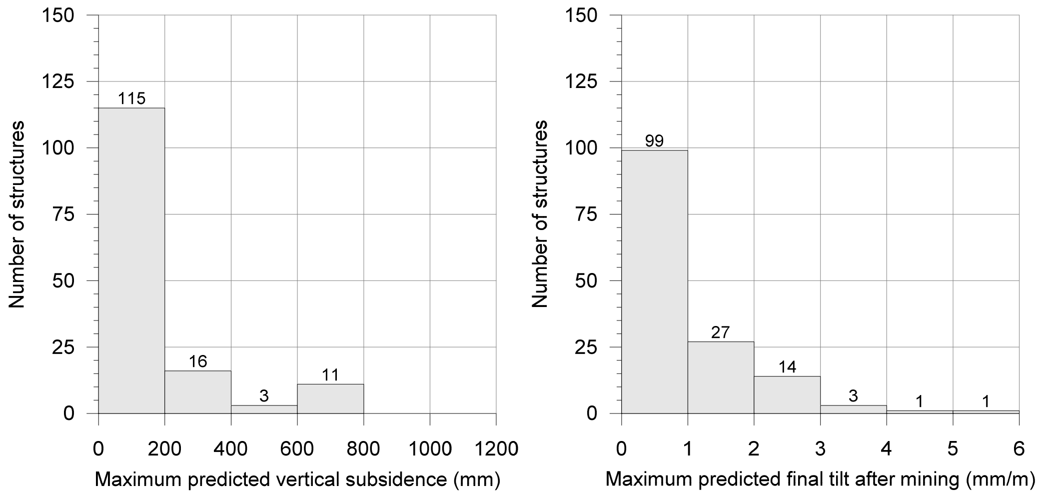

Fig. 6.16 Maximum predicted vertical subsidence (left-side) and final tilt (right-side) for the rural structures

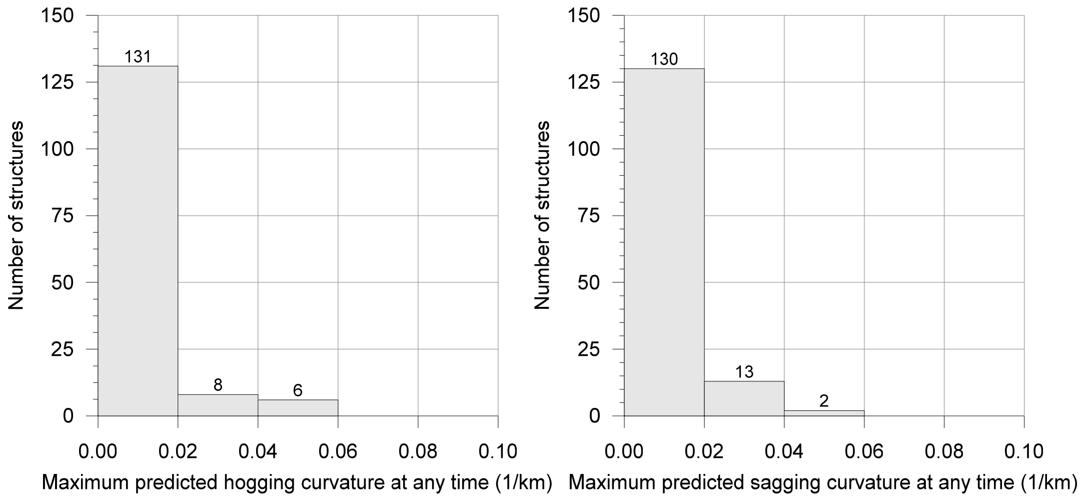

Fig. 6.17 Maximum predicted hogging curvature (left-side) and sagging curvature (right-side) at any time for the rural structures

The maximum predicted conventional strains for the rural, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1 mm/m tensile and compressive. Higher strains could develop at the structures due to irregular ground movements or topographic effects.

The predicted distributions of strain due to the extraction of LW W1-W2 are described in Chapter 4. The rural structures are at discrete locations and, therefore, the most relevant distribution of strain is the maximum strains measured in individual survey bays above previous longwall mining, which is summarised in Section 4.5.1. The maximum predicted total strains directly above the proposed longwalls are 1.0 mm/m tensile and 1.8 mm/m compressive based on the 95 % confidence level.

The strains have been predicted for each of the rural structures using the method described by Barbato (2017). This method considers the position of each structure relative to the longwalls, the surface slope, surface lithology and the potential for irregular anomalous movements.

The predicted total strains for each of the rural structures within the Study Area are provided in Table D.05, in Appendix D. Distributions of the predicted total strains based on the mean and on the 95 % confidence levels are provided in Fig. 6.18 and Fig. 6.19, respectively.

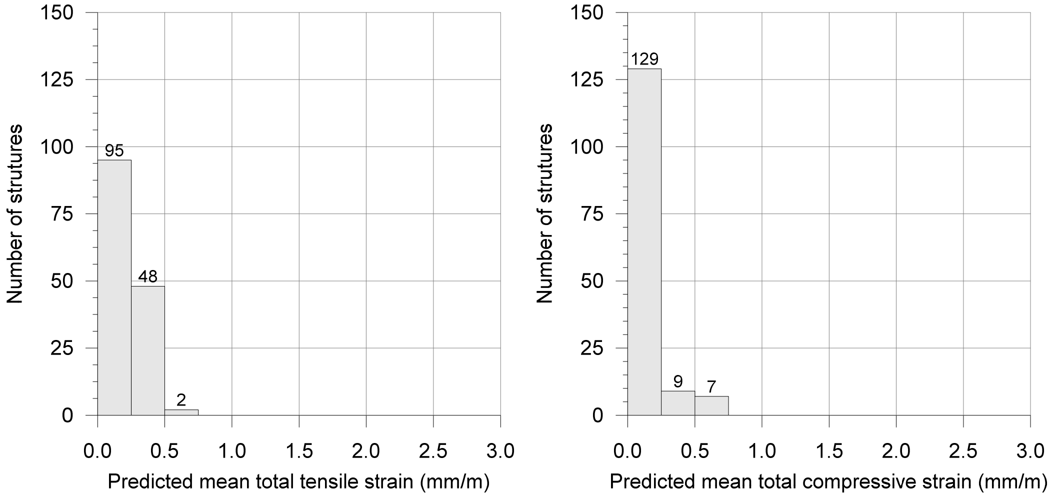

Fig. 6.18 Predicted total tensile strain (left-side) and total compressive strain (right-side) for the rural structures based on the mean

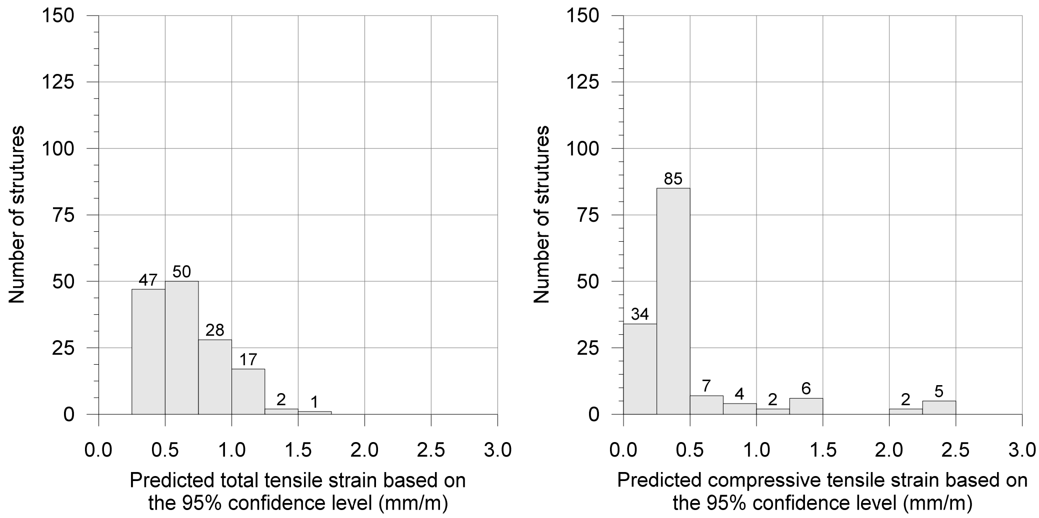

Fig. 6.19 Predicted total tensile strain (left-side) and total compressive strain (right-side) for the rural structures based on the 95 % confidence level

The rural structures within the Study Area are predicted to experience total tensile strains between 0.3 mm/m and 1.7 mm/m and total compressive strains between 0.2 mm/m and 2.4 mm/m based on the 95 % confidence levels. The predicted mean values range between 0.2 mm/m and 0.7 mm/m tensile and compressive.

6.14.3. Impact assessments for the rural structures

The majority of the rural structures within the Study Area are of lightweight construction and are expected to tolerate mining-induced tilt. It has been found from past longwall mining experience, that tilts of the magnitudes predicted for LW W1-W2 generally do not result in adverse impacts on rural structures. Some minor serviceability impacts could occur at the higher levels of predicted tilt, including door swings and issues with roof and pavement drainage. These serviceability impacts can generally be remediated using normal building maintenance techniques.

There is extensive experience of mining directly beneath rural structures at TCCO and elsewhere in the Southern Coalfield. This experience indicates that the incidence of impacts on rural structures is very low and these structures have remained in safe and serviceable conditions. This is not surprising as rural structures are generally small in size and of light-weight construction, which makes them less susceptible to impact than houses which are typically more rigid.

TCCO has mined directly beneath more than 2000 rural structures and 1900 associated residential structures of similar construction during the mining of LW22 to LW31. It has managed the mining-induced impacts with the implementation of suitable management strategies. The structures have remained safe and serviceable during mining.

Based on previous experiences, it is expected that the rural structures within the Study Area would remain safe and serviceable during the mining period, provided that they are in sound existing condition. The risk of impact could be greater if the structures are in poor existing condition, though the chances of there being a public safety risk remains very low. A number of rural structures that were in poor existing condition have been directly mined beneath and these structures have not experienced adverse impacts during mining.

Impacts on the rural structures that occur as the result of the extraction of LW W1-W2 are expected to be remediated using well established building techniques. With these remediation measures available, it is unlikely that there would be long term impacts on rural structures due to the extraction of the proposed longwalls.

6.14.4. Recommendations for the rural structures

TCCO has developed and acted in accordance with a risk management plan to manage potential impacts to rural structures during the mining of LW22 to LW32. The management plan provides for identification of buildings in poor pre-mining condition that are hazardous or may become hazardous due to mining, and monitoring of structures during active subsidence. If impacts occur, the structure will be repaired in accordance with the *Coal Mine Subsidence Compensation Act 2017*.

It is recommended that TCCO continue to develop management plans to manage potential impacts on rural structures during the mining of the proposed longwalls.

6.15. Tanks

There are water and gas tanks on some of the properties within the Study Area.

The tanks themselves are typically constructed above ground level and, therefore, are unlikely to experience the full ground movements resulting from the proposed mining. It is possible that any buried water pipelines associated with the tanks within the Study Area could be impacted by the ground strains, if they are anchored by the tanks, or by other structures in the ground. Any impacts are expected to be of a minor nature and easily repaired.

TCCO has developed and acted in accordance with a risk management plan to manage potential impacts to tanks during the mining of LW22 to LW32. The management plan provides for identification of structures in poor pre-mining condition that are hazardous or may become hazardous due to mining, and monitoring of structures during active subsidence. If impacts occur, the structure will be repaired in accordance with the *Coal Mine Subsidence Compensation Act 2017*. It is recommended that TCCO continue to develop management plans to manage potential impacts on tanks during the mining of the proposed longwalls.

6.16. Fences

There are fences located across the Study Area. The fences are constructed in a variety of ways, generally using either timber or metal materials. Fences are generally flexible in construction and can usually tolerate mine subsidence movements in the Southern Coalfield.

TCCO has mined directly beneath many fences during the mining of LW22 to LW32. A total of 69 properties have reported impacts to fences and gates. A higher incidence of impacts to urban fences has been observed, which is considered to be due to their typical type of construction, namely Colorbond fences and security gates that are fitted tightly between fences and houses. Rural fences are typically more flexible in construction by comparison. No impacts to fences securing livestock were reported. Damaged fences are relatively easy to rectify by re-tensioning of fencing wire, straightening of fence posts, and if necessary, replacing some sections of fencing.

The most vulnerable sections of farm fences are gates, particularly long gates or those with latches, as they are less tolerant to differential horizontal movements and tilts between the gate posts and the ground. One gate, for example, experienced adverse impacts during the extraction of LW32, although it is noted that this gate was located in close proximity to an area of irregular movement. If any gates are adversely impacted during the extraction of the proposed longwalls, they can be easily and quickly repaired.

TCCO has developed and acted in accordance with a risk management plan to manage potential impacts to fences during the mining of LW22 to LW32. The management plan provides for visual kerbside monitoring of fences during active subsidence.

The management plan is reviewed periodically by TCCO. It is recommended that TCCO continue to develop management plans to manage potential impacts during the mining of the proposed longwalls.

6.17. Farm Dams

6.17.1. Descriptions of the farm dams

The locations of the farm dams are shown in Drawing No. MSEC1019-21.

There are 19 farm dams that have been identified within the Study Area. The details of the dams are included in Table D.06, in Appendix D. The farm dams have maximum dimensions ranging between 3 m and 161 m and plan areas ranging between 14 m^2 and 15,000 m^2.

There is one farm dam (Ref. PSC_019_d01) located directly above LW W1 and three dams located directly above LW W2 (Refs. PSC_080_d01, PTH_031_d01 and PTH_031_d02). The remaining farm dams are located outside the proposed mining area.

The dams are typically of earthen construction and have been established by localised cut and fill operations within the natural streams. The farm dams are generally shallow, with the dam wall heights generally being less than 3 m.

6.17.2. Predictions for the farm dams

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

The maximum predicted values of total vertical subsidence, tilt and curvature for each of the farm dams within the Study Area are included in Table D.06, in Appendix D. The predicted tilts represent the maximum values in any direction after the completion of each of LW W1-W2. The predicted curvatures represent the maximum values in any direction at any time during or after the extraction of each of the proposed longwalls.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvatures for the farm dams is provided in Table 6.22. The table provides the maximum predicted values for the dams at any time during or after the extraction of each longwall.

Table 6.22 Maximum predicted total vertical subsidence, tilt and curvatures for the farm dams

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})
After LW W1	425	2.5	0.02	0.05
After LW W2	750	5.0	0.05	0.11

The maximum predicted tilt for the farm dams is 5.0 mm/m (i.e. 0.5 %, or 1 in 200). The maximum predicted curvatures are 0.05 km^{-1} hogging and 0.11 km^{-1} sagging, which represent minimum radii of curvature of 20 km and 9 km, respectively.

Distributions of the predicted vertical subsidence, tilt and curvatures for the farm dams within the Study Area are illustrated in Fig. 6.20 and Fig. 6.21.

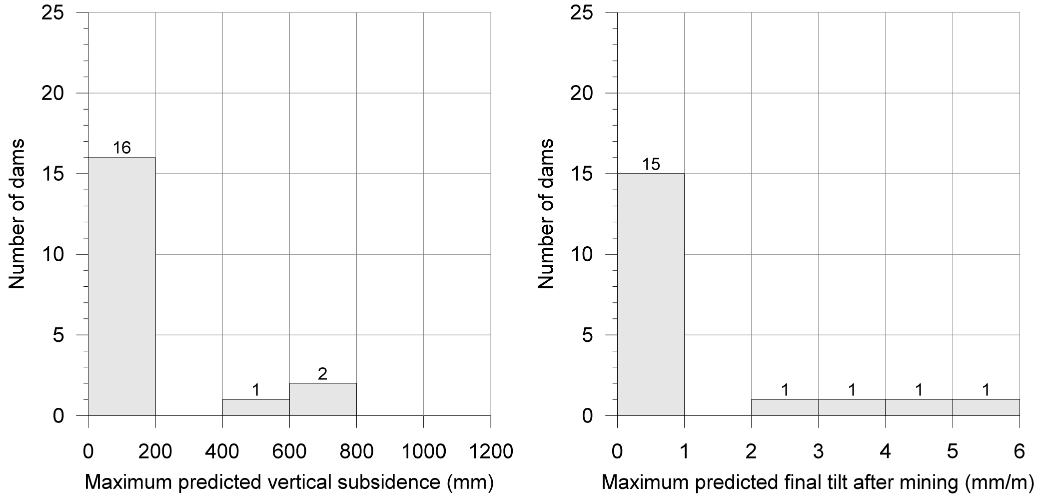

Fig. 6.20 Maximum predicted vertical subsidence (left-side) and final tilt (right-side) for the farm dams

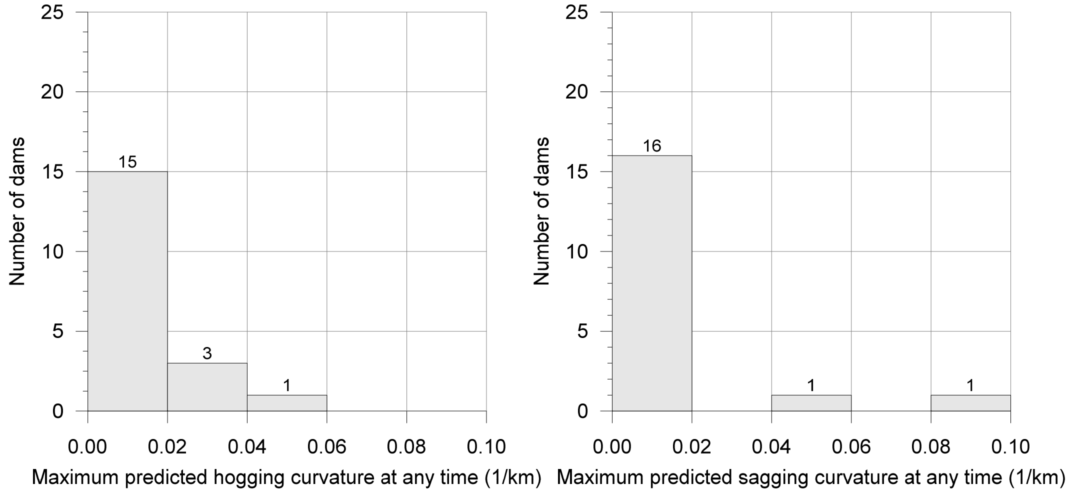

Fig. 6.21 Maximum predicted hogging curvature (left-side) and sagging curvature (right-side) at any time for the farm dams

The maximum predicted conventional strains for the farm dams, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1 mm/m tensile and 2 mm/m compressive. Higher strains could develop at the dams due to irregular ground movements or topographic effects.

The predicted distributions of strain due to the extraction of LW W1-W2 are described in Chapter 4. The farm dams are at discrete locations and, therefore, the most relevant distribution of strain is the maximum strains measured in individual survey bays above previous longwall mining, which is summarised in Section 4.5.1. The maximum predicted total strains directly above the proposed longwalls are 1.0 mm/m tensile and 1.8 mm/m compressive based on the 95 % confidence level.

The strains have been predicted for each of the farm dams using the method described by Barbato (2017). This method considers the position of each feature relative to the longwalls, the surface slope, surface lithology and the potential for irregular anomalous movements.

The predicted total strains for each of the farm dams within the Study Area are provided in Table D.06, in Appendix D. The distributions of the predicted total strains based on the mean and on the 95 % confidence levels are provided in Fig. 6.22 and Fig. 6.23, respectively.

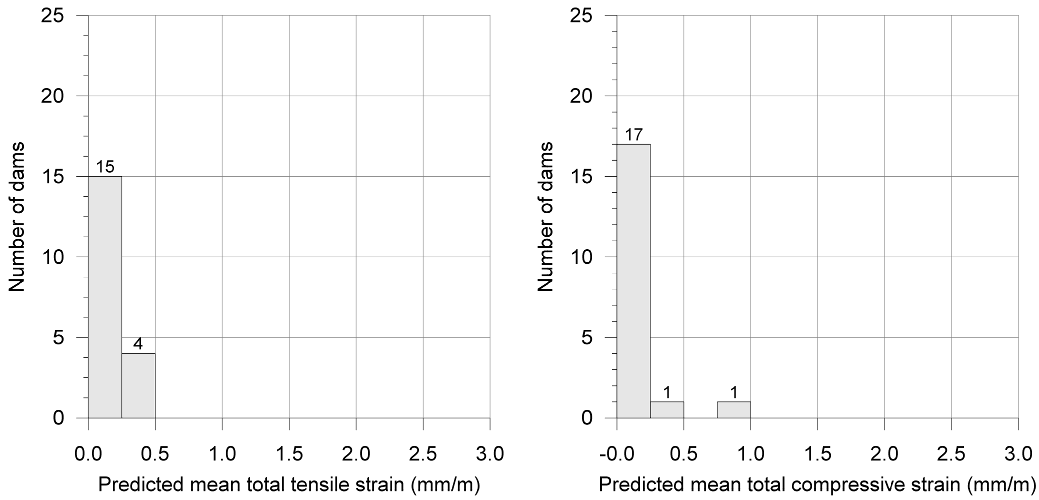

Fig. 6.22 Predicted total tensile strain (left-side) and total compressive strain (right-side) for the farm dams based on the mean

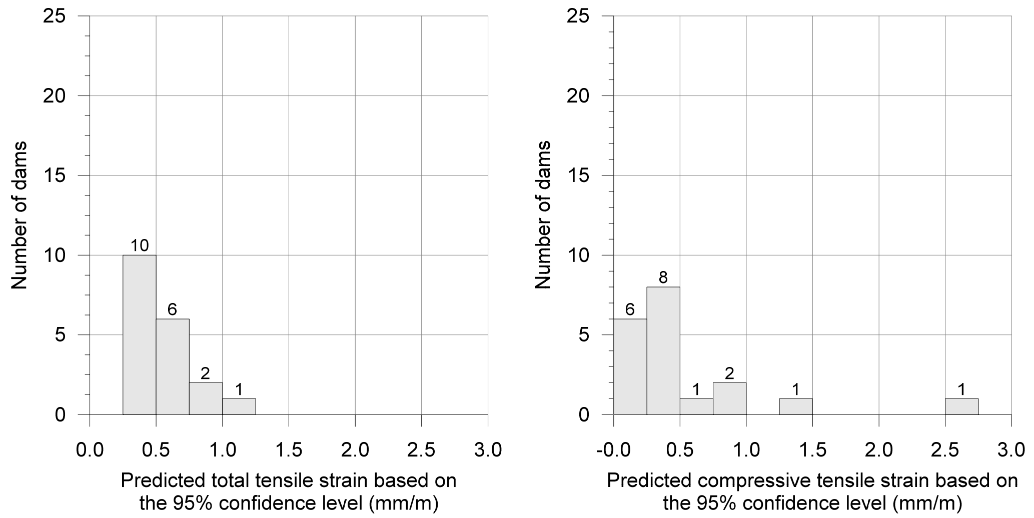

Fig. 6.23 Predicted total tensile strain (left-side) and total compressive strain (right-side) for the farm dams based on the 95 % confidence level

The farm dams within the Study Area are predicted to experience total tensile strains between 0.3 mm/m and 1.1 mm/m and total compressive strains between 0.2 mm/m and 2.7 mm/m based on the 95 % confidence levels. The predicted mean values range between 0.2 mm/m and 0.8 mm/m tensile and compressive.

The farm dams have typically been constructed along the alignments of streams and, therefore, may be subjected to valley related effects due to the extraction of LW W1-W2. The equivalent valley heights at the dams are small and it is expected, therefore, that the predicted valley related upsidence and closure movements at the dam walls would be much less than the predicted conventional subsidence movements and would not be substantial.

6.17.3. Impact assessments for the farm dams

The maximum predicted tilt for the farm dams within the Study Area is 5.0 mm/m (i.e. 0.5 %, or 1 in 200). Mining-induced tilts can affect the water levels around the perimeters of farm dams, with the freeboard increasing on one side and decreasing on the other. Tilt can potentially reduce the storage capacity of farm dams, by causing them to overflow, or can affect the stability of the dam walls.

The predicted changes in freeboard at the farm dams within the Study Area have been determined by taking the difference between the maximum predicted vertical subsidence and the minimum predicted vertical subsidence anywhere around the perimeter of each farm dam. The maximum predicted changes in freeboard for the farm dams are provided in Table D.06, in Appendix D, and are illustrated in Fig. 6.24.

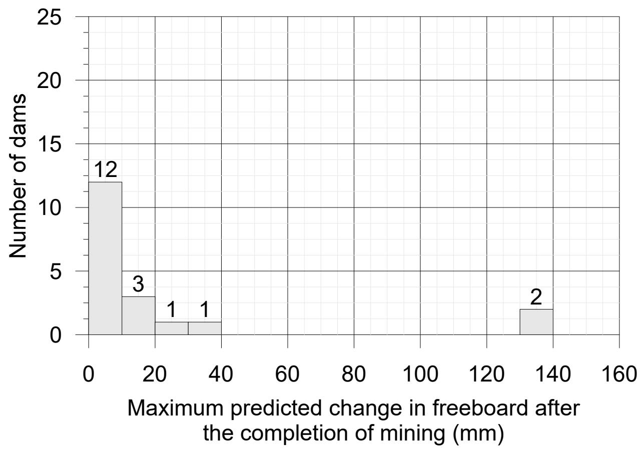

Fig. 6.24 Predicted changes in freeboard for the farm dams

The predicted changes in freeboard for the farm dams within the Study Area are small, varying from less than 20 mm to 140 mm. It is unlikely that the dams would experience adverse impacts on the storage capacities due to these small changes in freeboard.

The four farm dams located directly above LW W1-W2 could experience cracking in the bases of their walls due to the mining-induced curvatures and strains.

There is extensive experience of mining directly beneath farm dams in the Southern Coalfield, which indicates that the incidence of impacts on these features is very low. Farm dams are commonly constructed with cohesive materials in the bases and walls which can absorb the conventional subsidence movements typically experienced in the Southern Coalfield without the development of substantial cracking. Non-conventional movements can result in localised cracking and deformations at the surface and, where coincident with farm dams, could result in adverse impacts.

TCCO has mined LW22 to LW31 beneath a total of 103 dams. While a small number of landowners have advised of impacts, there has been one claim to Subsidence Advisory NSW for impacts on farm dams at the time of the report.

Similarly, South32 Illawarra Coal has mined directly beneath more than 200 farm dams in Appin Area 3, Appin Area 4, Appin Area 7, Appin Area 9 and West Cliff Area 5. Loss of water was reported for only a small number of dams.

Any substantial cracking in the dam bases or walls could be repaired by reinstating with cohesive materials. If any farm dams were to lose water as a result of mining, the mine would provide an alternative water source until the completion of repairs in accordance with the *Coal Mine Subsidence Compensation Act 2017*.

6.17.4. Recommendations for the farm dams

TCCO has developed and acted in accordance with a risk management plan to manage potential impacts to dams during the mining of LW22 to LW32. This includes an assessment of potential environmental or safety consequences as a result of dam breach. The management plan provides for visual monitoring of dams immediately prior to and after active subsidence at each dam. If impacts occur to the dams, TCCO will supply water to the landowner on a temporary basis until the dam is repaired in accordance with the Coal Mine Subsidence Compensation Act 2017.

It is recommended that TCCO continue to develop management plans to manage potential impacts on dams during the mining of LW W1-W2.

6.18. Wells and Bores

The locations of the registered groundwater bores are shown in Drawing No. MSEC1019-20. The locations and details of these were obtained from the Australian Groundwater Explorer, which is publicly available on line (BOM, 2019).

There were two registered groundwater bores identified within the Study Area, and a summary is provided in Table 6.23.

Table 6.23 Details of the registered groundwater bores within the Study Area

Ground licence number	Location	Depth (m)	Authorised / intended use
GW064469	410 m west of LW W1	91.0	Domestic
GW104090	Directly above LW W2	150.5	Irrigation / Stock

The groundwater bores could experience adverse impacts due to the extraction of LW W1-W2, particularly the bore located directly above the proposed mining area (i.e. Ref. GW104090). Impacts could include 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.

More detailed assessments are provided in the Groundwater Technical Report (HydroSimulations, 2019) and the Baseline Private Bore Assessment (GeoTerra, 2019).

6.19. Industrial, commercial and business establishments

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

6.20. Exploration Drill Holes

There are exploration drill holes located across the Study Area and further boreholes may be drilled to assist with monitoring during the proposed extraction of LW W1-W2. Exploration drill holes to seam level are grouted and capped prior to the proposed longwalls mining directly beneath them.

6.21. Aboriginal heritage sites

6.21.1. Descriptions of the Aboriginal heritage sites

The locations of the Aboriginal heritage sites within the Study Area are shown in Drawing No. MSEC1019-19. The locations and details have been provided by EMM (2019a).

Detailed descriptions of the Aboriginal heritage sites are provided by a specialist heritage consultant in the report by EMM (2019a). There were 25 Aboriginal heritage sites that have been identified within the Study Area and two additional sites located within the Study Area for natural features. There is only one site that is located directly above the proposed longwalls.

The identified Aboriginal heritage sites are listed in Table D.07, in Appendix D, and a summary is provided in Table 6.24.

Table 6.24 Aboriginal heritage sites identified within the Study Area

Type	Total number within the Study Area	Total number located directly above the proposed longwalls
Open camp sites (Artefact scatters and Isolated Finds)	6	0
Rock shelter with grinding grooves	1	0
Rock shelters	17	0
Grinding groove sites	1	0
Modified trees	1	1
PAD	1	0
Total	**27**	**1**

Further details on the Aboriginal heritage sites are provided in the report by EMM (2019a).

6.21.2. Predictions for the Aboriginal heritage sites

The maximum predicted subsidence parameters for the Aboriginal heritage sites due to the mining of LW W1-W2 are provided in Table D.07, in Appendix D. A summary of the maximum predicted vertical subsidence, tilt and curvatures for these sites is provided in Table 6.25. The predicted tilts are the maxima after the completion of any or all longwalls at any of the sites. The predicted curvatures are the maxima at any time during or after the extraction of the longwalls.

Table 6.25 Maximum predicted total vertical subsidence, tilt and curvature for the Aboriginal heritage sites

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})
Open sites (artefact scatters and isolated finds)	90	< 0.5	< 0.01	< 0.01
Rock shelter with grinding grooves	< 20	< 0.5	< 0.01	< 0.01
Rock shelters	70	< 0.5	< 0.01	< 0.01
Grinding groove sites	< 20	< 0.5	< 0.01	< 0.01
Modified Trees	725	1.0	0.02	0.02
PAD	< 20	< 0.5	< 0.01	< 0.01
Maximum	**725**	**1.0**	**0.02**	**0.02**

The predicted strains for the Aboriginal heritage sites have been based on the statistical analysis of strains provided in Section 4.5. The sites are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays above previous longwall mining, which are summarised in Section 4.5.1.

Site Ref. 52-2-2100 is located directly above LW W2. The maximum predicted strains for this site are 1.0 mm/m tensile and 1.8 mm/m compressive based on the 95 % confidence levels. The remaining Aboriginal heritage sites are located outside the proposed mining area and they are predicted to experience conventional strains of less than 0.5 mm/m tensile and compressive.

The rock shelters and grinding groove sites are located along the alignments of the streams and therefore these could experience valley related effects. However, the rock shelters are situated on the valley sides away from the valley upsidence and compressive strain due to valley closure effects.

A summary of the predicted valley related effects for the grinding groove sites is provided in Table 6.26. The predicted upsidence and closure movements are the maximum values which occur within 20 m of each of the sites along the alignments of the streams due to the extraction of LW W1-W2.

Table 6.26 Maximum predicted total upsidence and closure for the grinding groove sites

Site Ref.	Stream	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
52-2-2068	Stonequarry Creek	20	30
52-2-4430	Cedar Creek	50	80

These grinding groove sites could experience compressive strains due to these valley related effects. The predicted strains due to valley related effects have been determined from an analysis of ground monitoring lines for valleys with similar heights located at similar distances from previously extracted longwalls in the Southern Coalfield, as for these sites.

The sections of Cedar and Stonequarry Creeks adjacent to the proposed longwalls have effective valley heights ranging between 20 m and 30 m. The grinding groove sites are located at distances of 210 m and 250 m outside the proposed mining area. The maximum compressive strain measured at similar streams in the Southern Coalfield is 2 mm/m based on the 95 % confidence level.

6.21.3. Impact assessments for the Aboriginal heritage sites

The impact assessments for the Aboriginal heritage sites provided in this report should be read in conjunction with the assessments provided by EMM (2019a).

Open sites

There are six Open Camp Sites (OCS) located within the Study Area based on the 600 m boundary, being Site Refs. 52-2-2069, 52-2-2070, 52-2-2071, 52-2-2072, 52-2-2073 and SQC1. These sites contain stone artefact scatters. The OCS are all located outside the proposed mining area at distances ranging between 90 m and 320 m. There is also one Potential Archaeological Deposit (PAD) within the Study Area, being Site Ref. 52-2-4159. This site is located 570 m west of the proposed longwalls.

The OCS and PAD are predicted to experience vertical subsidence ranging from less than 20 mm up to 90 mm. Whilst these sites could experience low-levels of vertical subsidence, they are not expected to experience significant tilts, curvatures or conventional strains.

Surface cracking is not expected to develop at the OCS and PAD due to their distances from the proposed longwalls and the low-levels of predicted ground movements. Even if isolated surface cracking were to occur at or near to these sites, the artefacts themselves would not be directly impacted. However, if remediation of the surface soils were to be required near the OCS and PAD, it is recommended that TCCO seek the required approvals from the appropriate authorities prior to the remediation works.

The likelihoods of adverse impacts on the OCS and PAD are therefore considered to be *very unlikely*. Further assessments and recommendations for the OCS and PAD are provided in a report by *EMM* (2019a).

Modified tree

There is one Modified Tree that is located within the Study Area based on the 600 m boundary, being Site Ref. 52-2-2100. This site is located directly above LW W2 and it is predicted to experience vertical subsidence of 725 mm.

Impacts on trees are generally not observed in the Southern coalfield, except at very shallow depths of cover and/or in incised terrain. In this case, the Modified tree is located where the depth of cover is approximately 490 m and the natural surface slopes are less than 1 in 3 (i.e. less than the minimum to be considered a steep slope).

Cracking in surface soils at TCCO tends to be isolated and of a minor nature. The cracking is generally limited to the top few metres of the surface soils and it generally does not require remediation.

The likelihood of adverse impact on the Modified Tree is therefore considered to be *very unlikely*. Further assessments and recommendations for the Modified Tree are provided in a report by *EMM* (2019a).

Rock shelters

There are 18 rock shelters located within the Study Area based on the 600 m boundary, being Site Refs. 52-2-4213, 52-2-4214, 52-2-4385, 52-2-4386, 52-2-4387, 52-2-4388, 52-2-4389, 52-2-4390, 52-2-4391, 52-2-4392, 52-2-4393, 52-2-4430, 52-2-4431, CC1, CC2, CC3, CCT1 and MCR 2014-5. These sites are located within rock overhangs along Matthews Creek, Cedar Creek and their tributaries. The rock shelters are all located outside the proposed mining area at distances ranging between 170 m and 370 m.

The rock shelters are predicted to experience vertical subsidence ranging from less than 20 mm up to 70 mm. Whilst these sites could experience low-levels of vertical subsidence, they are not expected to experience significant tilts, curvatures or conventional strains.

The rock shelters are located along the streams and therefore they could experience valley related effects. However, these sites are located on the sides of the valleys and therefore are not expected to experience the valley related upsidence movements or compressive strains due to valley closure, which occur near the bases of the valleys.

Fracturing could occur in the bases of the streams near the rock shelters. However, this fracturing is expected to be minor and isolated due to their distances from the proposed longwalls. Fracturing is not expected to occur at the rock shelters themselves, as they are located on the valley sides. As discussed in Section 5.6, instabilities at the rock shelters are not expected as they will not be directly mined beneath.

The likelihoods of adverse impacts on the rock shelters are therefore considered to be *very unlikely*. Further assessments and recommendations for the rock shelters are provided in a report by *EMM* (2019a).

Grinding groove sites

There are two grinding groove sites located within the Study Area based on the 600 m boundary, being Site Refs. 52-2-2068 and 52-2-4430. These sites are both located outside the proposed mining area at distances of 250 m and 210 m, respectively.

The grinding groove sites are predicted to experience less than 20 mm vertical subsidence. Whilst these sites could experience very low-levels of vertical subsidence, they are not expected to experience significant tilts, curvatures or conventional strains.

The grinding groove sites are predicted to experience valley closure of 30 mm to 80 mm. The compressive strains due to the valley closure effects could be sufficient to result in fracturing of the rock in the bases of the streams. Minor and isolated fracturing has been observed up to approximately 400 m outside of previously extracted longwalls in the Southern Coalfield.

Site 52-2-2068 comprises several grinding grooves on a large rock platform along Stonequarry Creek. The site is located 250 m east of LW W2. It is possible, though unlikely, that fracturing could occur in the rock platform due to its large size. It would be expected that any fracturing would be minor and isolated due to the distance of the site from the proposed longwalls. The likelihood of adverse impact on Site 52-2-4430 is therefore considered to be *unlikely*.

A review of the fracturing along Cedar and Stone Quarry Creeks will be undertaken after the LW W1 face has mined a sufficient distance such that the majority of mining-induced movements have occurred (after approximately 1000 m of extraction). If impacts on Cedar and Stonequarry Creek are greater than anticipated, TCCO will consider amending the commencing position of LW W2 to further reduce the potential for impacts on Stonequarry Creek, including at Site 52-2-2068.

Site 52-2-4430 comprises a single grinding groove on a small rockbar along Cedar Creek. The likelihood of minor fracturing being coincident with the grinding groove is considered to be very low due to its small extent and its distance from the proposed longwalls. The likelihood of adverse impact on Site 52-2-4430 is therefore considered to be *very unlikely*.

6.21.4. Recommendations for the Aboriginal heritage sites

It is recommended that TCCO develop a management plan to manage the potential impacts to Aboriginal heritage sites. Tahmoor Mine has previously developed a management plan for rock shelter site 52-2-3254 on Redbank Creek. The management plan includes consultation with the community, monitoring and reporting. It is recommended that TCCO develop a similar management plan, in consultation with the community, for the Aboriginal heritage sites during the extraction of proposed longwalls.

6.22. European heritage sites

The heritage sites within the Study Area were identified by a specialist heritage consultant and the detailed descriptions are provided in the report by *EMM* (2019b). The structures identified as having heritage significance within the Study Area are shown in Drawing No. MSEC1019-19. There are also some additional heritage relics and artefacts that are located within the Study Area which are also shown in this drawing.

A summary of the items of heritage significance within the Study Area is provided in Table 6.27. The two railway bridges are located just outside the Study Area, but have been included in this list, as these structures could be sensitive to far-field movements.

Table 6.27 Items of European heritage significance

Item	Property or structure reference	Location	Description
Mill Hill, Millers House and Archaeological Relics, 675 Thirlmere Way, Picton	V06a	Above main headings between LW31 and LW W1-W2	Federation style weatherboard house, small cottage, brick well and possible archaeological remains of windmill
Queen Victoria Memorial Home, Thirlmere	Property V04	North-west of extracted LW29 and LW30 and south-west of LW W1	Large complex of buildings of various sizes and construction types. Four structures are located within Study Area, refer to Section 6.12 for further details
Harmony House Archaeological site	-	North-west of extracted LW29 and LW30 and south-west of LW W1	Archaeological site with the brick footings of a nineteenth century building and an underground beehive water reservoir with original cap
Rural Landscape, Thirlmere Way	-	Above main headings between LW31 and LW W1-W2	Example of pasture improvement on a working dairy farm
Railway culverts	-	Picton-Mittagong Loop Line	Brick and stone arch culverts

It is noted that the "Redbank Range Railway Tunnel", also referred to as the "Mushroom Tunnel", is listed as an item of heritage significance in the Wollondilly Local Environmental Plan (LEP). This tunnel is located adjacent to the Main Southern Railway, approximately 825 m to the east of LW W2, and is no longer in use as a railway tunnel. The tunnel is used to provide vehicular access to the Main Southern Railway from Argyle Street.

Detailed descriptions are provided by a specialist heritage consultant in the report by *EMM* (2019b). Further details, predictions and impact assessments for these items of heritage significance are provided below.

Brick and sandstone culverts along the Picton-Mittagong Loop Line

Whilst the culverts have not been heritage listed, EMM (2019b) has assessed the brick and sandstone culverts within the Study Area to have local significance on an individual and collective basis. The culverts have been identified and described in Section 6.2.1 and predictions for the culverts are provided in Section 6.2.2.

As discussed in Section 6.2.3, it is possible that the culverts will experience some cracking and spalling of the masonry as a result of the extraction of LW W1 W2. Cracking may occur in the masonry arch or in the headwalls.

The likelihood of adverse impact on the brick and sandstone culverts are considered to be *unlikely* for most of the culverts and *possible* for the culvert at 88.400 km, which is located directly above proposed LW W1.

It is recommended that TCCO develop management strategies for the culvert, to maintain its integrity during active subsidence, and to remediate it after the completion of active subsidence, if required. These management strategies should be developed in consultation with the heritage consultant and Wollondilly Shire Council. Further discussion on the culverts is provided in Section 6.2.

675 Thirlmere Way, Picton (Mill Hill, Miller's House)

Miller's House (Structure Ref. V06a) is located around 100 m from the end of previously extracted LW 31. No impacts were observed during the mining of LW 31. The house is located approximately 230 m from LW W1 and 370 m from LW W2.

The items of heritage significance consist of a single-storey weatherboard house, and archaeological relics. The weatherboard house sits on brick and steel piers, and is therefore inherently structurally flexible, making it less prone to subsidence impact. A photograph of the house is provided in Fig. 6.25.

Fig. 6.25 Mill Hill, Miller's House (Ref. V06a)

The structure is predicted to experience 80 mm vertical subsidence, the majority of which is predicted to be experienced during the mining of LWs 31 and 32. It is not expected to experience any substantial tilts, curvatures or strains. The assessed probabilities of impact have been determined using the method described in Appendix B and are: 93 % Nil or Category R0; 6 % Category R1 or R2; and 1 % Category R3 or greater. The repair categories R0 to R5 are described in Appendix B. It is expected, therefore, that the house would experience nil or only minor impacts resulting from the extraction of the proposed longwalls. Impacts on the structure are likely to be limited to the external cladding or internal finishes, which can be more readily repaired.

TCCO has developed and acted in accordance with a risk management plan to manage potential impacts on the Mill Hill property during the mining of LW31 and LW32. The management plan includes assessments by a structural engineer and heritage consultant, ground surveys and visual inspections. If impacts occur, the structure will be repaired in accordance with the *Coal Mine Subsidence Compensation Act 2017*.

It is recommended that TCCO continue to develop management plans to manage potential impacts on structures at the Mill Hill property during the mining of the proposed longwalls.

Queen Victoria Memorial Home

The Queen Victoria Memorial Home is located on Thirlmere Way and comprises a total of 46 buildings, one pool and 12 dams, of which, 4 buildings are located within the Study Area. The proposed longwalls do not mine directly beneath any of the structures or dams. The closest building to the proposed longwalls is approximately 310 m.

Further descriptions, predictions and impact assessments for the building structures associated with the Queen Victoria Memorial Home are provided in Section 6.12. It has been assessed that the potential for adverse impacts on these structures is *very unlikely*.

TCCO and QVMH have developed and acted in accordance with an agreed risk management plan to manage potential impacts to the QVMH property during the mining of LW30 and LW31. It is recommended that this management plan is reviewed and updated to incorporate LW W1-W2.

Harmony House Archaeological site

An archaeological site is located on the property to the south of LW W1. Its position within the property is not confirmed but, in any case, it is located outside of the proposed mining area. The site comprises brick footings of a nineteenth century building and an underground beehive water reservoir with original cap.

The archaeological site is predicted to experience vertical subsidence of less than 50 mm due to the extraction of LW W1-W2. Whilst the site could experience low-level of vertical subsidence, it is not expected to experience significant tilts, curvatures or conventional strains.

The likelihood of adverse impacts on the archaeological site is therefore considered to be *very unlikely*. Further assessments and recommendations for this site are provided in a report by *EMM* (2019b).

Rural Landscape, Thirlmere Way

The rural landscape on Thirlmere Way provides a good example of pasture improvement on a working dairy farm, and provides a picturesque setting important to the Queen Victoria Memorial Home. A photograph of the landscape is provided in Fig. 6.26 (Source: Niche, 2014c).

Fig. 6.26 Rural Landscape, Thirlmere Way (Source: Niche, 2014c)

The Rural Landscape adjacent to Thirlmere Way is partly located above LW 32. The landscape could experience the range of predicted subsidence movements for the proposed longwalls, as summarised in Chapter 4.

The vertical subsidence transitions from the maximum values directly above the proposed longwalls to slightly reduced values above the chain pillars. These variations in the vertical subsidence of around 200 mm to 300 mm occur over distances of 320 m and, therefore, are not visually perceptible. It is unlikely, therefore, that the vertical subsidence would reduce the visual aesthetics or the heritage value of the land.

The curvatures and strains could result in cracking or heaving in the surface soils. The surface deformations are expected to be isolated and of a minor nature, due to the high depths of cover at TCCO, with crack widths typically less than 25 mm. Any significant surface deformations could be remediated by locally regrading and recompacting the surface soils. No large scale slope failures are anticipated, as none have been observed in the Southern Coalfield as a result of longwall mining. It is unlikely, therefore, that the mining induced curvatures or strains would reduce the visual aesthetics or the heritage value of the land.

The likelihood of adverse impact on the rural landscape is therefore considered to be *unlikely*.

6.23. Survey control marks

The locations and details of the survey control marks were obtained using the *Six Viewer* (2019) and CORSnet-NSW (2019). The locations of the state survey control marks within the vicinity of the proposed longwalls are shown in Drawing No. MSEC1019-20.

The closest CORSnet-NSW station to LW W1-W2 is Station ID PCTN, which is located at No. 30 Fairleys Road, Picton at the Picton Sportsground building. The site was verified on 29 April 2016. The CORSnet site is approximately 1.6 kilometres from LW W2 at its closest point.

The state survey control marks are located across the Study Area and, therefore, would be 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.

It is possible that other survey control marks outside the immediate area and the PCTN CORSnet site could also be affected by far-field horizontal movements, up to 3 kilometres outside the Study Area. Far-field horizontal movements and the methods used to predict such movements are described further in Section 4.7.

6.23.1. Recommendations for the survey control marks

In accordance with the Surveying and Spatial Information Act (2002) and the Surveyor-General's Direction No. 11 (2017), TCCO is required to make a POSI application to disturb the survey control marks.

It will be necessary on the completion of the longwalls, when the ground has stabilised, to re-establish any state survey control marks that are required for future use. Consultation between TCCO and Spatial Services NSW will be required throughout the mining period to ensure that these survey marks are reinstated at an appropriate time, as required.
TCCO and Spatial Services NSW have developed and acted in accordance with an agreed risk management plan to manage potential impacts to survey control marks during the mining of LW32. It is recommended that the management plan is reviewed and updated to incorporate LW W1-W2.

6.24. Houses

6.24.1. Descriptions of the houses

The locations of the houses are shown in Drawing No. MSEC1019-21.

There are 62 houses that have been identified within the Study Area. The details of the houses are included in Table D.04, in Appendix D. The locations, sizes, and construction details of the houses were determined from aerial photographs of the area in 2013 and 2018, kerbside inspections in December 2014 and March 2019 and *Google Street View®* in December 2014 and March 2019.

It was noticed during the kerbside inspection in March 2019 that there is currently some construction activity within the Study Area. It is possible that the total number of houses affected by the extraction of the proposed longwalls will increase from the current count.

The following provides further discussions on the details of the houses within the Study Area.

Locations

The main township of Picton is located to the east of the Study Area. There are 26 houses located directly above LW W1 and no houses located directly above LW W2. The houses located within the Study Area and outside of the proposed longwalls are predominately located within the Stonequarry Estate, to the west of LW W1 and east of the Picton to Mittagong Loop Line, with other houses located in the northern and southern parts of the Study Area.

Maximum plan dimension, plan area and height

Distributions of the maximum plan dimensions and plan areas of the houses within the Study Area are provided in Fig. 6.27. The majority of the houses have maximum dimensions between 20 m and 40 m, with an average value of approximately 29 m. The majority of the houses have plan areas between 200 m^2 and 600 m^2, with an average value of approximately 400 m^2.

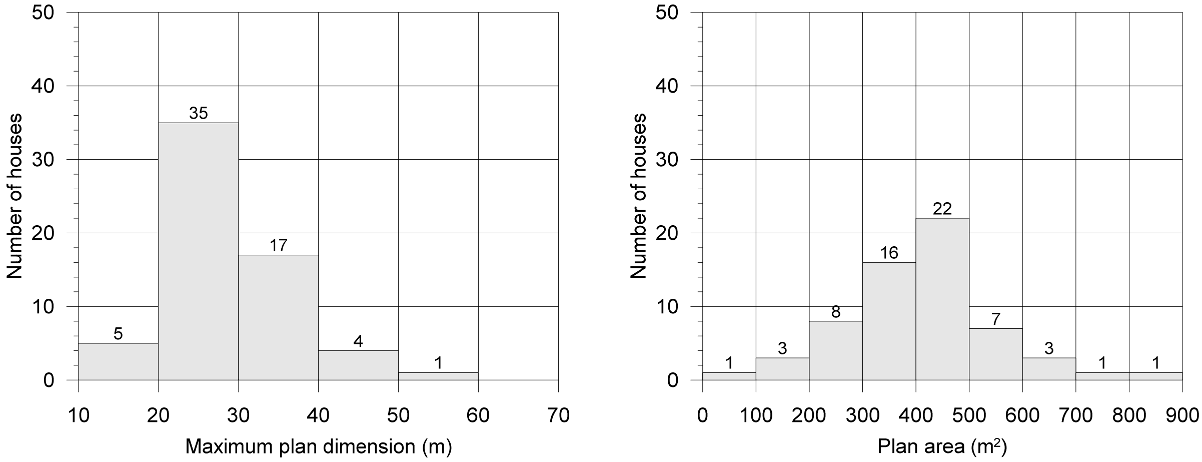

Fig. 6.27 Distribution of houses by maximum plan dimension and plan area

The houses have been categorised into four groups, on the basis of their maximum plan dimension and the number of stories. A summary of these house type categories is provided in Table 6.28. It is noted that two-storey houses include split-level houses.

Table 6.28 House type categories

House Type	Description	Number	Percentage
H1	Single-storey with maximum plan dimension less than 30 m	32	52 %
H2	Single-storey with maximum plan dimension of 30 m or greater	18	29 %
H3	Two-storey with maximum plan dimension less than 30 m	8	13 %
H4	Two-storey with maximum plan dimension of 30 m or greater	4	6 %

It can be seen from the above table that the majority of houses within the Study Area are single-storey with a maximum plan dimension less than 30 m (i.e. Type H1), and there are only four two-storey houses with a maximum plan dimension greater than 30 m (i.e. Type H4). A map showing the spatial distribution of house type categories within the Study Area is shown in Drawing No. MSEC1019-23.

Type of construction

Distributions of the wall and footing constructions of the houses within the Study Area are provided in Fig. 6.28. The majority of the houses within the Study Area are either brick or brick-veneer construction and are founded on strip footings.

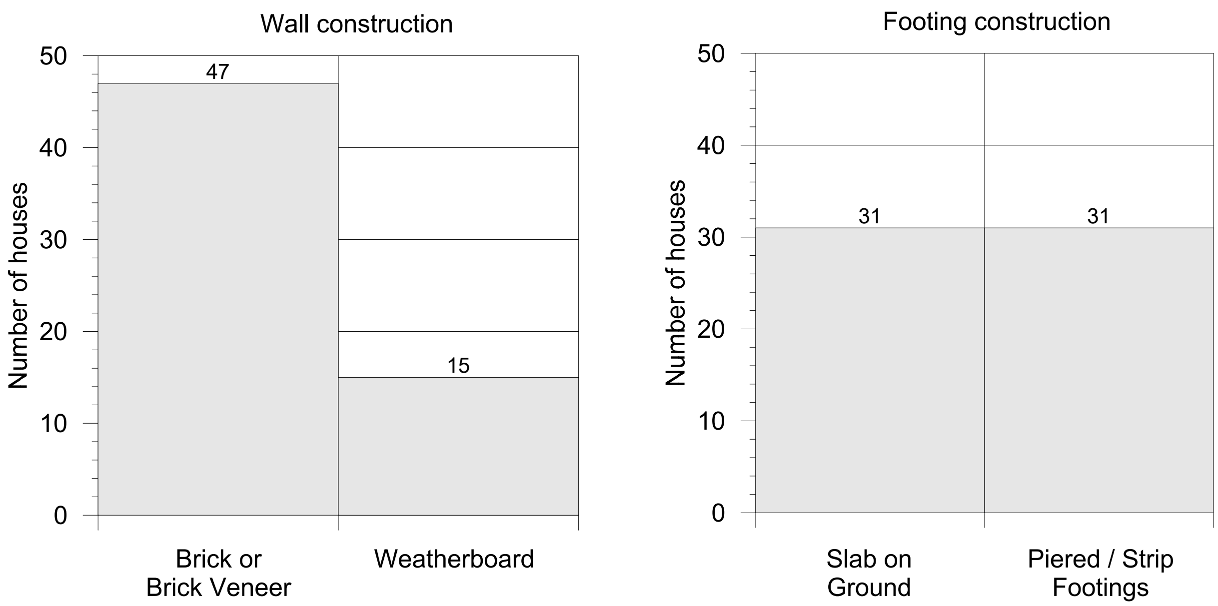

Fig. 6.28 Distributions of wall and footing construction for houses within the Study Area

Following a review of impacts to houses during the mining of TCCO LW22 to LW25, it was found that there was a noticeable difference in structural performance in response to mine subsidence movements between the following construction types:

- brick or brick-veneer houses constructed on a ground slab;
- brick or brick-veneer houses constructed on strip footings; and
- weatherboard or fibro houses constructed on either ground slabs or strip footings.

A summary of houses by construction type is provided in Table 6.29. A map showing the spatial distribution of construction types within the Study Area is shown in Drawing No. MSEC1019-24. It was observed that some houses have been constructed with masonry walls at basement level, with weatherboard linings for the main living areas above. These houses have been reported as brick in Table 6.29.

Table 6.29 Distribution of houses by construction type

Description	Number	Percentage
Brick or brick-veneer houses constructed on a ground slab	30	48 %
Brick or brick-veneer houses constructed on strip footings	22	36 %
Weatherboard or fibro houses constructed on either ground slabs or strip footings or other	10	16 %

Age of houses

The ages of the houses have been determined by examination of a series of historical aerial photographs provided by Land and Property Information, TCCO and Nearmap. The photographs that were available over the Study Area were taken in 1961, 1966, 1975, 1983, 1994, 2002, 2005, 2008 and 2018 and TCCO commissioned orthophotographs of the area in 2013 and 2018.

A histogram showing the distribution of houses by age is shown in Fig. 6.29. The houses within the Study Area are predominately less than 20 years old. A map showing the spatial distribution of construction types within the Study Area is shown in Drawing No. MSEC1019-22.

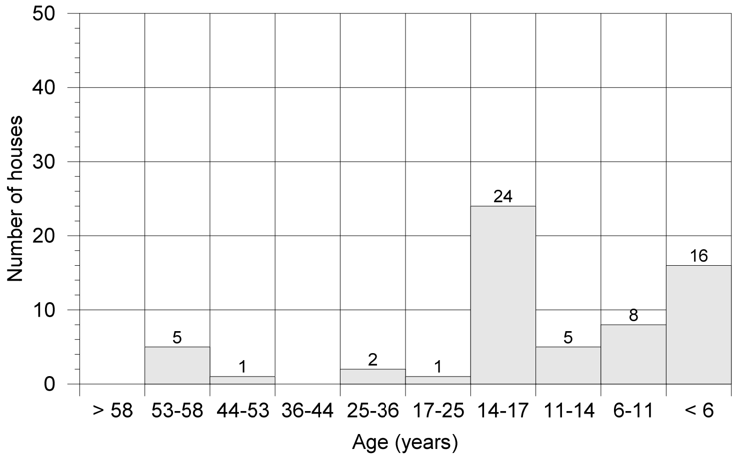

Fig. 6.29 Distribution of houses by age

Houses on steep slopes

There are eleven houses within the Study Area that are located on or near steep slopes. The locations of the building structures on or near steep slopes are shown in Drawing No. MSEC1019-11.

The houses within the Study Area on or near steep slopes comprise: five Type H1, three Type H2, one Type H3 and two Type H4. The construction types of these houses are: two brick on slab on ground, two brick on piered footings and seven timber framed houses.

Houses above 'hidden' creeks

One house within the Study Area has been identified directly above a 'hidden' creek, being Ref. PSC_027_h01. This house is located outside the extents of the proposed longwalls, at a distance of 160 m west of the tailgate of LW W1, as shown in Drawing No. MSEC1019-11. There are other houses that are located close to, but not directly above hidden creeks.

Houses outside declared Mine Subsidence Districts

The locations of the declared Mine Subsidence Districts (MSD) are shown in Drawing No. MSEC1019-03. The Study Area is located entirely within the Picton MSD. The Picton MSD district was proclaimed in 1997 and originally encompassed properties on Stonequarry Creek Road, Carramar Close, Attunga Close and Booyong Close and parts of Thirlmere Way. The Picton MSD was expanded in 2017 and now covers all properties within the Study Area.

A total of 52 of the 62 houses (84%) within the Study Area are located within the original boundary of the Picton MSD and were constructed after the declaration of the Picton MSD in 1997. There are eight houses within the Study Area that were constructed prior to 1994 (i.e. prior to the declaration of the Picton MSD). An additional two houses within the Study Area have been identified as having been constructed on or after the original declaration of the Picton MSD in 1997 but located outside the original boundary of the Picton MSD as declared in 1997.

Nine of the houses constructed prior to the declaration of the Picton MSD are Type H1, i.e. single storey houses with lengths of less than 30 m and one house is Type H2, i.e. single storey house with length greater than 30 m. The wall construction of these houses comprise five brick or brick-veneer, and five weatherboard. The footing types of these houses comprise three slab on ground, three piered footings, and three strip footings.

Future house construction

The statistics on building age provide an indication of the rate of growth of houses within the Study Area. The total number of houses within the Study Area versus time is illustrated in Fig. 6.30.

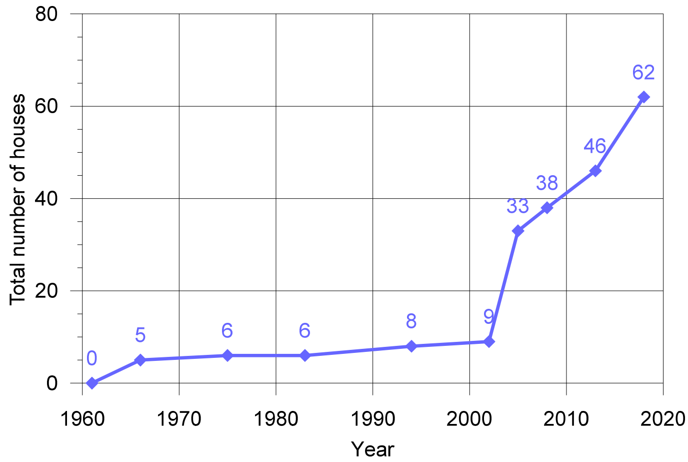

Fig. 6.30 Total number of houses within the Study Area versus time

The majority of the houses within the Study Area have been constructed since 2002. There have been 53 houses constructed between 2002 and 2018. This represents an average rate of construction of approximately 3.3 houses per year.

6.24.2. Predictions for the houses

Predictions of conventional vertical subsidence, tilt and curvature have been made at the centroid and at the vertices of each house, as well as 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 maximum predicted values of total vertical subsidence, tilt and curvature for each of the houses within the Study Area are included in Table D.05, in Appendix D. The predicted tilts represent the maximum values in any direction after the completion of each of LW W1-W2. The predicted curvatures represent the maximum values in any direction at any time during or after the extraction of each of the proposed longwalls.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvatures for the houses is provided in Table 6.30. The table provides the maximum predicted values for the houses at any time during or after the extraction of each longwall.

Table 6.30 Maximum predicted total vertical subsidence, tilt and curvatures for the houses

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})
After LW W1	425	2.5	0.02	0.05
After LW W2	700	4.0	0.03	0.05

The maximum predicted tilt for the houses is 4.0 mm/m (i.e. 0.4 %, or 1 in 250). The maximum predicted curvatures are 0.03 km^{-1} hogging and 0.05 km^{-1} sagging, which represent minimum radii of curvature of 33 km and 20 km, respectively.

Distributions of the predicted vertical subsidence, tilt and curvatures for the houses within the Study Area are illustrated in Fig. 6.31, Fig. 6.32 and Fig. 6.33.

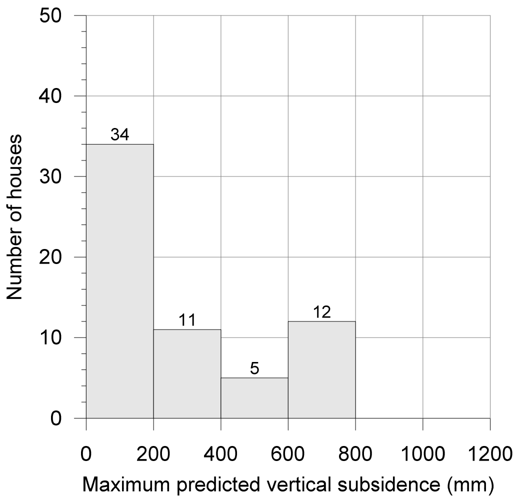

Fig. 6.31 Maximum predicted vertical subsidence for the houses

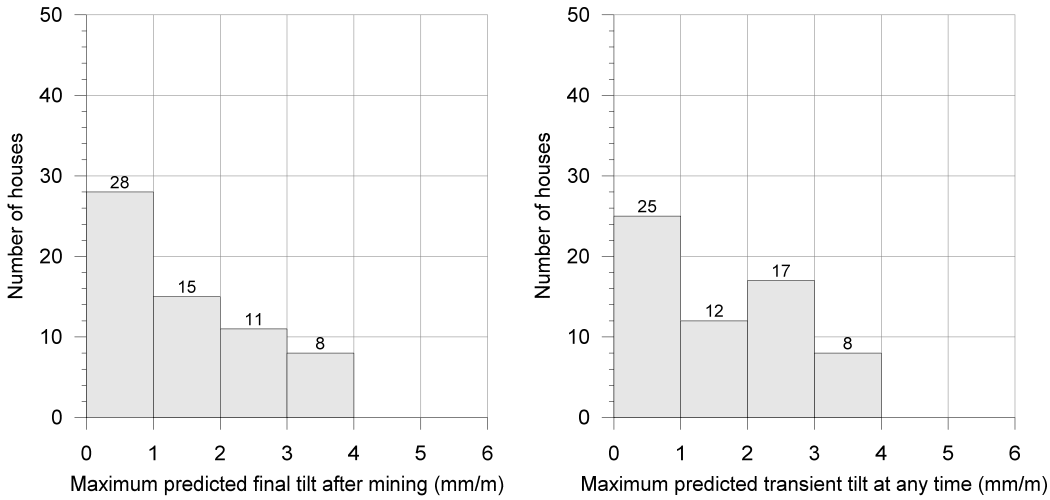

Fig. 6.32 Maximum predicted final tilt (left-side) and transient tilt (right-side) for the houses

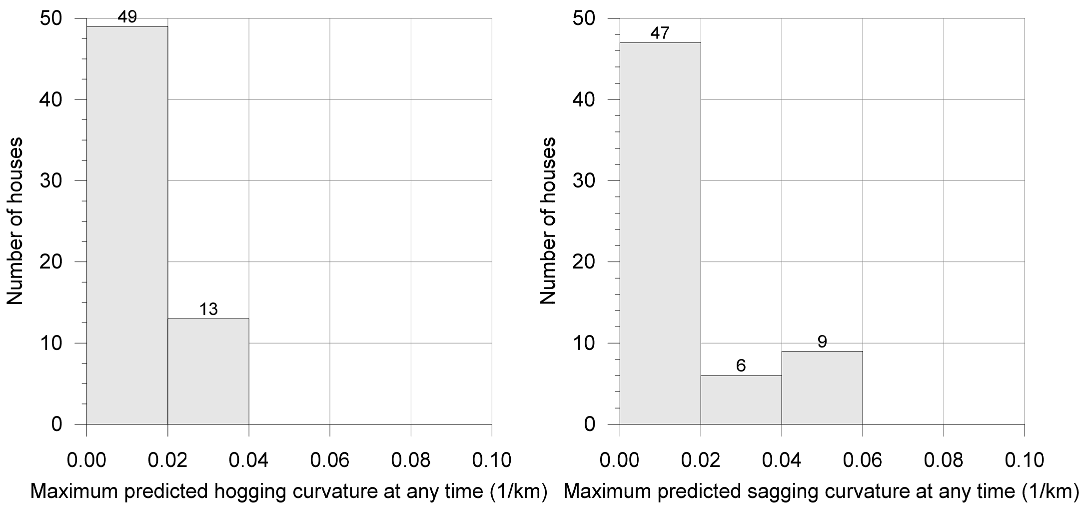

Fig. 6.33 Maximum predicted hogging curvature (left-side) and sagging curvature (right-side) at any time for the houses

The maximum predicted conventional strains for the houses, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 0.5 mm/m tensile and 1 mm/m compressive. Higher strains could develop at the houses due to irregular ground movements or topographic effects.

The predicted distributions of strain due to the extraction of LW W1-W2 are described in Chapter 4. The houses are at discrete locations and, therefore, the most relevant distribution of strain is the maximum strains measured in individual survey bays above previous longwall mining, which is summarised in Section 4.5.1. The maximum predicted total strains directly above the proposed longwalls are 1.0 mm/m tensile and 1.8 mm/m compressive based on the 95 % confidence level.

The strains have been predicted for each of the houses using the method described by Barbato (2017). This method considers the position of each house relative to the longwalls, the surface slope, surface lithology and the potential for irregular anomalous movements.

The predicted total strains for each of the houses within the Study Area are provided in Table D.05, in Appendix D. The distributions of the predicted total strains based on the mean and on the 95 % confidence levels are provided in Fig. 6.34 and Fig. 6.35, respectively.

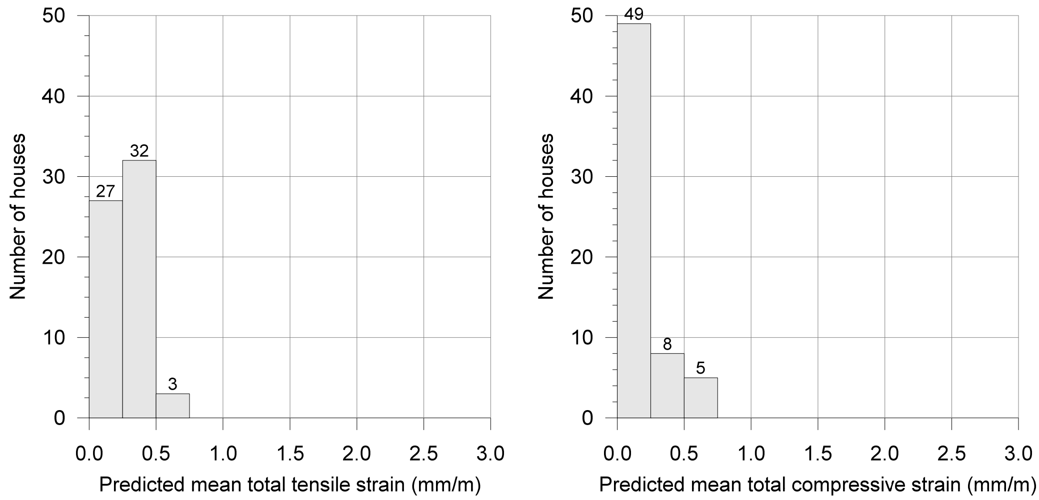

Fig. 6.34 Predicted total tensile strain (left-side) and total compressive strain (right-side) for the houses based on the mean

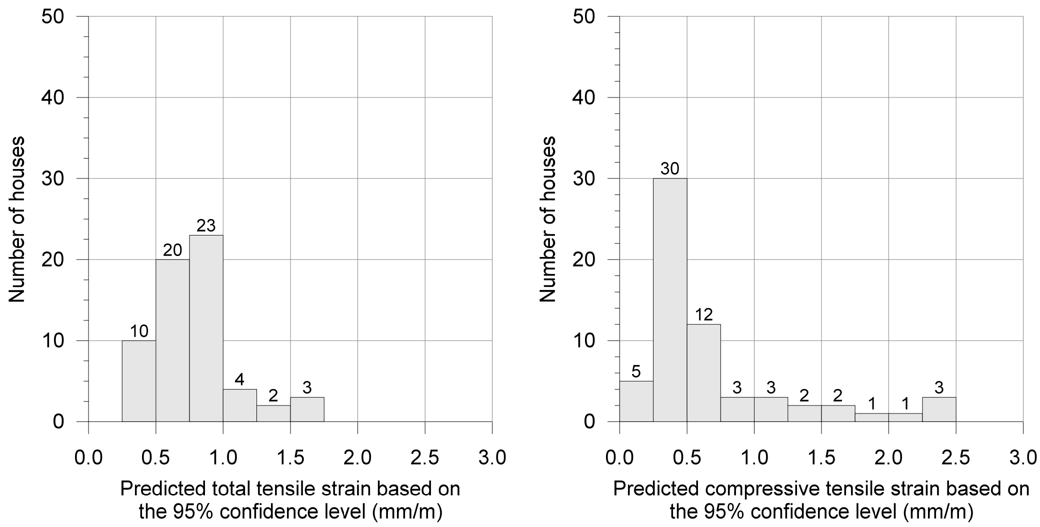

Fig. 6.35 Predicted total tensile strain (left-side) and total compressive strain (right-side) for the houses based on the 95 % confidence level

The houses within the Study Area are predicted to experience total tensile strains between 0.3 mm/m and 1.7 mm/m and total compressive strains between 0.2 mm/m and 2.4 mm/m based on the 95 % confidence levels. The predicted mean values range between 0.2 mm/m and 0.7 mm/m tensile and compressive.

6.24.3. Impact Assessments for the Houses

The following sections provide the impact assessments for the houses within the Study Area.

Potential impacts resulting from vertical subsidence

Vertical subsidence does not directly affect the stability or serviceability of houses. The potential for impacts on houses is affected by differential subsidence, which includes tilt, curvature and strain, and the impact assessments based on these parameters are described in the following sections.

Vertical subsidence can, in some cases, affect the heights of houses above the flood level. A detailed study has been undertaken by WRM (2019) to determine the extent of the flood prone areas after the completion of mining. The study found that stream flows are generally contained within the channels of Matthews, Cedar and Stonequarry Creeks. The subsidence resulting from the proposed extraction of LW W1-W2 results in a negligible change in flood levels in the catchment area (WRM, 2019).

Potential impacts resulting from tilt

The maximum predicted tilt for the houses within the Study Area is 4.0 mm/m (i.e. 0.4 %, or 1 in 250). The distribution of predicted final tilts for the houses within the Study Area is provided in Fig. 6.36. The greatest tilts occur at the houses located above the southern end of LW W1.

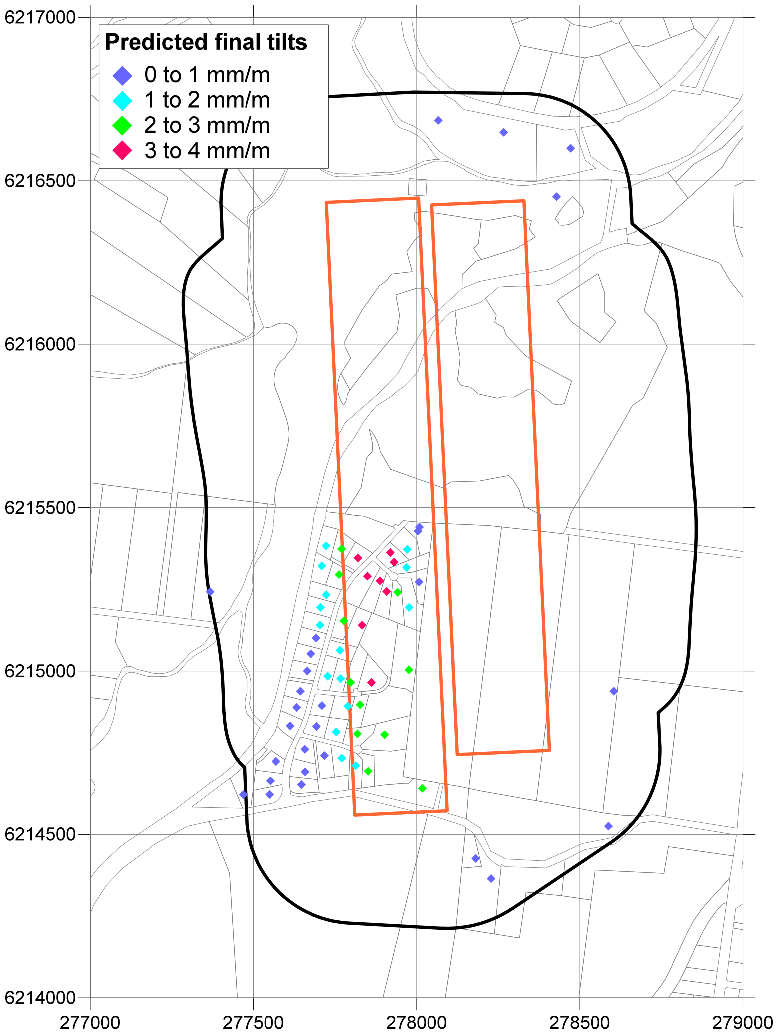

Fig. 6.36 Distribution of predicted final total tilts for the houses within the Study Area

It has been found from past longwall mining experience that tilts of less than 7 mm/m generally do not result in adverse impacts on houses. Some minor serviceability impacts can occur at these levels of tilt, including door swings and issues with roof gutter and wet area drainage, all of which can be remediated using normal building maintenance techniques.

It is expected, therefore, that only minor serviceability impacts would occur for the houses within the Study Area as a result of the mining-induced tilt. It is possible, however, that more substantial serviceability impacts could develop at some houses, as a result of non-conventional ground movements, which could require the relevelling of wet areas or, in some cases, the relevelling of parts of the building structures.

It is expected that, in all cases, the houses within the Study Area will remain in safe and serviceable condition as a result of the mining induced tilts, as tilts by themselves rarely impact on the stability of building structures at the levels that are predicted to occur.

Potential impacts resulting from curvature and strain

It has been found from past longwall mining experience that the majority of impacts on houses are a result of the mining-induced curvature and strains.

The maximum predicted curvatures for the houses within the Study Area are 0.03 km^{-1} hogging and 0.05 km^{-1} sagging, which represent minimum radii of curvatures of 33 km and 20 km, respectively.

The distributions of the maximum predicted curvatures for the houses within the Study Area are provided in Fig. 6.37. It can be seen that the greatest predicted curvatures occur directly above the proposed longwalls, as expected.

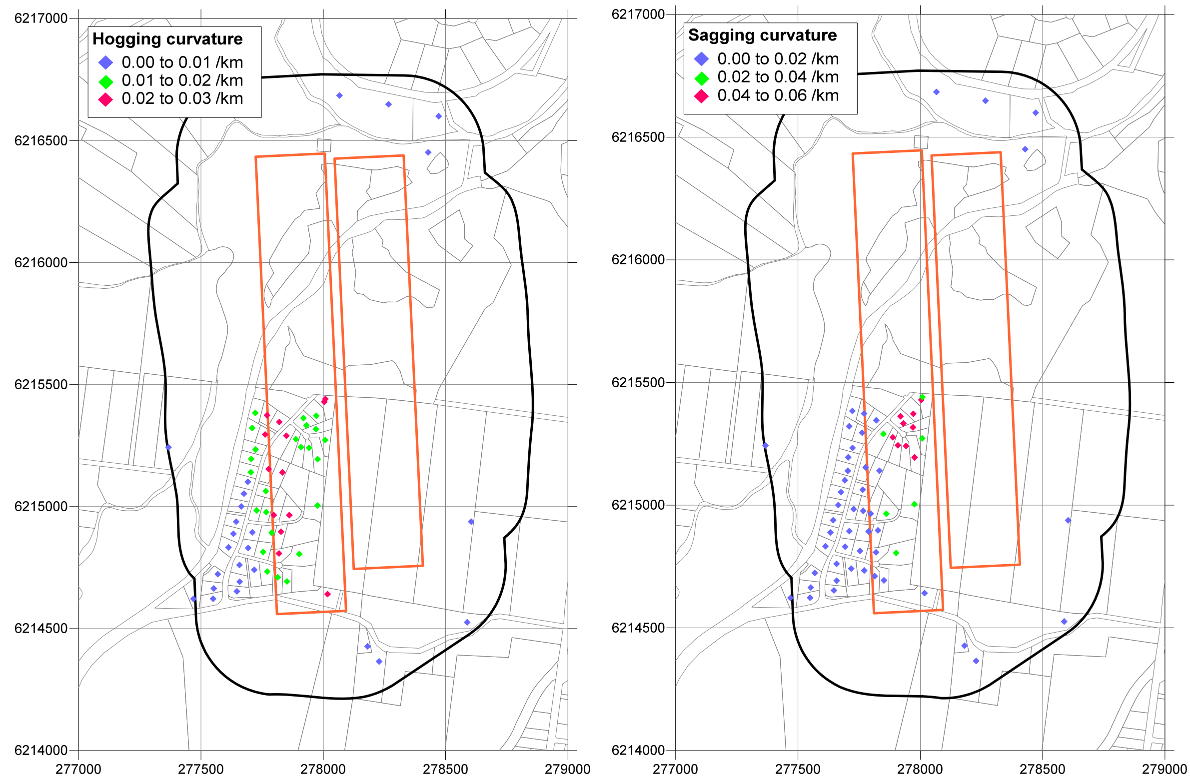

Fig. 6.37 Distributions of maximum predicted total hogging curvature (left-side) and sagging curvature (right-side) for the houses within the Study Area

Building structures have been directly mined beneath at a number of collieries throughout the NSW Coalfields. The experience gained has provided substantial information that has been used to continually development of the methods of impact assessment for houses. The assessments provided in this report are based on the latest research, which is summarised in Appendix B.

The probabilities of impacts for each house within the Study Area have been assessed using the method developed as part of ACARP Research Project C12015 (Waddington, 2009), which has been updated based on observations of impacts at Tahmoor Mine up to 2016 when the extraction of Longwall 29 was completed. This method uses the primary parameters of predicted ground curvature and type of construction for each house, as identified and described in Section 6.24.1.

Trend analyses following the mining of Tahmoor Longwalls 22 to 29 indicate that the chance of impact is higher for the following houses:-

- Houses predicted to experience higher strains and curvatures,
- Houses with masonry walls,
- Masonry walled houses that are constructed on strip footings,
- Larger houses, and
- Houses with variable foundations, such as those with extensions added.

The probabilities of impacts for each house within the Study Area have been assessed using the method developed as part of ACARP Research Project C12015 (Waddington, 2009), which has been updated based on observations of impacts at Tahmoor Mine up to 2016 when the extraction of Longwall 29 was completed. This method uses the primary parameters of ground curvature and type of construction and is described in Appendix B. The parameter of strain is indirectly used in this method due to its relationship with curvature.

A summary of the maximum predicted subsidence effects and the assessed impacts for each of the houses within the Study Area is provided in Table D.05, in Appendix D. The overall distribution of the assessed impacts for the houses within the Study Area is provided in Table 6.31.

Table 6.31 Assessed impacts for the houses within the Study Area

Location	Repair category			
	No Claim or R0	R1 or R2	R3 or R4	R5
Houses directly above LW W1-W2 (26 total)	72 % (≈ 19 houses)	20 % (≈ 5 houses)	7 % (≈ 2 houses)	1 % (≈ 1 house)
Houses outside of LW W1-W2 (36 total)	90 % (≈ 32 houses)	9 % (≈ 3 houses)	2 % (≈ 1 houses)	< 1 % (≈ 0 house)
All houses within the Study Area (62 total)	82 % (≈ 51 houses)	13 % (≈ 8 houses)	4 % (≈ 2 houses)	1 % (≈ 1 house)

The repair categories R0 to R5 are described in Appendix B.

It has been assessed that: 82 % or approximately 51 houses would experience Nil or Category R0 impacts, 13 % or approximately8 houses would experience Category R1 or R2 impacts, 4 % or approximately 2 houses would experience Category R3 or R4 impacts and that 1 % or approximately 1 house would experience Category R5 impacts.

In comparison, extensive data has come from the extraction of Tahmoor Longwalls 22 to 29, where approximately 1,900 houses have experienced mine subsidence movements. A summary of the observed distribution of impacts for all houses within a 35° angle of draw of previously extracted Longwalls 22 to 29 as at 2016 is provided in Table 6.32.

Table 6.32 Observed Frequency of Impacts for Building Structures Resulting from the Extraction of Tahmoor Longwalls 22 to 29

Group	Repair Category			
	No Claim or R0	R1 or R2	R3 or R4	R5
All houses within 35 degree angle of draw of LWs 22 to 29 (total of 1890)	1430 (76 %)	329 (17 %)	111 (6 %)	20 (1%)

A reasonable correlation can be found when comparing the assessed distributions in Table 6.31 with previous experiences as summarised in Table 6.32. The overall assessed distributions of impacts within the Study Area are lower than previously observed due to a number of contributing factors.

- There are a large proportion of houses within the Study Area that are not directly mined beneath.
- Compared to the majority of houses above Longwalls 22 to 29, mining-induced curvatures are also predicted to be lower for houses within the Study Area because they are located above or adjacent to LW W1, the extraction of which is expected to result in reduced subsidence, being the first panel in a series.
- A sizeable proportion of houses have been constructed using lightweight timber-frames and weatherboard style structures.

There are other factors that are not reflected in the assessed distributions of potential impacts. A sizeable proportion of houses within the Study Area have been constructed on large footprints in undulating terrain and this may result in a higher observed frequency of impacts. The majority of the houses are also relatively young in age and have been designed to accommodate mine subsidence movements.

Severe impacts have previously occurred as a result of substantial non-conventional movements and in plateau areas away from incised valleys, the locations of which cannot be predicted prior to mining. The impacts, however, develop gradually such that they can be detected early and repairs can be undertaken incrementally to ensure that the houses remain safe and serviceable during mining.

As noted in Appendix B, at the time of writing ACARP Research Project C12015, the observed proportion of houses where Subsidence Advisory NSW and affected landowners had decided to rebuild rather than repair (Category R5) impacts was less than 0.5 %. Since the publication of the research report, the proportion of houses where a decision has been made to rebuild has increased to approximately: 0.7 %.

The observed proportion of houses with Category R1 to R4 impacts have also increased since the original ACARP study. This is partly due to the time lag effect between the mining impact, when damage is claimed by residents and when the nature and level of the damage requiring repairs is assessed in detail by SA NSW. The latest review includes observations up to the end of Longwall 29 in 2016, which was approximately two years after the completion of Longwall 27 and one year after the completion of Longwall 28, which was the last panel to directly mine beneath the urban areas of Tahmoor.

The primary risk associated with mining beneath houses is public safety. Historically, residents have not been exposed to immediate and sudden safety hazards as a result of impacts that occur due to mine subsidence movements in the NSW Coalfields, where the depths of cover were greater than 350 metres, such as the case above the proposed longwalls.

Emphasis is placed on the words “immediate and sudden” as in rare cases, some structures have experienced severe impacts, but the impacts did not present an immediate risk to public safety as they developed gradually with ample time to relocate residents.

All houses within the Study Area are expected to remain safe throughout the mining period, provided that effective management measures are adopted during mining and these are described in Section 6.24.4 and Section 6.26.

Potential impacts from ‘hidden’ creeks

Hidden creeks are defined as natural watercourses that appear to have been covered during development of a property or road. Hidden creeks have been identified from surface contours and historical aerial photographs.

One house has been identified above a ‘hidden’ creek, being Ref. PSC_027_h01, which is located at the corner of Thirlmere Way and Stonequarry Creek Road above Rumker Gully. This house is located outside the extents of the proposed longwalls, at a distance of 70 metres south-west of the maingate of LW37. This house could experience slightly higher compressive strains due to valley closure movements. Tahmoor Mine

This house is considered to have a greater chance of experiencing non-conventional upsidence and closure movements during mining. When tested against observations during the mining of Longwalls 22 to 28, however, no clear increase in frequency of impact is observed.

A total of 52 houses above hidden creeks have experienced subsidence during the mining of Longwalls 22 to 29 and 22 houses have experienced impacts, including five houses directly above Longwall 27. The impacted houses include some on Oxley Grove, Tahmoor, where a creek had been infilled, and houses on York Street and Remembrance Drive, Tahmoor, where a small tributary to Myrtle Creek had been infilled. The rate of impact is higher than the overall rate of impact of 42 % and may represent a trend, though the impacts to these houses have been generally very minor (less than Category 1) and the sample size is small.

The observations of very minor impacts may be explained by the fact that the valleys in which the houses are located are very shallow and may not be sufficiently incised to generate significant upsidence and closure movements. If any movements do occur, it is also possible that they may not be completely transferred from the bedrock to the house through the constructed fill, depending on the design of the building foundations.

6.24.4. Management of potential impacts on houses

Tahmoor Mine has extensive experience of mining beneath urban areas. It has developed and acted in accordance with a risk management plan to manage potential impacts to residential structures during the mining of Longwalls 22 to 32.

The Subsidence Management Process has been developed in consideration of the following facts and observations:

1. Australian standards have been available for use in the design of structures since 1948. The majority of the houses within the Study Area (84%) have been constructed within and after the declaration of the Picton Mine Subsidence District;
2. There is sufficient redundancy in structural design such that ductile deformation will develop and be noticeable to residents before structural failure occurs;
3. Subsidence movements develop gradually over time at Tahmoor Mine as they have above other previously extracted longwalls at similar depths of cover;
4. Experiences during the mining of Longwalls 22 to 32 have found that the most effective method of managing potential impacts on the safety and serviceability of structures are by way of community consultation. Residents living within the active subsidence zone have often provided early feedback to Tahmoor Mine and/or SA NSW about impacts developing at their houses or along their local roads. Contact is made well before impacts develop to a level of severity sufficient to become a safety hazard;
5. On the basis of the above, there is sufficient time for residents to notify Tahmoor Mine or SA NSW of significant displacement or deflection well before structural failure will occur;
6. The conclusions are supported by the observation that residents have not been exposed to immediate and sudden safety hazards as a result of impacts that occur due to mine subsidence movements at Tahmoor Mine and above other previously extracted longwalls at similar depths of cover. This includes the recent experience at Tahmoor Mine during the mining of Longwalls 22 to 32, which have affected more than 2000 houses and civil structures; and
7. While severe impacts have developed during mining, there is sufficient redundancy in structural design such that when structures have experienced severe impacts, they have developed gradually with ample time for residents to notify Tahmoor Mine or SA NSW to repair the structure and/or relocate residents before structural failure occurs.

While the three most important factors in managing risks to public safety are redundancy in structural design, gradual development of subsidence movements and an effective community consultation program, a number of additional management measures have been undertaken, including site specific investigations, regular surveys and inspections during mining and triggered response measures. Further details on methods to control risks to public safety are described in Section 6.26.

With appropriate management plans in place, it is considered that the houses will remain safe and serviceable at all times during the extraction of the proposed longwalls, even if actual subsidence movements were greater than the predictions or substantial non-conventional movements occurred.

Impacts to the houses would be repaired or, if required, replaced in accordance with the *Coal Mine Subsidence Compensation Act 2017*.

6.24.5. Flats or Units

There were no flats or units identified within the Study Area.

6.25. Associated residential structures

6.25.1. Swimming pools

There are 16 privately owned swimming pools and one spa located within the Study Area, all of which are inground. The locations of the swimming pools are shown in Drawing Nos. MSEC1019-21 and details are provided in Table D.04, in Appendix D.

Predictions of conventional subsidence, tilt and curvature have been made at the centroid and around the perimeters of each pool. A summary of the maximum predicted values of conventional subsidence, tilt and curvature for each pool within the Study Area is provided in Table D.05, in Appendix D.

The predicted strains for the pools have been based on the statistical analysis of strains provided in Section 4.5. The pools are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays above previous longwall mining, which are summarised Section 4.5.1. The pools are expected to experience both tensile and compressive strains as the extraction faces of the proposed longwalls pass beneath them. At the completion of the proposed longwalls, the pools in locations of hogging curvature are more likely to be in final tensile zones and the pools in locations of sagging curvature are more likely to be in final compressive zones.

Mining-induced tilts are more noticeable in pools than other structures due to the presence of the water line and the small gap to the edge coping, particularly when the pool lining has been tiled. Skimmer boxes are also susceptible to being lifted above the water line due to mining tilt.

The Australian Standard AS2783-1992 (Use of reinforced concrete for small swimming pools) requires that pools be constructed level ± 15 mm from one end to the other. This represents a tilt of approximately 3.3 mm/m for pools that are 10 metres in length. Australian Standard AS/NZS 1839:1994 (Swimming pools – Pre-moulded fibre-reinforced plastics – Installation) also requires that pools be constructed with a tilt of 3 mm/m or less.

It can be seen from Table D.11, that nine pools within the Study Area (i.e. 53 % of the total) are predicted to experience final tilts greater than 3 mm/m, at the completion of the proposed longwalls, which is greater than the Australian Standard. It is likely, therefore that these pools would require remediation of the pool copings after the completion of active subsidence. It is possible, if the tilts were fully realised at the pools with the higher predicted tilts, that the final tilts could be difficult to remediate and, in these cases, the pools would need to be rebuilt.

The maximum predicted conventional curvatures for the pools are 0.07 km^{-1} hogging and 0.11 km^{-1} sagging, which represent minimum radii of curvature of 14 kilometres and 9 kilometres, respectively. The ranges of predicted maximum curvatures for the pools are similar to those previously experienced at Tahmoor Mine. The incidence and levels of impacts on the pools within the Study Area, therefore, are expected to be similar to those previously experienced at the colliery.

Observations during the mining of Tahmoor Mine Longwalls 22 to 32 have shown that pools, particularly in-ground pools, are more susceptible to severe impacts than houses and other structures. Pools cannot be easily repaired and most of the impacted pools need to be replaced in order to restore them to pre-mining condition or better.

As of June 2017, a total of 157 pools have experienced mine subsidence movements during the mining of Longwalls 22 to 30, of which 141 were located directly above the extracted longwalls. A total of 36 pools have reported impacts, all of which were located directly above the extracted longwalls. This represents an impact rate of approximately 23 %. A higher proportion of impacts have been observed for in-ground pools, particularly fibreglass pools. The majority of the impacts related to tilt or cracking, though in a small number of cases the impacts were limited to damage to skimmer boxes or the edge coping.

In addition to the above, a number of pool gates have been impacted by mine subsidence during the mining of Longwall 22 to 32. While the gates can be easily repaired, the consequence of breaching pool fence integrity is considered to be severe. As a result, TCCO inspects the integrity of pool fences once a week during the active subsidence period.

Impacts to the pools, fences and gates would be repaired or, if required, replaced in accordance with the *Coal Mine Subsidence Compensation Act 2017*.

6.25.2. Other associated residential structures

A total of 145 associated residential structures (i.e. rural structures) have been identified within the Study Area. The locations of the rural structures are shown in Drawing Nos. MSEC1019-21 and details are provided in Table D.04, in Appendix D.

The risks to the rural structures are that they could be damaged and/or rendered unserviceable from mine subsidence impacts. These structures include: garages; sheds; carports; tanks; greenhouses; hothouses; playhouses; and shade structures.

These structures are able to tolerate greater subsidence movements than houses, as they are generally lighter, more flexible in construction, and smaller in size. The risk of damage to sheds and other domestic structures, therefore, is considerably less when compared to houses.

A small number of sheds and other domestic structures have reported impacts during the mining of Longwalls 22 to 32, all of which are considered to be relatively minor and easy to repair. Impacts to the rural structures would be repaired or, if required, replaced in accordance with the *Coal Mine Subsidence Compensation Act 2017*.

It is therefore concluded that all associated residential structures are expected to remain safe, serviceable and repairable after mining has completed, provided that they are in sound existing condition. The risk of impact is clearly greater if structures are in poor condition though the chances of there being a public safety risk remain very low. There have been observations of the performance of some structures in poor pre-mining condition and these buildings have not experienced impacts during mining.

6.25.3. Rigid external pavements

Adverse impacts on rigid external pavements, such as driveways and footpaths, are often reported to Subsidence Advisory NSW in the Southern Coalfield. This is because pavements are typically thin relative to their length and width. The design of external pavements is also not regulated by Council or Subsidence Advisory NSW.

A study by Mine Subsidence Engineering Consultants of 120 properties at Tahmoor and Thirlmere indicated that 98 % of the properties with external concrete pavements demonstrated some form of cracking prior to mining. These cracks are sometimes difficult to distinguish from cracks caused by mine subsidence. It is therefore uncertain how many claims for damage can be genuinely attributed to mine subsidence impacts.

It is anticipated that some impacts are likely to occur to these pavements in the form of cracking and buckling, although the majority are expected to be minor and would be easily repaired. A total of 133 properties have reported impacts to external pavements during the mining of Longwalls 22 to 31. Impacts to external pavements would be repaired or, if required, replaced in accordance with the *Coal Mine Subsidence Compensation Act 2017*.

6.25.4. Fences in urban areas

There are a number of fences within the Study Area. The fences are constructed in a variety of ways, generally using either timber or metal materials. Fences are generally flexible in construction and can usually tolerate mine subsidence movements in the Southern Coalfield.

The maximum predicted tilt resulting from the extraction of the proposed longwalls is 6.0 mm/m (i.e. 0.6 %, or 1 in 165). Fence post tilts of less than 10 mm/m are barely noticeable.

The most vulnerable sections of fences are gates, particularly long gates or those with latches, as they are less tolerant to differential horizontal movements and tilts between the gate posts and the ground. It has also been found that Colorbond fences are particularly susceptible to mine subsidence impacts as there is very little flexibility in their construction.

A total of 73 impacts have been reported to gates and fences within the urban areas during the extraction of Longwalls 22 to 31. These gates and fences are typically Colorbond gates, which have been constructed with small clearances. Gates are often fixed to one side of the house. This form of construction is vulnerable to differential movements that can occur between the fence post and the house.

It is therefore assessed that some fences could experience impacts as a result of the extraction of the proposed longwalls. Some impacts may occur to gates, which may need ongoing repairs as mining occurs. Damaged fences and gates are relatively easy to rectify by re-tensioning of fencing wire, straightening of fence posts, and if necessary, replacing some sections of fencing. Impacts to fences would be repaired or, if required, replaced in accordance with the *Coal Mine Subsidence Compensation Act 2017*.

As discussed in Section 6.25.1, it is recommended that pool fences are monitored during mining in the interests of public safety.

6.25.5. Management of potential impacts to residential structures

Tahmoor Mine has developed and acted in accordance with a risk management plan to manage potential impacts to residential structures during the mining of Longwalls 22 to 32. The management plan provides for identification of buildings in poor pre-mining condition that are hazardous or may become hazardous due to mining, and visual kerbside monitoring of structures during active subsidence. Impacts would be repaired or, if required, replaced in accordance with the *Coal Mine Subsidence Compensation Act 2017*.

The management plan is reviewed periodically by Tahmoor Mine. It is recommended that Tahmoor Mine continue to develop management plans to manage potential impacts during the mining of the proposed longwalls.

6.26. Managing Public safety

The primary risk associated with mining beneath structures is public safety. Historically, residents have not been exposed to immediate and sudden safety hazards as a result of impacts that occur due to mine subsidence movements in the NSW Coalfields, where the depths of cover were greater than 350 metres, such as the case above the proposed longwalls. This includes the recent experience at Tahmoor, which has affected more than 2000 houses and civil structures.

Emphasis is placed on the words “immediate and sudden” as in rare cases, some structures have experienced severe impacts, but the impacts did not present an immediate risk to public safety as they developed gradually with ample time to relocate residents.

The existing condition of structures varies above LW W1-W2. This is a function of age, structural design, construction workmanship and maintenance. Pre-mining hazard identification inspections undertaken by Tahmoor Mine have identified elements of structures that did not appear to comply fully with Australian

Standards, in regard to design and construction. In a small number of cases, the existing structural condition has been considered potentially unsafe and Tahmoor Mine has undertaken measures to repair the defect.

There is a remote possibility that the comparatively small additional contribution of mine subsidence movements could be sufficient to result in the structures that do not meet Australian Standards to become potentially unstable.

It is recommended that Tahmoor Coking Coal Operations continues its current practice of ensuring that built structures remain safe and serviceable at all times during mining. It is recommended that Tahmoor Mine, in consultation with landowners, study the potential for impacts on the structures and other infrastructure and develop management measures. The study would require input from structural and subsidence engineers. The risk management process includes the following processes:-

1. Regular consultation, cooperation and coordination with the community before, during and after mining. This includes letters and door knocking to all residents of structures that will soon be affected by subsidence. The letters offer a free pre-mining inspection and hazard identification inspection by a structural engineer;
2. Site-specific investigations, where they are necessary and appropriate, into the conditions of buildings and associated structures and their surrounding environment (where access is allowed). The site-specific investigations have been and will continue to be undertaken early so that there is adequate time, if required, to arrange additional inspections and/or surveys and implement any mitigation measures before mining-induced impacts are experienced;

   For properties located directly above the first 300 m of the commencing end of a longwall, the investigations are targeted to be undertaken prior to extraction or at the latest, they will be undertaken prior to the first 200 m of extraction of the longwall.

   The site-specific investigations include the following:

   a) Identification of structures from aerial photographs and kerbside inspections;
   b) Front of house risk and visual screening inspections by Tahmoor Coking Coal Operations in company with a structural engineer for all properties that are predicted to experience more than 20 mm of incremental vertical subsidence due to the extraction of each upcoming longwall. The purpose of the inspections is to identify hazards where access has not been granted by the landowner.

      In some cases, particularly in semi-rural and rural areas, it is difficult to inspect a structure that is remote from the street front. Where these cases involve properties that are located directly above a longwall, Tahmoor Coking Coal Operations will request access to conduct a pre-mining inspection and hazard identification inspection by a structural engineer;
   c) Tahmoor Coking Coal Operations will request access to conduct pre-mining geotechnical inspections of structures located on or immediately adjacent to steep slopes that are predicted to experience more than 20 mm of incremental vertical subsidence due to the extraction of each longwall;
   d) Tahmoor Coking Coal Operations will request access to conduct pre-mining hazard identification inspections by a structural engineer (where access is allowed by the landowner) to properties with structures that have been specifically targeted on the basis that may be more sensitive to mine subsidence movements. These include:
      i) Commercial and business establishments, public amenities and public utilities;
      ii) Structures of heritage significance;
      iii) Structures that are located above hidden creeks;
      iv) Structures that are located above mapped geological structures;
      v) Structures that are located on or adjacent to steep slopes or that have been recommended for structural inspection by the geotechnical engineer;
      vi) Structures that have been identified as being potentially unstable or unsafe by landowners (Item 1), or from the front of house inspections (Item 2b);
      vii) Houses and units located outside the declared Mine Subsidence Districts; and
      viii) Houses and units estimated to have been constructed prior to the declaration of the Picton Mine Subsidence District as originally declared in 1997 or if outside the original declared boundary, prior to the declaration of the current boundary in 2017.
3. Implementation of pre-mining mitigation measures following inspections by the geotechnical engineer and the structural engineer, in consultation and agreement with the landowner.

4. Surveys and inspections during mining within the active subsidence area:
   a) detailed visual inspections and vehicle-based inspections along the streets;
   b) ground surveys along the streets;
   c) specific ground surveys for selected properties, where recommended by the geotechnical engineer or structural engineer due to their proximity to steep slopes or pre-existing condition;
   d) visual inspections of residential structures that are either: located on or adjacent to steep slopes, are in poor existing condition (based on the hazard identification inspections), have previously reported impacts, or where recommended by the Structures Response Group;
   e) visual inspections of pool fences and gates; and
   f) visual inspections of commercial, industrial and business establishments, public amenities and public utilities.

Front of house risk and visual screening inspections have been completed by Tahmoor Coking Coal Operations in company with a structural engineer for structures within the Study Area. One unoccupied house is in a dilapidated condition and it is proposed to erect bunting and warning signs around the structures to discourage access, subject to approval by the landowner.

The management plan also provides for additional visual inspections and ground surveys in the event that increased subsidence is observed. This includes pre-mining checks of structures within the affected area, daily visual inspections during active subsidence and weekly ground surveys along streets. Tahmoor Mine also consults with Subsidence Advisory NSW to determine whether additional resources are required to assist with undertaking repairs to impacted structures.

6.27. Known future developments

As discussed in Section 6.24, development continues on subdivided lots along Stonequarry Creek Road, Carramar Close, Attunga Close and Booyong Close. A small number of additional buildings are expected to be constructed prior to the extraction of the proposed longwalls.

7.0 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 A. REFERENCES

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APPENDIX B. METHOD OF IMPACT ASSESSMENTS FOR HOUSES

APPENDIX B METHOD OF IMPACT ASSESSMENT FOR HOUSES

B.1. Introduction

The methods for predicting and assessing impacts on building structures have developed over time as knowledge and experience has grown. MSEC has provided predictions and impact assessments for the building structures within the *Study Area* using the latest methods available at this time.

Longwall mining has occurred directly beneath building structures at a number of collieries in the Southern Coalfield, including Appin, West Cliff, Tower and Tahmoor Collieries. The most extensive data has come from extraction of Tahmoor Mine Longwalls 22 to 29, where approximately 1900 houses have experienced subsidence movements. The experiences gained during the mining of these longwalls, as well as longwalls at other collieries in the Southern and Newcastle Coalfields, have provided substantial additional information that has been used to further develop the methods.

The information was initially collected during the mining of Tahmoor Mine Longwalls 22 to 24A and reviewed in two parallel studies, one as part of a funded ACARP Research Project C12015 (Waddington, 2009), and the other at the request of Industry and Investment NSW (now the Department of Planning and Environment – Resources Regulator).

The outcomes of these studies include:-

- Review of the performance of the previous method,
- Recommendations for improving the method of Impact Classification, and
- Recommendations for improving the method of Impact Assessment.

Additional information was collected in 2016 after the completion of Longwall 29 and impact assessments for the houses in this report have been based on the updated information provided. A summary is provided in the following sections.

B.2. Review of the Performance of the Previous Method

The previous method of impact assessment applied predictions of curvature on the overall length of each house to predict a crack width in the external walls that was classified based primarily in accordance with Table C1 of Australian Standard 2870-1996. This method did not include impacts to other elements, finishes or services.

Extensive data on house impacts has come from extraction of Tahmoor Mine Longwalls 22 to 25 and a comparison between predicted and observed impacts is provided in Table B.1. The comparison is based on pre-mining predictions that were provided in SMP Applications for these longwalls and the observations of impacts using the previous method of impact classification. The comparison is based on information up to 30 November 2008. At that point in time, the length of extraction of Longwall 25 was 611 metres.

A total of 1037 houses and civil structures were affected by subsidence due to the mining of Tahmoor Mine Longwalls 22 to 25 at that time. A total of 175 claims had been received by the MSB, now SA NSW (not including claims that were refused) of which 14 claims did not relate to the main residence or civil structure.

Table B.1 Summary of Comparison between Observed and Predicted Impacts for each Structure

Strain Impact Category	Total No. of Observed Impacts for Structures predicted to be Strain Impact Category 0	Total No. of Observed Impacts for Structures predicted to be Strain Impact Category 1	Total No. of Observed Impacts for Structures predicted to be Strain Impact Category 2	Total
No impact	483	373	20	876
Cat 0	31	70	6	107
Cat 1	8	9	1	18
Cat 2	7	11	2	20
Cat 3	2	2	0	4
Cat 4	3	5	0	8
Cat 5	3	1	0	4
Total	537	471	29	1037
% claim	**10 %**	**21 %**	**31 %**	16 %
% Obs > Pred	**4 %**	**4 %**	**0 %**	-
% Obs <= Pred	**96 %**	**96 %**	**100 %**	-

Note: Predicted impacts due to conventional subsidence only, as described in the SMP Application.

Given that observed impacts are less than or equal to predicted impacts in 96 % of cases, it is considered that the previous methods are generally conservative even though non-conventional movements were not taken into account in the predictions and assessments. However, when compared on a house by house basis, the predictions have been substantially exceeded in a small proportion of cases.

The majority, if not all, of the houses that have experienced Category 3, 4 or 5 impacts are considered to have experienced substantial non-conventional subsidence movements. The consideration is based on nearby ground survey results, where localised bumps are observed in subsidence profiles and high localised strain is observed. The potential for impact from non-conventional movements were discussed generally and not included in the specific impact assessments for each structure.

The inability to specify the number or probability of impacts due to the potential for non-conventional movements is a shortcoming of the previous method. It was considered that there was substantial room for improvement in this area and recommendations are provided to improve the previous method.

The comparison shows a favourable observation that the overall proportion of claims increased for increasing observed ground movements. This suggests that the main parameters currently used to make impact assessments (namely predicted conventional curvature and maximum plan dimension of each structure) are credible. Please note that we have stated predicted conventional curvature rather than strain, as predictions of strain were directly based on predictions of conventional curvature.

A substantial over-prediction is observed at the low end of the spectrum of impacts (Category 0 and 1). A number of causes and/or possible causes for the deviations have been identified:

- Construction methods and standards may mitigate against small differential ground movements.
- The impacts may have occurred but the residents have not made a claim for the following reasons:-
  - All structures contain some existing, pre-mining defects. A pre-mining field investigation of 119 structures showed that it is very rare for all elements of a building to be free of cracks. Cracks up to 3 mm in width are commonly found in buildings. Cracks up to 1 mm in width are very common. There is a higher incidence of cracking in brittle forms of construction such as masonry walls and tiled surfaces.
  - In light of the above, additional very slight Category 0 and 1 impacts may not have been noticed by residents. A forensic investigation of all structures before or after mining may reveal that the number of actual impacts is greater than currently known.
  - Similarly, impacts have been noticed but some residents may consider them to be too trivial to make a claim. While difficult to prove statistically, it is considered that the frequency of claims from tenanted properties is less than the frequency of claims from owner-occupied properties.
- The impacts have been noticed but some residents are yet to make a claim at this stage. It has been observed that there is a noticeable time lag between the moment of impact and the moment of making a claim. At the time of the original study in 2008, more claims were therefore expected to be received in the future within areas that have already been directly mined beneath. This has been confirmed by the findings of the most recent study based on information received in 2016. It has also been found that as assessments and repairs were progressively determined at each house, the level of impacts at each house has generally been greater than was originally reported.
- The predictive method is deliberately conservative in a number of ways.
  - Predicted subsidence movements for each structure are based on the maximum predicted subsidence movements within 20 metres of the structure.
  - An additional 0.2 mm/m of strain was added
  - Maximum strains were applied to the maximum plan dimension, regardless of the maximum predicted strain orientation.
  - The method of impact assessment does not provide for “nil impacts”. The minimum assessed level of impact is Category 0.
  - The impact data was based on double-storey full masonry structures in the UK.

Finally, it is considered that the previous method impact classification has masked the true nature and extent of impacts. It is recommended that an improved method of classification be adopted before embarking on any further analysis. This is discussed in the next chapter of this report.

B.3. Method of Impact Classification

B.3.1. Previous Method

The impacts to structures were previously classified in accordance with Table C1 of Australian Standard 2870-1996, but the table has been extended by the addition of Category 5 and is reproduced below.

Table B.2 Classification of Damage with Reference to Strain

Impact Category	Description of typical damage to walls and required repair	Approximate crack width limit
0	Hairline cracks.	< 0.1 mm
1	Fine cracks which do not need repair.	0.1 mm to 1.0 mm
2	Cracks noticeable but easily filled. Doors and windows stick slightly	1 mm to 5 mm
3	Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weather-tightness often impaired	5 mm to 15 mm, or a number of cracks 3 mm to 5 mm in one group
4	Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window or door frames distort. Walls lean or bulge noticeably. Some loss of bearing in beams. Service pipes disrupted.	15 mm to 25 mm but also depends on number of cracks
5	As above but worse, and requiring partial or complete rebuilding. Roof and floor beams lose bearing and need shoring up. Windows broken with distortion. If compressive damage, severe buckling and bulging of the roof and walls.	> 25 mm

Note 1 of Table C1 states that *"Crack width is the main factor by which damage to walls is categorized. The width may be supplemented by other factors, including serviceability, in assessing category of damage.*

Impacts relating to tilt were classified according to matching impacts with the description in Table B.3, not the observed actual tilt. This is because many houses that had experience tilts greater than 5 mm had not made a claim to the MSB (now SA NSW).

Table B.3 Classification of Damage with Reference to Tilt

Impact Category	Tilt (mm/m)	Description
A	< 5	Unlikely that remedial work will be required.
B	5 to 7	Adjustment to roof drainage and wet area floors might be required.
C	7 to 10	Minor structural work might be required to rectify tilt. Adjustments to roof drainage and wet area floors will probably be required and remedial work to surface water drainage and sewerage systems might be necessary.
D	> 10	Considerable structural work might be required to rectify tilt. Jacking to level or rebuilding could be necessary in the worst cases. Remedial work to surface water drainage and sewerage systems might be necessary.

B.3.2. Need for Improvement to the Previous Method of Impact Classification

It is very difficult to design a method of impact classification that covers all possible scenarios and permutations. The application of any method is likely to find some instances that do not quite fit within the classification criteria.

Exposure to a large number of affected structures has allowed the mining industry to appreciate where improvements can be made to all aspects including the identification of areas for improvement in the previous method of impact classification.

A number of difficulties have been experienced with the previous method during the mining period. The difficulty centres on the use of crack width as the main classifying factor, as specified in Table C1 of Australian Standard 2870-1996.

A benefit of using crack width as the main factor is that it provides a clear objective measure by which to classify impact. However, experience has shown that crack width is a poor measure of the overall impact and extent of repair to a structure. The previous method of impact classification may be useful for assessing impact to newly built structures in a non-subsidence environment but further improvement and clarification is recommended before it can be effectively applied to houses impacted by mine subsidence.

The following aspects highlight areas where the previous classification system could be improved.-

- *Slippage on Damp Proof Course*

  Many houses have experienced slippage along the damp proof course in Tahmoor. Slippage on some houses is relatively small (less than 10 mm) though substantial slippage has been observed in a number of cases, such as shown in Fig. B.1 below.

Fig. B.1 Example of slippage on damp proof course

Under the previous classification method, the “crack” width of the slippage may be very small (Category 1) but the distortion in the brickwork is substantial. Moreover, the extent of work required to repair the impact is substantial as it usually involves re-lining the whole external skin of the structure. Such impacts would be considered Category 4 based on extent of repair but only Category 1 or 2 based on maximum crack width.

There is no reference to slippage of damp proof course in the previous method of impact classification. However, if the extent of repair was used instead of using crack width as the main factor, the impact category would be properly classified as either Category 4 or Category 5.

It was recommended that slippage of damp proof courses be added to the previous impact classification table.

- *Cracks to brickwork*

  In some cases, cracks are observed in mortar only. For example, movement joints in some structures have been improperly filled with mortar instead of a flexible sealant, as shown in Fig. B.2. In these situations, the measured crack width may be substantial but the impact is relatively simple to repair regardless of the crack width.

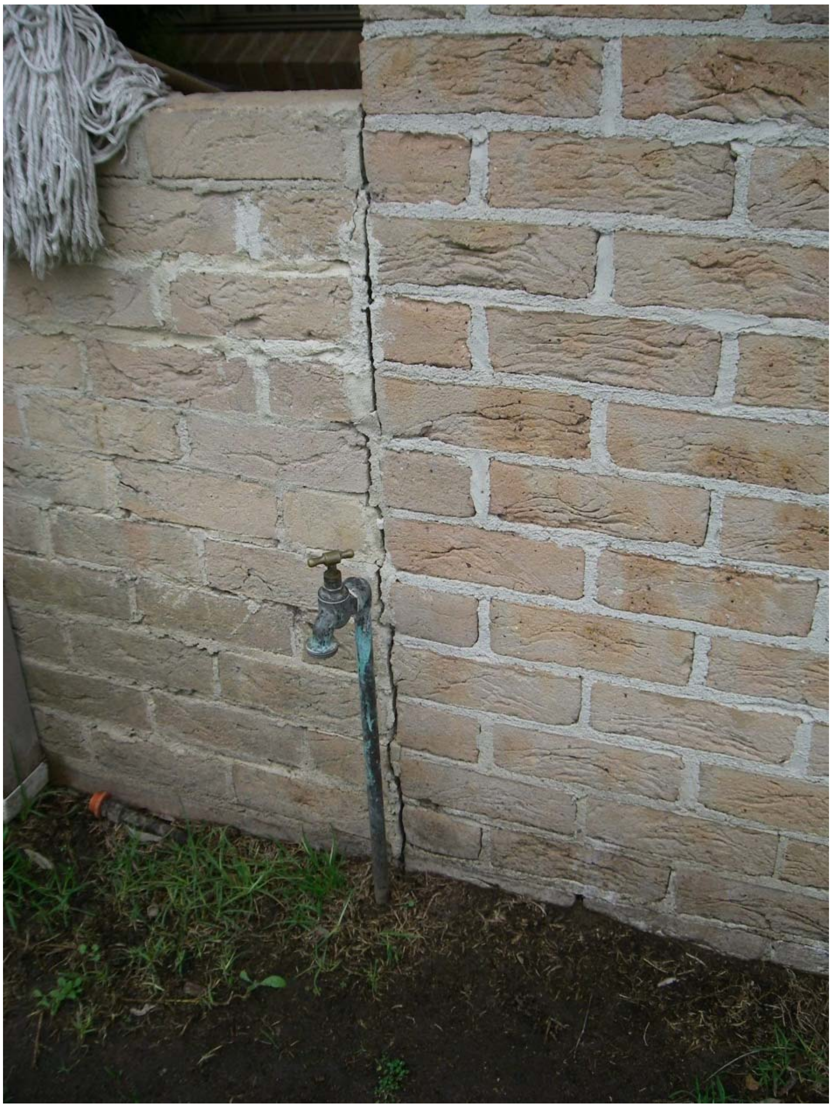

Fig. B.2 Example of crack in mortar only

In other cases, a small number of isolated bricks have been observed to crack or become loose. This is usually straightforward to repair. Under the previous impact classification method, a completely loose brick could be strictly classified as Category 5 as the crack width is infinitely large. This is clearly not the intention of the previous method but clarification is recommended to avoid confusion.

If a panel of brickwork is cracked, the method of repair is the same regardless of the width. While it is considered reasonable to classify large and severe cracks by its width, it is recommended that cracks less than 5 mm in width be treated the same rather than spread across Categories 0, 1 and 2.

If a brick lined structure contains many cracks of width less than 3 mm, the impact would be classified as no more than Category 2 under the previous method of impact classification. The extent of repair may be substantially more than a house that has experienced only one single 5 mm crack. However, it is recognised that it is very difficult to develop a simple method of classifying impacts based on multiple cracks in wall panels. How many cracks are needed to justify an increase in impact category?

- *Structures without masonry walls*

  Timber framed structures with lightweight external linings such weatherboard panels and fibro sheeting are not referenced in the previous classification table. If crack widths were strictly adopted to classify impacts, it may be possible to classify movement in external wall linings beyond Category 3 when in reality the repairs are usually minor.

  It was recommended that the impact classification table be extended to include structures with other types of external linings.

- *Minor impacts such as door swings*

  Experience has shown that one of the earliest signs of impact is the report of a sticking door. In some instances, the only observed impact is one or two sticking doors. It takes less than half an hour to repair a sticking door and impact is considered negligible.

  Such an impact would be rightly classified as Category 0 based on the previous method of impact classification as there is no observed crack. However, the previous classification table suggests that sticking doors and windows occur when Category 2 crack widths develop. It was recommended that the impact classification table be amended in this respect.

B.3.3. Broad Recommendations for Improvement of Previous Method of Impact Classification

It was recommended that crack width no longer be used as the main factor for classifying impacts. This does not mean that the use of crack width should be abandoned altogether. Crack width remains a good indicator of the severity of impacts and should be used to assist classification, particularly for impacts that are moderate or greater.

By focussing on crack width, the previous impact classification table appears to be classifying impacts from a structural stability perspective. It was recommended that a revised impact classification table be more closely aligned with all aspects of a building, including its finishes and services. Residents who are affected by impacts are concerned as much about impacts to internal linings, finishes and services as they are about cracks to their external walls and a revised impact classification method should reflect this.

With crack width no longer used as the main factor, it was recommended that the wording of the descriptions of impact in the classification table be extended to cover impacts to more elements of buildings. In keeping with the previous method of assessment, the level of impact should distinguish between cosmetic, serviceability and stability related impacts:-

- Low impact levels should relate to cosmetic impacts that do affect the structural integrity of the building and are relatively straight-forward to repair,
- Mid-level impact categories should relate to impacts to serviceability and minor structural issues, and
- High level impacts should be reserved for structural stability issues and impacts requiring extensive repairs.

B.3.4. Revised Method of Impact Classification

The following revised method of impact classification has been developed.

Table B.4 Revised Classification based on the Extent of Repairs

Repair Category	Extent of Repairs
Nil	No repairs required
R0 **Adjustment**	One or more of the following, where the damage does not require the removal or replacement of any external or internal claddings or linings:- - **Door** or **window** jams or swings, or - Movement of **cornices**, or - Movement at external or internal **expansion joints**.
R1 **Very Minor Repair**	One or more of the following, where the damage can be repaired by filling, patching or painting without the removal or replacement of any external or internal brickwork, claddings or linings:- - Cracks in **brick mortar** only, or isolated cracked, broken, or loose **bricks** in the external façade, or - Cracks or movement < 5 mm in width in any external or internal wall **claddings**, **linings**, or **finish**, or - Isolated cracked, loose, or drummy floor or wall **tiles**, or - Minor repairs to any **services** or **gutters**.
R2 **Minor Repair**	One or more of the following, where the damage affects a small proportion of external or internal claddings or linings, but does not affect the integrity of external brickwork or structural elements:- - Continuous cracking in **bricks** < 5 mm in width in one or more locations in the total external façade, or - Slippage along the **damp proof course** of 2 to 5 mm anywhere in the total external façade, or - Cracks or movement ≥ 5 mm in width in any external or internal wall **claddings**, **linings**, **finish**, or - Several cracked, loose or drummy floor or wall **tiles**, or - Replacement of any **services**.
R3 **Substantial Repair**	One or more of the following, where the damage requires the removal or replacement of a large proportion of external brickwork, or affects the stability of isolated structural elements:- - Continuous cracking in **bricks** of 5 to 15 mm in width in one or more locations in the total external façade, or - Slippage along the **damp proof course** of 5 to 15 mm anywhere in the total external façade, or - Loss of bearing to isolated walls, piers, columns, or other load-bearing elements, or - Loss of stability of isolated structural elements.
R4 **Extensive Repair**	One or more of the following, where the damage requires the removal or replacement of a large proportion of external brickwork, or the replacement or repair of several structural elements:- - Continuous cracking in **bricks** > 15 mm in width in one or more locations in the total external façade, or - Slippage along the damp proof course of 15 mm or greater anywhere in the total external façade, or - Relevelling of building, or - Loss of stability of several structural elements.
R5 **Re-build**	Extensive damage to house where the MSB (now SA NSW) and the owner have agreed to rebuild as the cost of repair is greater than the cost of replacement.

As discussed at the start of this chapter, it is very difficult to design a method of impact classification that covers all possible scenarios and permutations. While the method has been floated among some members of the mining industry, it is recommended that this table be reviewed broadly.

The recommended method has attempted to follow the current Australian Standard in terms of the number of impact categories and crack widths for Categories 3 and 4. The method is based on the extent of repairs required to repair the physical damage that has occurred, and does not include additional work that is occasionally required because replacement finishes cannot match existing damaged ones. It is therefore likely that the actual cost of repairs will vary greatly between houses depending on the nature of the existing level and type of finishes used.

The impacts experienced at Tahmoor Mine have been classified in accordance with the revised method of classification with good results. The method allowed clearer trends to be found when undertaking statistical analyses.

A comparison between the previous and revised methods is shown in Fig. B.3.

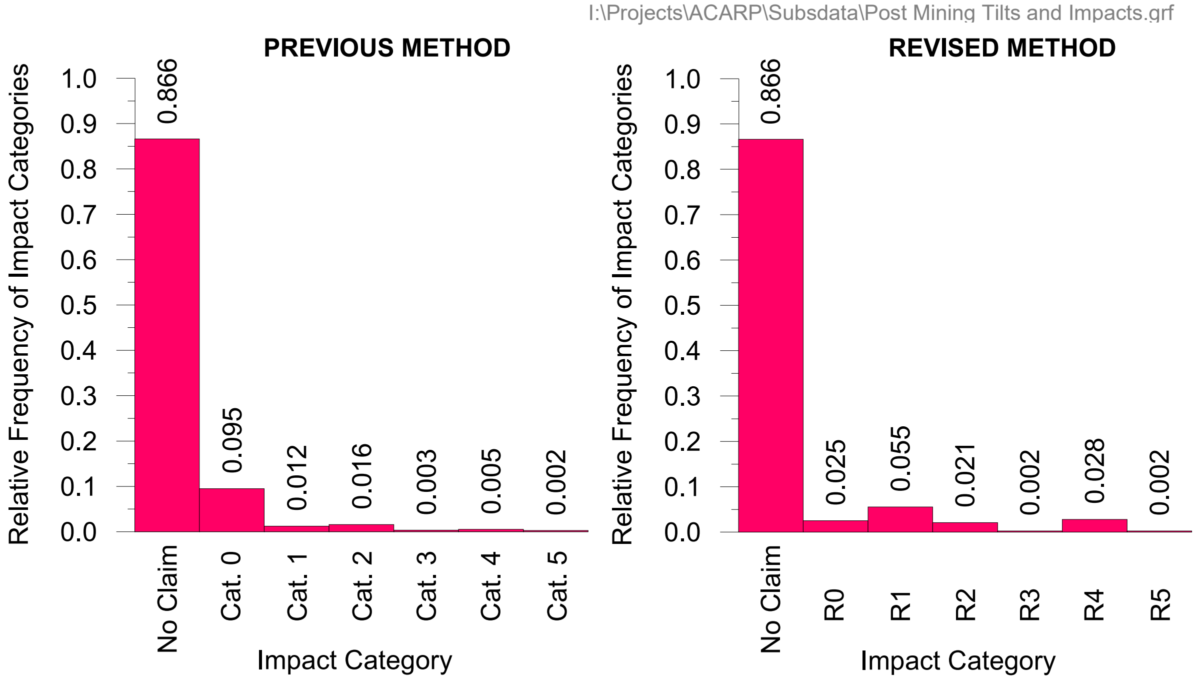

Fig. B.3 Comparison between Previous and Revised Methods of Impact Classification

It can be seen that there was an increased proportion in the higher impact categories using the revised method. This is brought about mainly by the recorded slippage on damp proof courses, which are classified as either Category 3 or Category 4 when they were previously classified as Category 1 or 2.

There was also a noticeable reduction in proportion of Category 0 impacts and noticeable increase in proportion of Category 1 impacts using the revised method. This is because the revised method reserves Category 0 impacts for impacts that did not result in cracking any linings, while the previous method allows hairline cracking to occur.

The consistent low proportion of Category 3 impacts under both the previous and current methods raises questions as to whether this category should be merged with Category 4.

B.4. Method of Impact Assessment

B.4.1. Need for Improvement of the Previous Method

The previous method of impact assessment provided specific quantitative predictions based on predicted conventional subsidence movements and general qualitative statements concerning the potential for impacts due to non-conventional movements. These non-conventional movements are additional to the predicted conventional movements.

This message was quite complex and created the potential for confusion and misunderstanding among members of the community who may easily focus on numbers and letters in a table that deal specifically with their house and misunderstand the message contained in the accompanying words of caution about the low level of reliability concerning predictions of conventional strain and potential for non-conventional movements.

This was unfortunately a necessary shortcoming of the previous method at the time as there was very little statistical information available to quantify the potential for impacts due to non-conventional movement. However, a great deal of statistical information was available following the mining of Tahmoor Mine Longwalls 22 to 24A at the time of the 2009 ACARP study and the method and message to the community could be improved. Additional statistical information was collected in 2016, which was approximately two years after the completion of Longwall 27 and one year after the completion of Longwall 28, which was the last panel to directly mine beneath the urban areas of Tahmoor. The timing of the data is such that it accounts for much of the time lag effect that occurs between the time of impact, when damage is claimed by residents and when the nature and level of the damage requiring repairs is assessed in detail by SA NSW.

While additional statistical information is now available, there remains limited knowledge at this point in time to accurately predict the locations of non-conventional movement. Substantial gains are still to be made in this area.

In the meantime, therefore, a probabilistic method of impact assessment has been developed. The method combines the potential for impacts from both conventional and non-conventional subsidence movement.

B.4.2. Factors that Could be Used to Develop a Probabilistic Method of Prediction

Trend analyses have highlighted a number of factors that could be used to develop a probabilistic method. The trends examined were:-

- *Ground tilt*

  This was found to be an ineffective parameter at Tahmoor Mine as ground tilts have been relatively benign and a low number of claims have been made solely in relation to tilt.

- *Ground strain*

  There appears to be a clear link between ground strain and impacts, particularly compressive strain. The difficulty with adopting ground strain as a predictive factor lies in the ability to accurately predict ground strain at a point.

  Another challenge with using strain to develop a probabilistic method is that there is limited information that links maximum observed strains with observed impacts at a structure. Horizontal strain is a two-dimensional parameter and it has been measured along survey lines that are oriented in one direction only.

  The above issues are less problematic for curvature and the statistical analysis on the relationship between strain and curvature shows that the observed frequency of high strains increased with increasing observed curvature.

- *Ground curvature*

  Curvature appears to be the most effective subsidence parameter to develop a probabilistic method. The trend analysis showed that the frequency of impacts increased with increasing observed curvature.

  It should be noted that we are referring to conventional curvature and not curvatures that have developed as a result of non-conventional subsidence behaviour. This is because conventional curvature can be readily predicted with reasonable correlation with observations. It is also a relatively straight-forward exercise to estimate the observed smoothed or "conventional" mining-induced curvature that has previously been experienced at houses provided some ground monitoring is undertaken across and along extracted longwalls.

  Non-conventional curvature cannot be predicted prior to mining and is accounted for by using a probabilistic method of impact assessment.

  It has also been shown that the observed frequency of high strains increased with increasing observed curvature.

- *Position of structure relative to longwall*

  A clear trend was understandably found that structures located directly above goaf were substantially more likely to experience impact. The calculated probabilities may be applicable for mining conditions that are similar to those experienced at Tahmoor Mine but will be less applicable for other mining conditions. An effective probabilistic method should create a link between the magnitude of differential subsidence movements and impact.

- *Construction type*

  Two trends have been observed. Not surprisingly, structures constructed with lightweight flexible external linings are able to accommodate a far greater range of subsidence movements than brittle inflexible linings such as masonry. The analyses merely quantified what was already well known. The second observation was that houses constructed with strip footings were noticeably more likely to experience impacts than houses constructed with a ground slab, particularly in relation to higher levels of impact. This is because houses with strip footings are more susceptible to slippage along the damp proof course.

- *Structure size*

  Trend analysis showed that larger structures attract a higher likelihood of impact. This is understandable as the chance of impacts increases with increasing footprint area. However, it is noted that the probability of severe impacts was not substantially greater for larger structures even though this would be expected if considering probabilities theoretically rather than empirically. It may be worthwhile including structure size as a factor in the development of a probabilistic method, though it is considered that it is a third order effect behind subsidence movements and construction type.

- *Structure age*

  The trend analysis for structure age did not reveal any noticeable trends.

- *Extensions, variable foundations and building joints*

  There is a clear trend of a higher frequency of impacts for structures that include extensions, variable foundations and building joints. The increased frequency appears to be related mainly to lower impact categories.

- *Urban or rural setting*

  While trends were observed, it is considered that they can be explained by other factors. However, consideration can be made to provide a more conservative estimate of probabilities in rural areas if structure size has not been taken into account.

B.4.3. Revised Method of Impact Assessment

A revised method of impact assessment has been developed, based on information received in 2016 at a time when the extraction of Longwall 29 had been completed. The method is probabilistic and currently includes conventional ground curvature and construction type as input factors.

At the time of the original 2009 ACARP study, the trends in the data were difficult to determine within small ranges of curvature because of the relatively low number of buildings that reported damage at this time. A decision was therefore taken to analyse the data in a limited number of curvature ranges, so that where possible a reasonable sample size would be available in each range. The ranges of curvature originally chosen were 5 to 15 kilometres, 15 to 50 kilometres and greater than 50 kilometres.

Additional information provided in 2016 has demonstrated that the proportion of houses reporting impacts has increased. This has allowed statistical analyses to be conducted using narrower bands of observed curvatures though some inconsistencies remain in some bands due to the sample sizes. The ranges of curvature provided in this report are 2.5 to 15 kilometres, 15 to 50 kilometres and greater than 50 kilometres.

Because the incidence of damage for different construction types showed strong trends and because the sample size was reasonable for each type of structure, the data were analysed to determine the effect of radius of curvature on the incidence of damage for each of the three structure types and for each of the three curvature ranges.

The following probabilities are proposed in Table B.5.

Table B.5 Probabilities of Impact based on Curvature and Construction Type based on the Revised Method of Impact Classification

R (km)	Repair Category			
	No Repair or R0	R1 or R2	R3 or R4	R5
Brick or brick-veneer houses with Slab on Ground				
> 50	90 ~ 95 %	3 ~ 10 %	1 %	< 0.5 %
15 to 50	70 ~ 75 %	20 ~ 25 %	5 ~ 10 %	< 0.5 %
2.5 to 15	45 ~ 65 %	25 ~ 35 %	10 ~ 15 %	1 ~ 3 %
Brick or brick-veneer houses with Strip Footing				
> 50	85 ~ 90 %	5 ~ 15 %	1 ~ 3 %	< 2 %
15 to 50	60 ~ 75 %	20 ~ 30 %	5 ~ 15 %	1 ~ 3 %
2.5 to 15	45 ~ 65 %	25 ~ 30 %	5 ~ 15 %	5 ~ 10 %
Timber-framed houses with flexible external linings of any foundation type				
> 50	90 ~ 95 %	3 ~ 10 %	1 %	< 0.5 %
15 to 50	75 ~ 85 %	10 ~ 20 %	5 ~ 10 %	< 0.5 %
2.5 to 15	70 ~ 80 %	20 ~ 25 %	7 ~ 12 %	< 0.5 %

The results have been expressed as a range of values rather than a single number, recognising that the data had considerable scatter within each curvature range. While structure size and building extensions have not been included in the predictive tables, it is recommended to adopt percentages at the higher end of the range for larger structures or those with building extensions.

The percentages stated in each table are the percentages of building structures of that type that would be likely to be damaged to the level indicated within each curvature range. The levels of damage in the tables are indicated with reference to the repair categories described in the damage classification given in Table B.4.

To place these values in context, Table B.6 shows the actual percentages recorded at Tahmoor Mine for all buildings within the sample.

Table B.6 Observed Frequency of Impacts observed for all buildings at Tahmoor Mine

R (km)	Repair Category			
	No Claim or R0	R1 or R2	R3 or R4	R5
> 50	91%	7%	2%	0%
15 to 50	72%	20%	7%	1%
5 to 15	59%	27%	14%	3%

It can be seen that the proposed probabilities for the higher impact categories have been increased compared to those observed to date. These have been deliberately increased, because it has been noticed that some of the claims for damage have been submitted well after the event and it is possible that the numbers damaged in this category could be increased as further claims are received and investigated. These numbers are sensitive to change. In light of the above, it is recommended that the probabilities be revisited in the future as mining progresses.

The ranges provided in Table B.5 have been converted into a set of probability curves to remove artificial discontinuities that are formed by dividing curvatures into three categories. These are shown in Fig. B.4. The probability curves are applicable for all houses and civil structures.

At the time of writing ACARP Research Project C12015 (Waddington, 2009), the observed proportion of houses where the MSB (now SA NSW) and affected landowners had agreed to rebuild rather than repair (Category R5) impacts was less than 0.5 %. Since the publication of the research report, the proportion of houses where a decision has been made to rebuild has increased to approximately 1.1% overall and 3.2% above Longwalls 24A to 27 within the observed zone of increased subsidence. The decision to rebuild rather than repair a house is based on a variety of factors. Whilst acknowledging the significance of a decision to rebuild compared to repair a house, all houses previously impacted at Tahmoor Mine could have been repaired rather than replaced, including those where a decision has been made to rebuild them. This does not diminish the significance of this category from a social and economic impact point of view and it is important to continue recording the number of instances where a decision has been made to rebuild a house.

B.4.4. Review of Observed Probabilities as mining continues

Reviews of observed probabilities are continually undertaken as Tahmoor Mine and other mines continue to extract beneath houses. The provision of additional information on impact on houses in 2016 has improved the level of understanding on the nature and frequency of impacts during the mining of Longwalls 22 to 29 compared to the information that was collected for the previous 2009 ACARP study, which was conducted after the mining of Longwalls 22 to 24A.

Additional statistical information was collected in 2016, which was approximately two years after the completion of Longwall 27 and one year after the completion of Longwall 28, which was the last panel to directly mine beneath the urban areas of Tahmoor.

A finding from the additional information is that the proportion of houses that have experienced impacts has increased over time. The reasons for the increase are due to the time lag effect that occurs between the mining impact, when damage is claimed by residents and when the nature and level of the damage requiring repairs is assessed in detail by SA NSW.

In light of the above, it is recommended that the probabilities be revisited in the future.

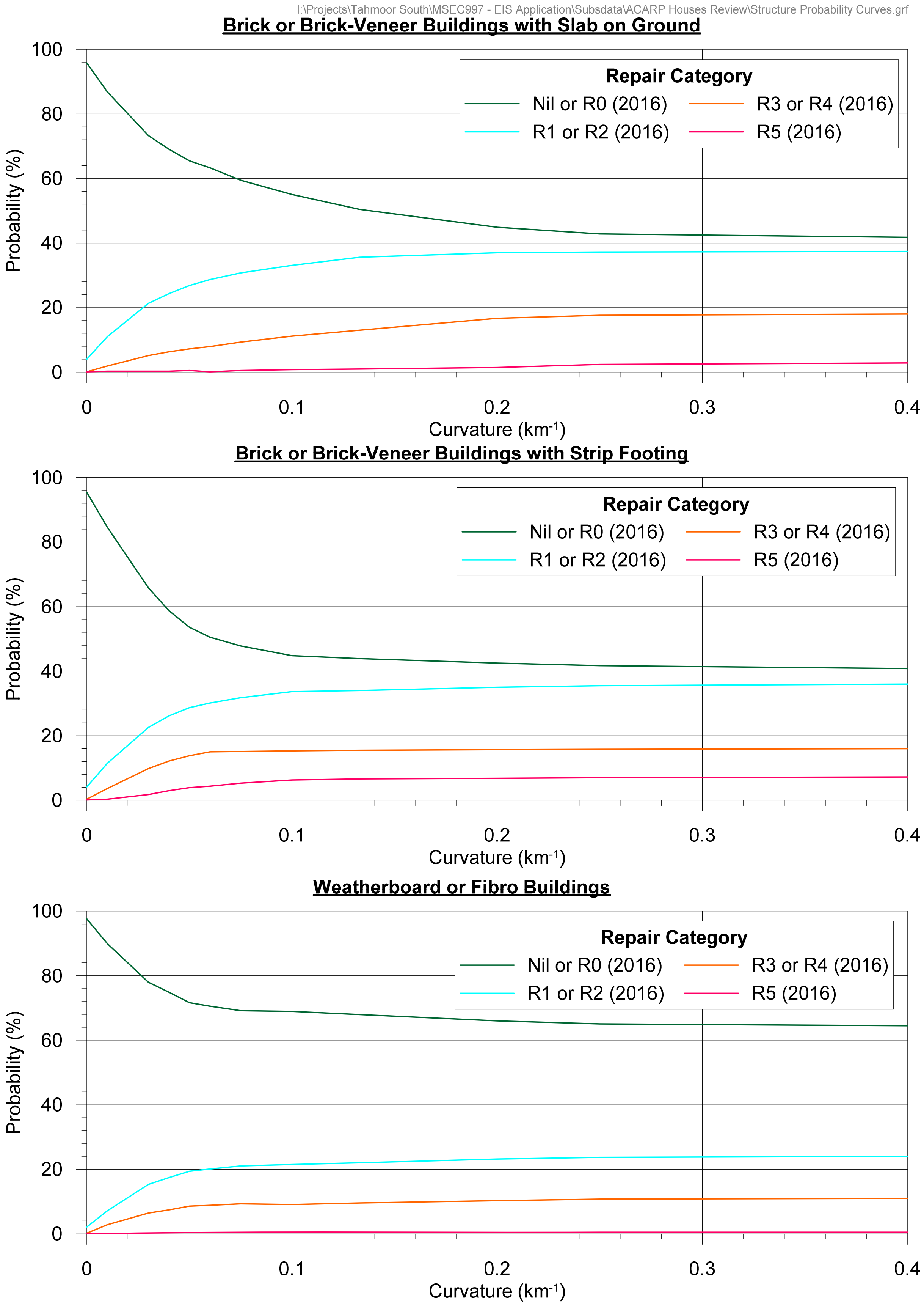

Fig. B.4 Probability Curves for Impacts to Buildings (based on observations up to Longwall 29)

APPENDIX C. FIGURES

Predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 1 due to LW W1-W2

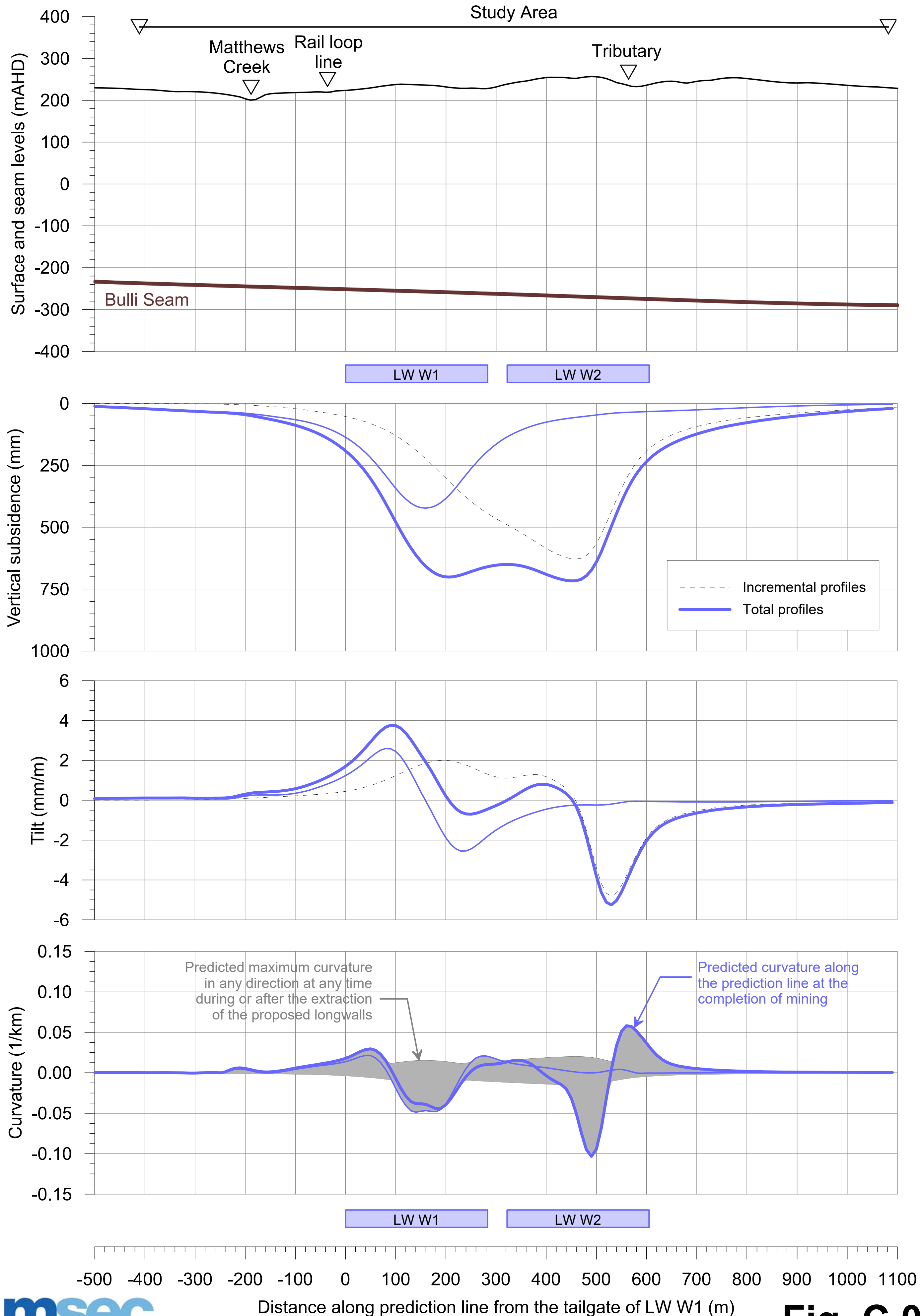

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Fig. C.01

Predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 2 due to LW W1-W2

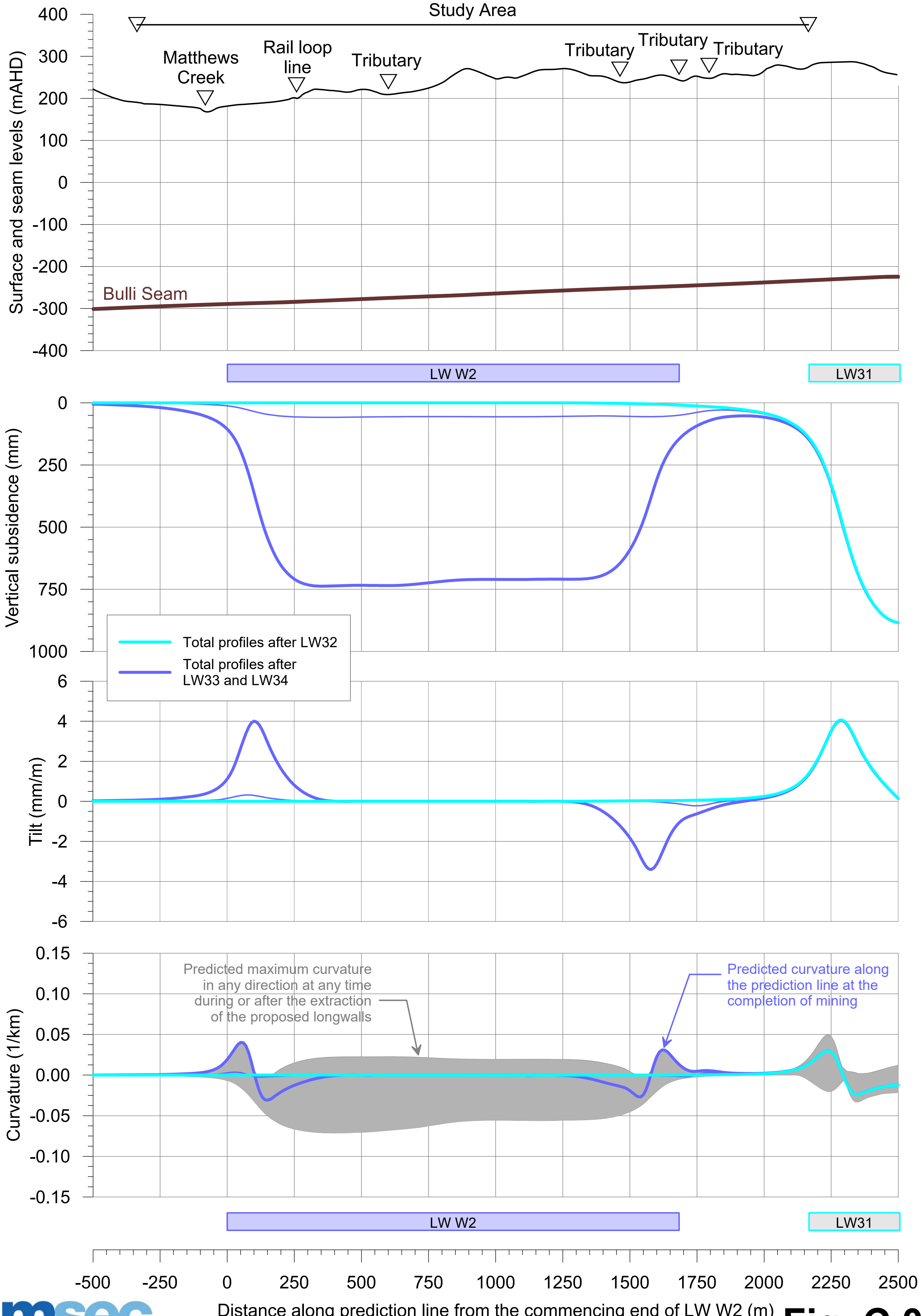

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Fig. C.02

Predicted profiles of vertical subsidence, upsidence and closure along Matthews Creek due to the extraction of LW W1-W2

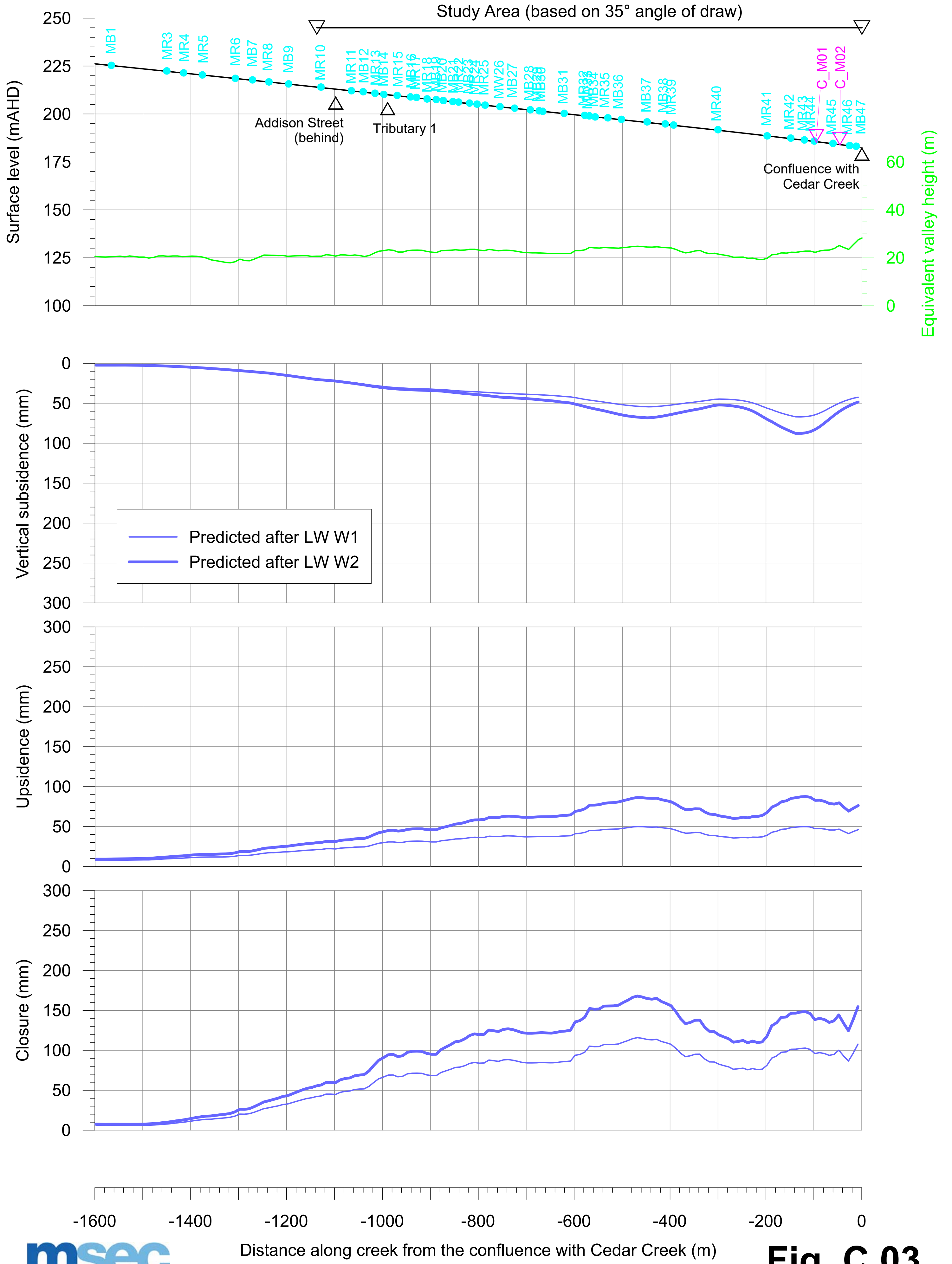

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Fig. C.03

Predicted profiles of vertical subsidence, upsidence and closure along Cedar Creek due to the extraction of LW W1-W2

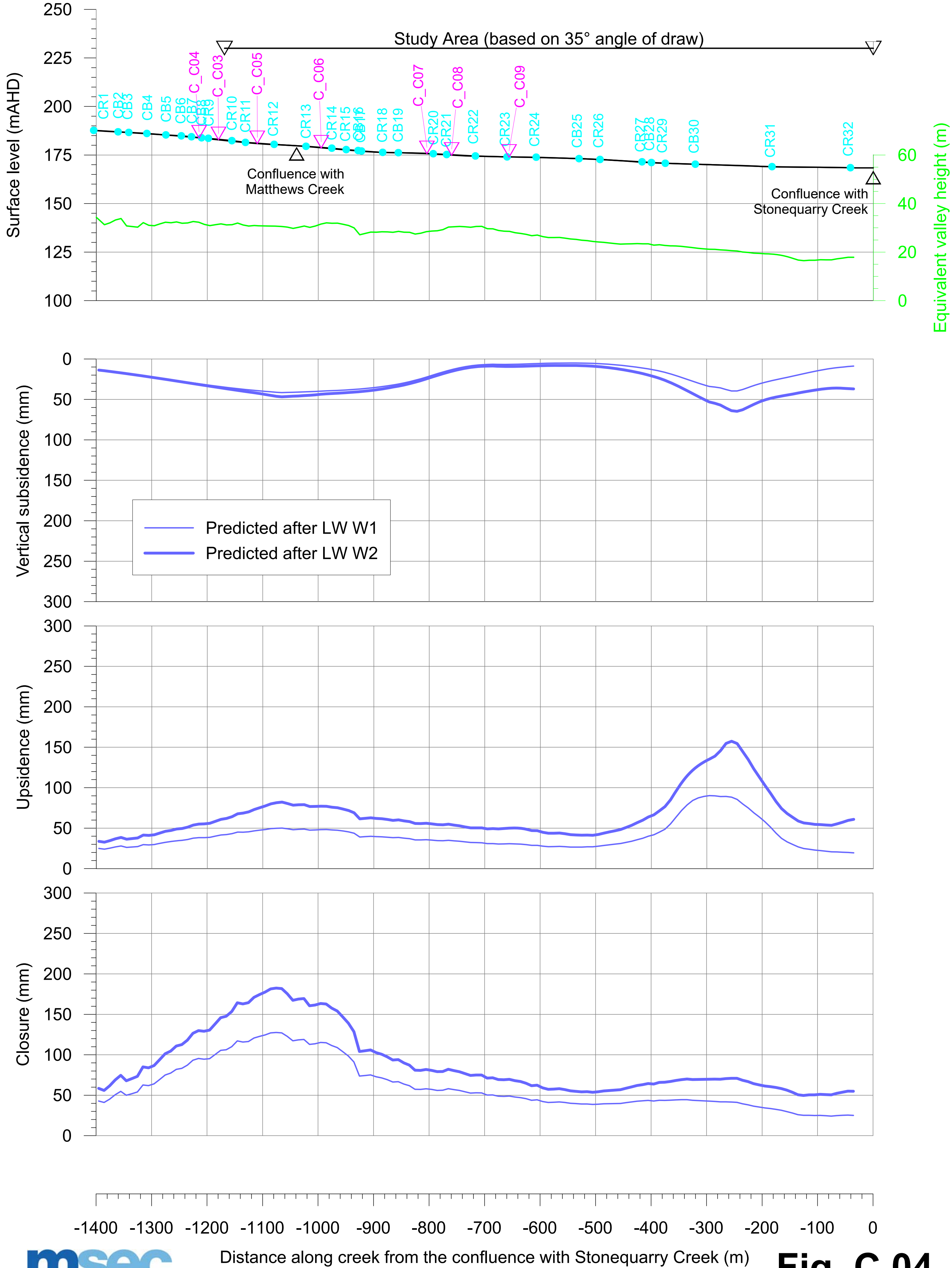

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Fig. C.04

Predicted profiles of vertical subsidence, upsidence and closure along Stonequarry Creek due to the extraction of LW W1-W2

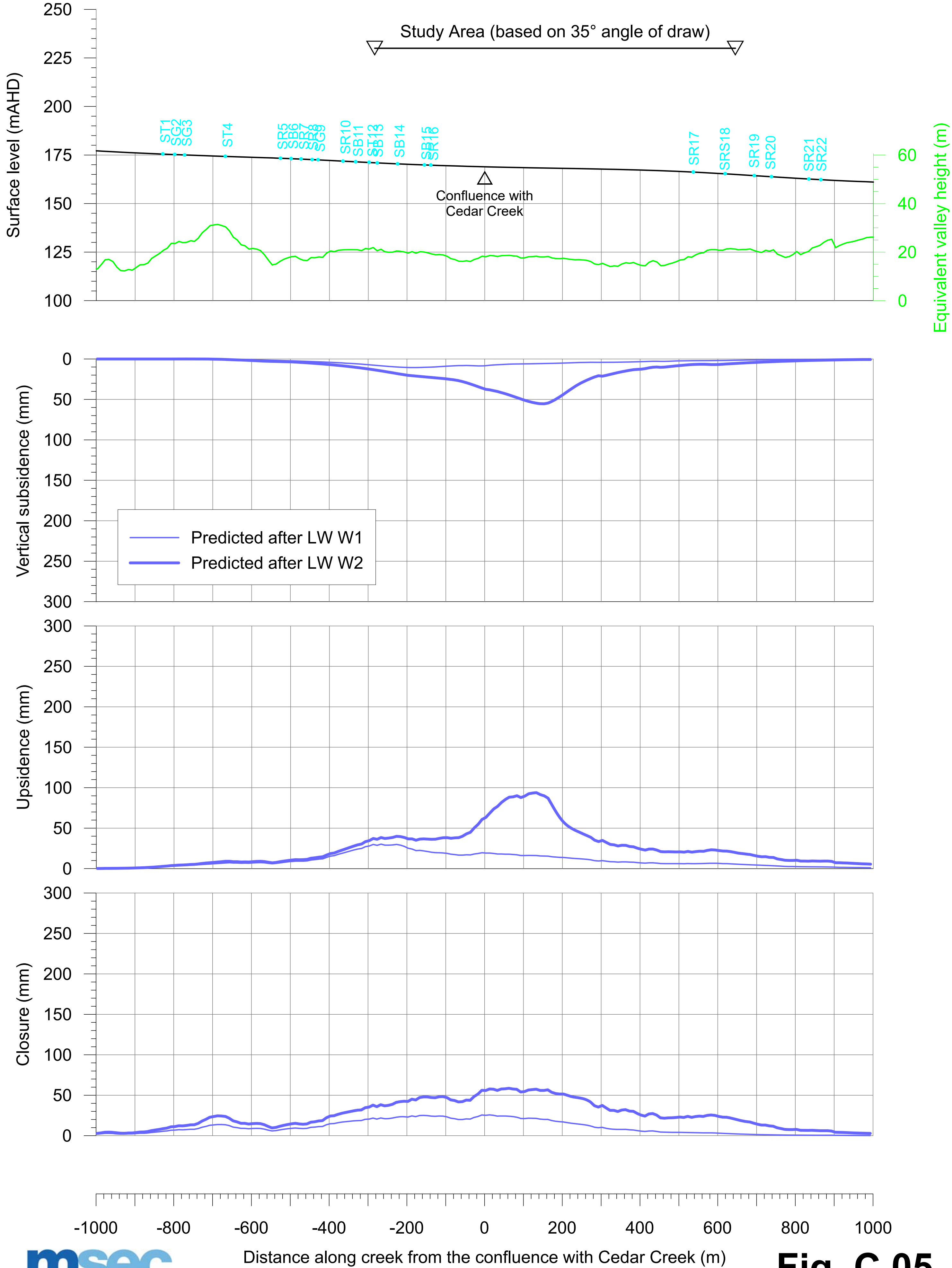

Fig. C.05

Predicted profiles of vertical subsidence, upsidence and closure along Rumker Gully due to the extraction of LW W1-W2

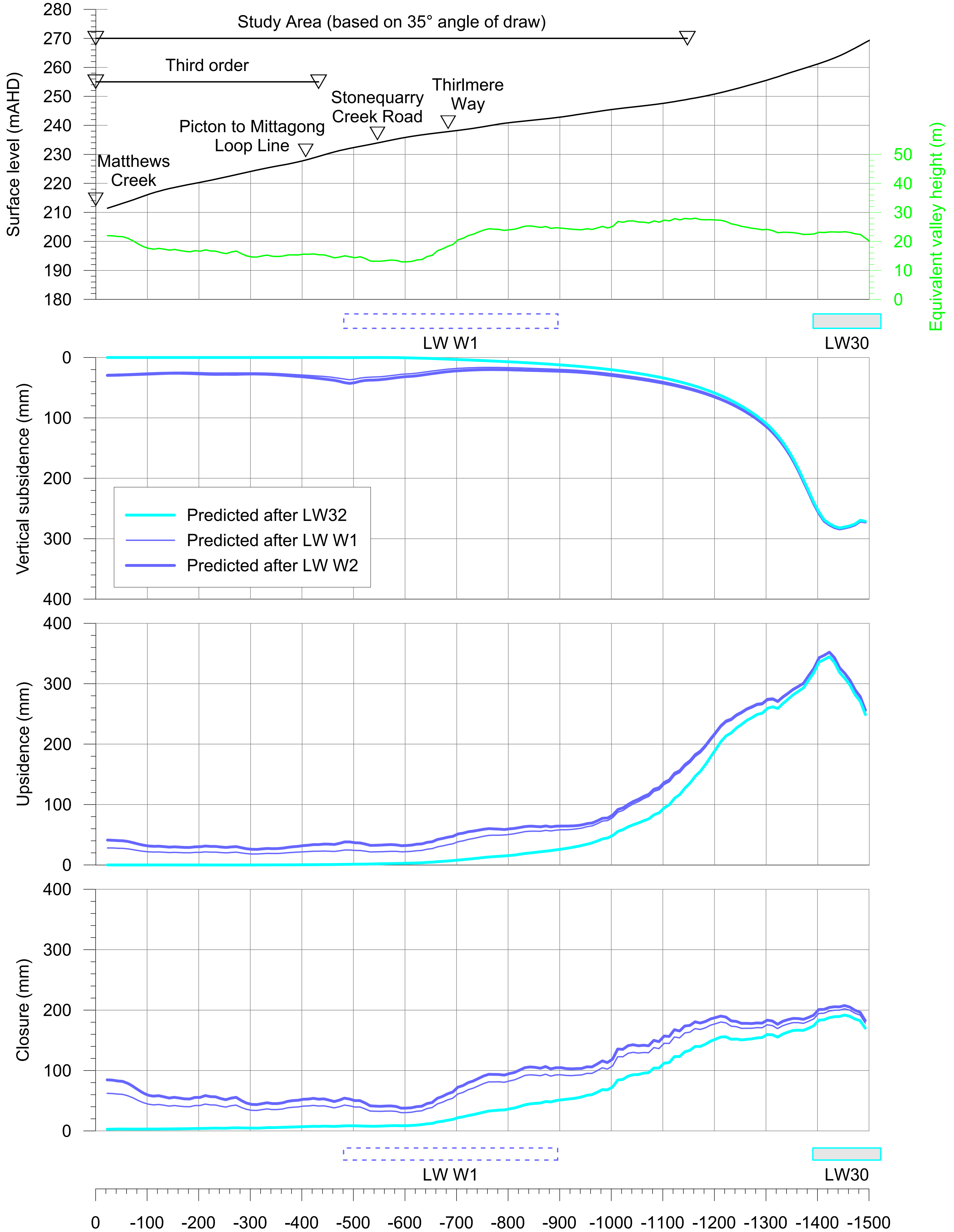

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Fig. C.06

Predicted profiles of vertical subsidence and change in grade along the alignment of the Picton to Mittagong Loop Line due to LW W1-W2

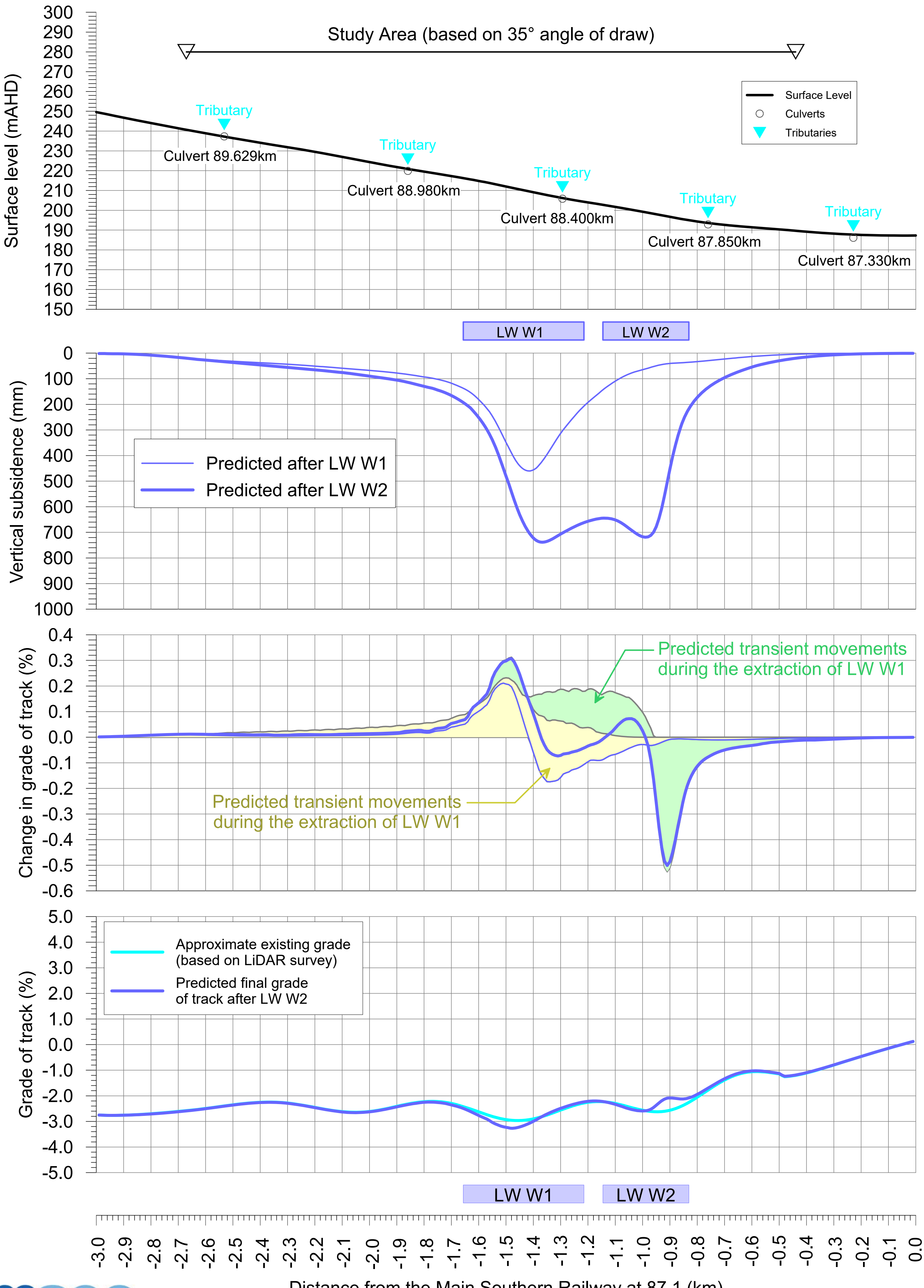

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Fig. C.07

Predicted profiles of horizontal movement, change in cant and long twist across the alignment of the Picton to Mittagong Loop Line due to LW W1-W2

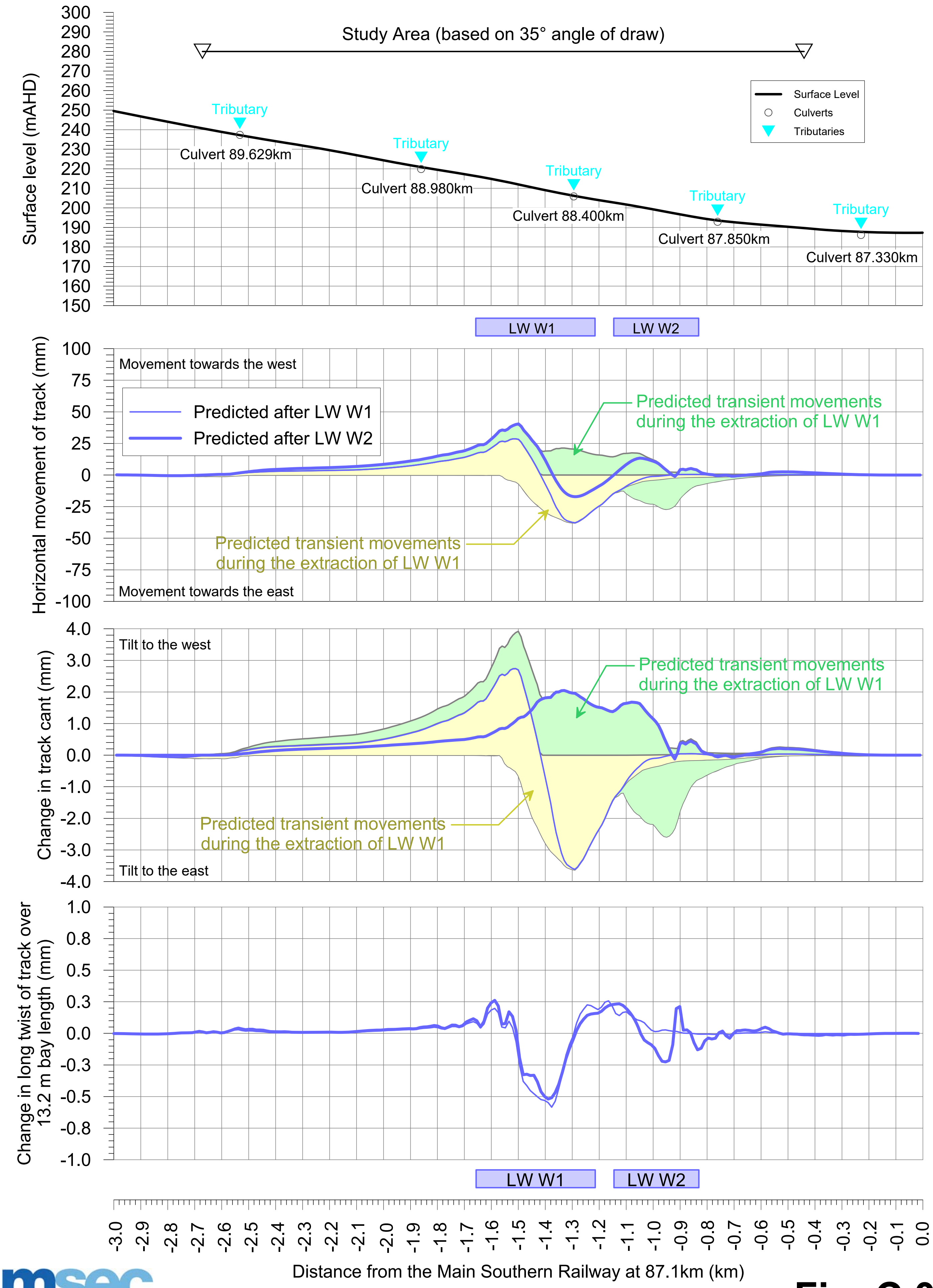

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Fig. C.08

Predicted profiles of vertical subsidence, tilt and curvature along Thirlmere Way due to LW W1-W2

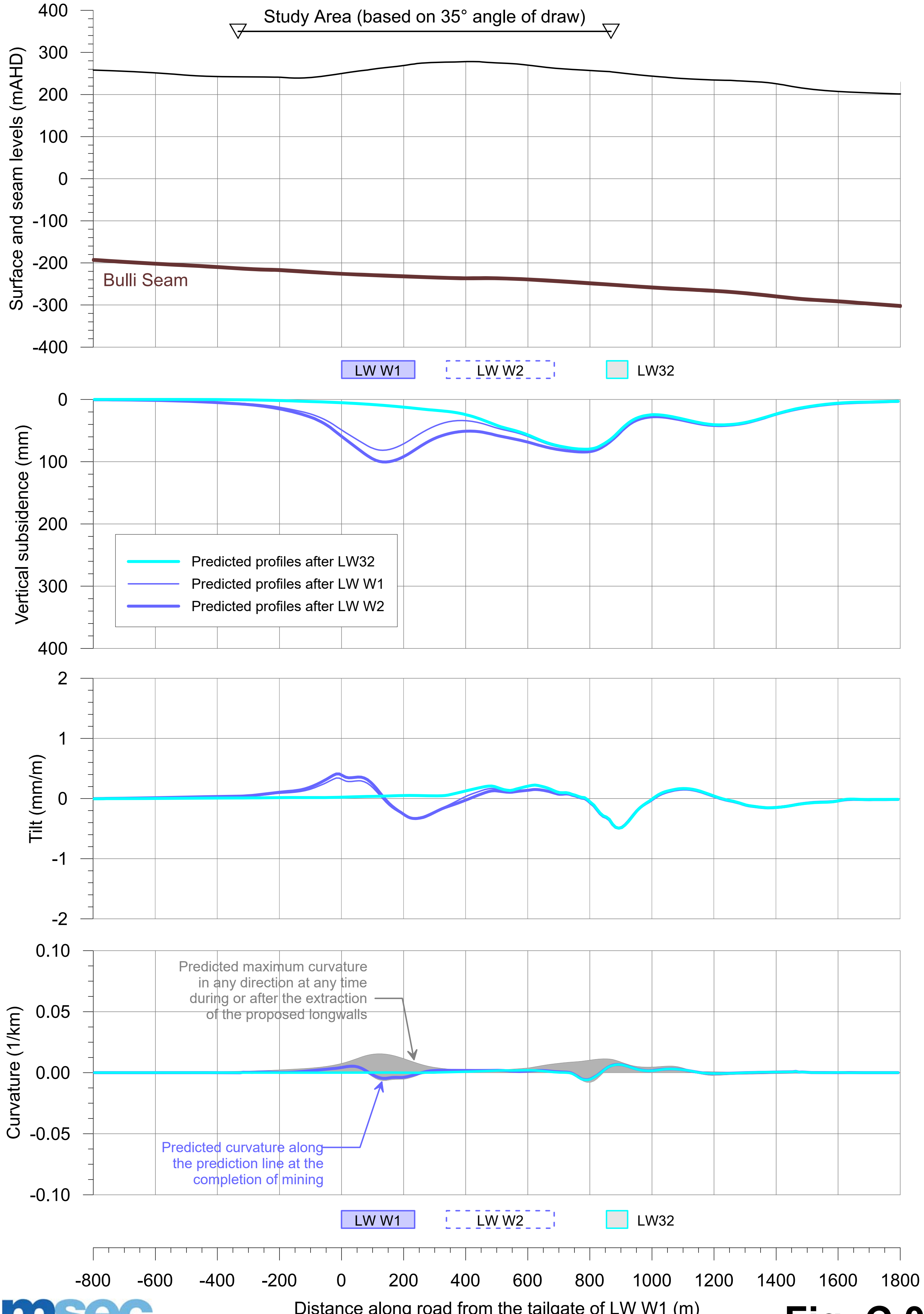

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Fig. C.09

Predicted profiles of vertical subsidence, tilt and curvature along Stonequarry Creek Road due to LW W1-W2

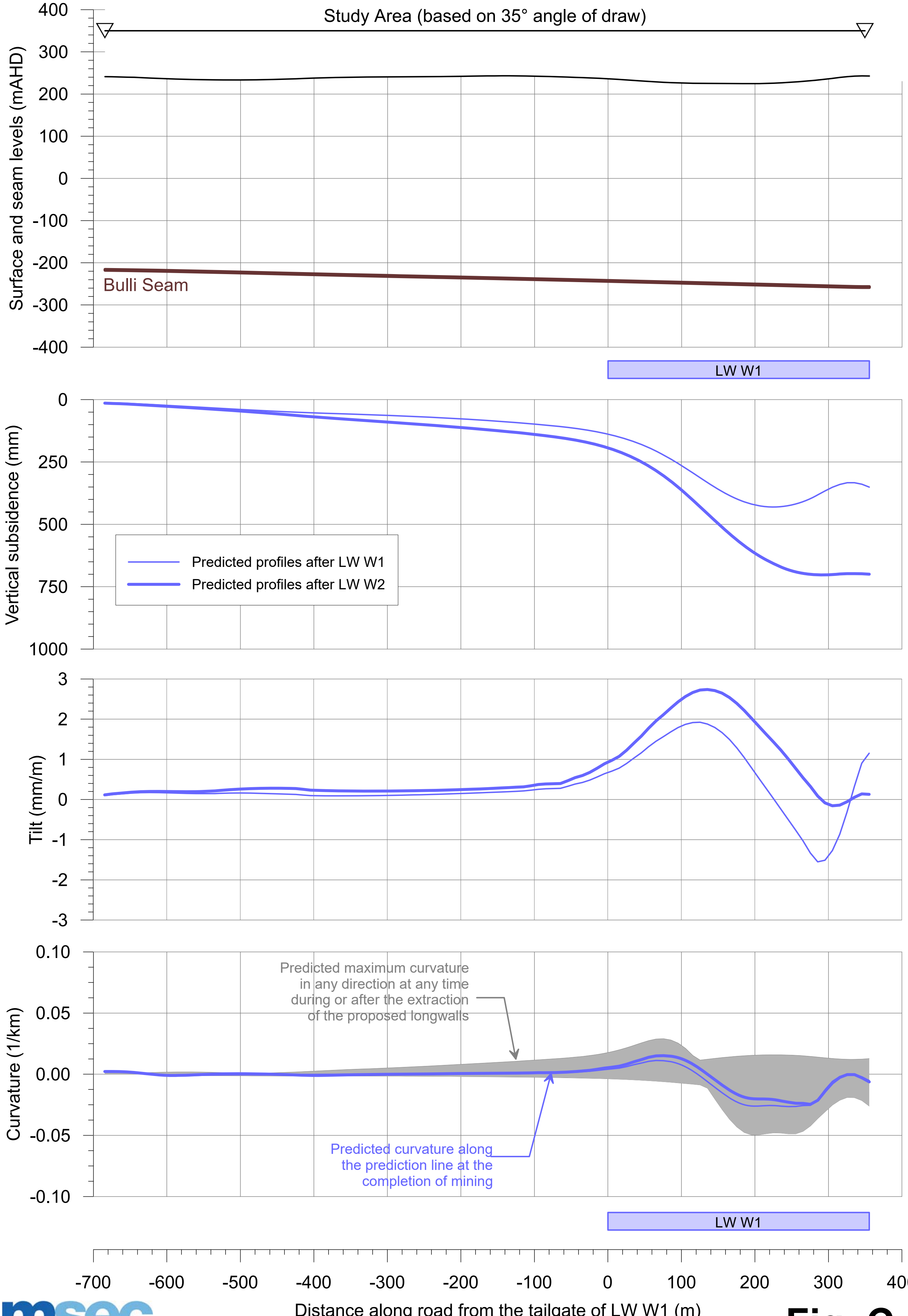

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Fig. C.10

APPENDIX D. TABLES

Table D.01 - Mapped stream features along Matthews Creek

Label	Description	Approximate distance from LW W1-W2 (m)	Predicted total subsidence after LW W1 (mm)	Predicted total subsidence after LW W2 (mm)	Predicted total upsidence after LW W1 (mm)	Predicted total upsidence after LW W2 (mm)	Predicted total closure after LW W1 (mm)	Predicted total closure after LW W2 (mm)
MB1	Boulder Constrained Pool	715	< 20	< 20	< 20	< 20	< 20	< 20
MR3	Rockbar Constrained Pool	670	< 20	< 20	< 20	< 20	< 20	< 20
MR4	Rockbar Constrained Pool	635	< 20	< 20	< 20	< 20	< 20	< 20
MR5	Rockbar Constrained Pool	595	< 20	< 20	< 20	< 20	< 20	< 20
MR6	Rockbar Constrained Pool	535	< 20	< 20	< 20	< 20	20	30
MB7	Boulder Constrained Pool	510	< 20	< 20	< 20	20	30	40
MR8	Rockbar Constrained Pool	480	< 20	< 20	< 20	20	30	40
MB9	Boulder Constrained Pool	445	< 20	< 20	< 20	30	40	50
MR10	Rockbar Constrained Pool	390	20	20	20	30	50	60
MR11	Rockbar Constrained Pool	360	30	30	20	30	50	70
MB12	Boulder Constrained Pool	345	30	30	30	40	60	80
MR13	Rockbar Constrained Pool	325	30	30	30	40	70	90
MB14	Boulder Constrained Pool	310	30	30	30	50	70	90
MR15	Rockbar Constrained Pool	295	30	30	30	50	70	100
MB16	Boulder Constrained Pool	285	30	30	30	50	70	100
MR17	Rockbar Constrained Pool	285	30	30	30	50	70	100
MR18	Rockbar Constrained Pool	285	30	30	30	50	70	100
MB19	Boulder Constrained Pool	285	30	40	30	50	70	100
MB20	Boulder Constrained Pool	280	30	40	30	50	80	110
MB21	Boulder Constrained Pool	270	30	40	30	50	80	110
MR22	Rockbar Constrained Pool	260	40	40	40	60	80	120
MB23	Boulder Constrained Pool	245	40	40	40	60	80	120
MR24	Rockbar Constrained Pool	235	40	40	40	60	80	120
MR25	Rockbar Constrained Pool	225	40	40	40	60	90	130
MW26	Waterfall Rock Bar Constrained Pool	210	40	40	40	60	90	130
MB27	Boulder Constrained Pool	205	40	40	40	60	90	130
MB28	Boulder Constrained Pool	200	40	50	40	60	80	120
MB29	Boulder Constrained Pool	195	40	50	40	60	80	120
MB30	Boulder Constrained Pool	195	40	50	40	60	80	120
MB31	Boulder Constrained Pool	190	40	50	40	70	90	140
MR32	Rockbar Constrained Pool	175	50	60	50	80	110	150
MW33	Waterfall Rock Bar Constrained Pool	175	50	60	50	80	110	150
MB34	Boulder Constrained Pool	170	50	60	50	80	110	160
MR35	Rockbar Constrained Pool	165	50	60	50	80	110	160
MB36	Boulder Constrained Pool	155	50	70	50	90	110	170
MB37	Boulder Constrained Pool	145	50	70	50	90	110	170
MB38	Boulder Constrained Pool	150	50	70	50	80	110	160
MR39	Rockbar Constrained Pool	155	50	60	50	80	110	160
MR40	Rockbar Constrained Pool	180	50	50	40	60	80	120
MR41	Rockbar Constrained Pool	150	60	80	40	80	90	130
MR42	Rockbar Constrained Pool	115	70	90	50	90	100	150
MR43	Rockbar Constrained Pool	110	70	90	50	90	100	150
MR44	Rockbar Constrained Pool	110	60	80	50	80	100	140
MR45	Rockbar Constrained Pool	145	50	70	50	80	100	140
MR46	Rockbar Constrained Pool	180	50	50	50	80	110	150
MB47	Boulder Constrained Pool	195	40	50	50	80	110	160
		Maximum	**70**	**90**	**50**	**90**	**125**	**175**

Table D.02 - Mapped stream features along Cedar Creek

Label	Description	Approximate distance from LW W1-W2 (m)	Predicted total subsidence after LW W1 (mm)	Predicted total subsidence after LW W2 (mm)	Predicted total upsidence after LW W1 (mm)	Predicted total upsidence after LW W2 (mm)	Predicted total closure after LW W1 (mm)	Predicted total closure after LW W2 (mm)
CR1	Rockbar Constrained Pool	530	< 20	< 20	30	30	40	60
CB2	Boulder Constrained Pool	485	< 20	< 20	30	40	50	70
CB3	Boulder Constrained Pool	465	< 20	20	30	40	50	70
CB4	Boulder Constrained Pool	435	20	20	30	40	70	90
CB5	Boulder Constrained Pool	405	30	30	30	50	80	110
CB6	Boulder Constrained Pool	380	30	30	40	50	90	130
CB7	Boulder Constrained Pool	360	30	30	40	60	100	130
CB8	Boulder Constrained Pool	345	30	30	40	60	100	140
CR9	Rockbar Constrained Pool	330	30	40	40	60	110	150
CR10	Rockbar Constrained Pool	290	40	40	50	70	120	160
CR11	Rockbar Constrained Pool	265	40	40	50	70	120	170
CR12	Rockbar Constrained Pool	220	40	50	50	80	130	180
CR13	Rockbar Constrained Pool	225	40	50	50	80	120	170
CR14	Rockbar Constrained Pool	230	40	40	50	80	120	160
CR15	Rockbar Constrained Pool	235	40	40	50	80	110	150
CB16	Boulder Constrained Pool	240	40	40	50	70	100	140
CB17	Boulder Constrained Pool	240	40	40	50	70	100	140
CR18	Rockbar Constrained Pool	245	40	40	40	60	80	110
CB19	Boulder Constrained Pool	245	30	40	40	60	70	100
CR20	Rockbar Constrained Pool	235	20	30	40	60	60	80
CR21	Rockbar Constrained Pool	235	< 20	20	30	50	60	80
CR22	Rockbar Constrained Pool	235	< 20	< 20	30	50	50	80
CR23	Rockbar Constrained Pool	200	< 20	< 20	30	50	50	70
CR24	Rockbar Constrained Pool	165	< 20	< 20	30	50	50	60
CB25	Boulder Constrained Pool	160	< 20	< 20	30	40	40	60
CR26	Rockbar Constrained Pool	160	< 20	< 20	30	50	40	60
CR27	Rockbar Constrained Pool	95	< 20	20	40	70	40	60
CB28	Boulder Constrained Pool	90	< 20	30	50	80	40	70
CR29	Rockbar Constrained Pool	85	20	30	60	100	40	70
CB30	Boulder Constrained Pool	80	30	50	90	130	40	70
CR31	Rockbar Constrained Pool	95	30	50	60	110	40	60
CR32	Rockbar Constrained Pool	125	< 20	40	20	60	30	60
		Maximum	**40**	**50**	**90**	**125**	**125**	**175**

Table D.03 - Mapped stream features along Stonequarry Creek

Label	Description	Approximate distance from LW W1-W2 (m)	Predicted total subsidence after LW W1 (mm)	Predicted total subsidence after LW W2 (mm)	Predicted total upsidence after LW W1 (mm)	Predicted total upsidence after LW W2 (mm)	Predicted total closure after LW W1 (mm)	Predicted total closure after LW W2 (mm)
ST1	Tree Plant Roots Constrained Pool	780	< 20	< 20	< 20	< 20	< 20	< 20
SG2	Gravel Bar Constrained Pool	760	< 20	< 20	< 20	< 20	< 20	< 20
SG3	Gravel Bar Constrained Pool	745	< 20	< 20	< 20	< 20	< 20	< 20
ST4	Tree Plant Roots Constrained Pool	660	< 20	< 20	< 20	< 20	< 20	20
SR5	Rockbar Constrained Pool	545	< 20	< 20	< 20	< 20	< 20	< 20
SB6	Boulder Constrained Pool	520	< 20	< 20	< 20	< 20	< 20	< 20
SR7	Rockbar Constrained Pool	495	< 20	< 20	< 20	< 20	< 20	< 20
SR8	Rockbar Constrained Pool	465	< 20	< 20	< 20	< 20	< 20	< 20
SG9	Gravel Bar Constrained Pool	450	< 20	< 20	< 20	< 20	< 20	20
SR10	Rockbar Constrained Pool	395	< 20	< 20	20	30	< 20	30
SB11	Boulder Constrained Pool	365	< 20	< 20	20	30	< 20	30
ST12	Tree Plant Roots Constrained Pool	335	< 20	< 20	30	40	20	40
SB13	Boulder Constrained Pool	320	< 20	< 20	30	40	20	40
SB14	Boulder Constrained Pool	270	< 20	< 20	30	40	20	40
SB15	Boulder Constrained Pool	220	< 20	20	20	40	30	50
SR16	Rockbar Constrained Pool	210	< 20	20	20	40	30	50
SR17	Rockbar Constrained Pool	240	< 20	< 20	< 20	20	< 20	20
SRS18	Rock Shelf	300	< 20	< 20	< 20	20	< 20	20
SR19	Rockbar Constrained Pool	375	< 20	< 20	< 20	< 20	< 20	< 20
SR20	Rockbar Constrained Pool	420	< 20	< 20	< 20	< 20	< 20	< 20
SR21	Rockbar Constrained Pool	510	< 20	< 20	< 20	< 20	< 20	< 20
SR22	Rockbar Constrained Pool	540	< 20	< 20	< 20	< 20	< 20	< 20
		Maximum	**< 20**	**20**	**30**	**40**	**30**	**50**

Table D.04 - Details of the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Type	Description	Maximum Structure Plan Length (m)	Planar Area (m2)	Houses Number of Storeys	Houses: Single Storey with Length less than 30 metres (H1)	Houses: Single Storey with Length greater than 30 metres (H2)	Houses: Double Storey with Length less than 30 metres (H3)	Houses: Double Storey with Length greater than 30 metres (H4)	House Wall Type: Brick or Brick Veneer	House Wall Type: Weatherboard	House Wall Type: Fibro	House Roof Type: Tiled	House Roof Type: Metal Sheet	House Footing Type: Slab on Ground	House Footing Type: Suspended on Piered Footings	House Footing Type: Suspended on Strip Footings	Other Structures: Rural (R)	Other Structures: Public Amenities (PA)	Other Structures: Public Utilities (PU)	Other Structures: Commerical (C)
PAT_001_h01	277728	6214984	House		52.1	689.7	1		1			1				1	1						
PAT_001_r01	277730	6214967	Rural	Garage	9.3	73.1														1			
PAT_001_r02	277735	6214966	Rural	Shed	4.4	12.8														1			
PAT_001_t01	277735	6215023	Rural	Tank	5.9	27.1														1			
PAT_002_h01	277767	6214976	House		27.0	405.9	1	1				1				1	1	1	1				
PAT_003_h01	277799	6214970	House		27.6	508.4	1	1				1				1		1	1				
PAT_003_r01	277817	6214962	Rural	Garage	0.0	83.3														1			
PAT_004_h01	277857	6214964	House		35.9	344.6	2				1		1			1		1	1				
PAT_006_h01	277972	6215004	House		19.6	271.0	1	1					1			1		1	1				
PAT_006_r01	277957	6215033	Rural	Shed	8.4	52.5														1			
PAT_006_r02	277943	6215026	Rural	Shed	5.6	20.8														1			
PAT_006_r03	277943	6215032	Rural	Shed	5.7	14.4														1			
PAT_006_r04	277946	6215032	Rural	Shed	5.7	18.0														1			
PAT_006_r06	277989	6215035	Rural	Shed	3.5	10.4														1			
PAT_006_r07	277988	6215045	Rural	Shed	12.9	99.6														1			
PAT_006_r08	277937	6215048	Rural	Shed	4.7	13.8														1			
PAT_008_h01	277827	6214897	House		29.5	434.4	1	1				1				1		1	1				
PAT_009_h01	277789	6214889	House		28.7	358.5	1	1				1				1	1						
PAT_010_h01	277711	6214893	House		32.1	551.1	1		1			1				1	1						
PAT_010_r01	277726	6214909	Rural	Garage	10.0	67.8														1			
PBG_001_h01	277921	6215362	House		29.1	477.5	1	1					1			1	1						
PBG_001_h02	277933	6215333	House		23.4	224.5	1	1					1			1	1						
PBG_002_h01	277972	6215315	House		26.5	418.4	2			1		1				1		1	1				
PBG_003_h01	278008	6215271	House		25.2	301.3	1	1				1				1		1	1				
PBG_003_r01	278011	6215301	Rural	Garage	9.6	63.3														1			
PBG_004_h01	277979	6215192	House		29.8	385.7	2			1		1				1		1	1				
PBG_004_r01	277998	6215151	Rural	Shed	4.9	15.0														1			
PBG_005_h01	277942	6215242	House		35.8	464.6	2				1	1				1	1	1	1				
PBG_005_r01	277937	6215224	Rural	Pergola	4.7	21.1														1			
PBG_006_h01	277908	6215247	House		22.8	378.4	2			1			1			1		1	1				
PBG_007_h01	277888	6215277	House		26.7	446.2	1	1				1				1	1						
PBG_008_h01	277850	6215290	House		30.3	441.9	1		1			1				1	1						
PBL_002_p01	278479	6216590	Pool		7.3	25.6																	
PBL_013_h01	278472	6216601	House		17.1	156.4	1	1				1				1	1						
PBL_013_r01	278477	6216596	Rural	Pergola	10.1	30.1														1			
PBL_013_r02	278466	6216581	Rural	Garage	13.2	110.6														1			
PBL_013_r03	278471	6216570	Rural	Shed	6.2	24.7														1			
PBL_013_r04	278466	6216569	Rural	Shed	4.3	14.1														1			

Table D.04 - Details of the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Type	Description	Maximum Structure Plan Length (m)	Planar Area (m2)	Houses Number of Storeys	Houses				House Wall Type			House Roof Type		House Footing Type			Other Structures			
								Single Storey with Length less than 30 metres	Single Storey with Length greater than 30 metres	Double Storey with Length less than 30 metres	Double Storey with Length greater than 30 metres	Brick or Brick Veneer	Weatherboard	Fibro	Tiled	Metal Sheet	Slab on Ground	Suspended on Piered Footings	Suspended on Strip Footings	Rural	Public Amenities	Public Utilities	Commerical
								H1	H2	H3	H4									R	PA	PU	C
PBL_013_r05	278492	6216561	Rural	Shed	6.1	14.3														1			
PBL_013_r06	278470	6216574	Rural	Shed	5.8	13.8														1			
PBL_013_r07	278436	6216625	Rural	Shed	4.8	12.4														1			
PBL_013_t01	278472	6216564	Rural	Tank	2.5	5.1														1			
PBL_013_t02	278472	6216562	Rural	Tank	1.3	1.4														1			
PBL_013_t03	278483	6216602	Rural	Tank	3.2	7.9														1			
PBL_017_h01	278267	6216650	House		12.0	122.2	1	1					1			1		1					
PBL_017_r02	278265	6216642	Rural	Pergola	10.2	33.4														1			
PBL_017_r03	278294	6216607	Rural	Shed	5.3	18.6														1			
PBL_017_r04	278233	6216633	Rural	Shed	7.8	55.4														1			
PBL_017_r06	278191	6216667	Rural	Shed	6.2	32.3														1			
PBL_017_r07	278191	6216672	Rural	Shed	3.9	11.0														1			
PBL_017_r08	278180	6216670	Rural	Shed	6.2	25.6														1			
PBL_017_r09	278175	6216671	Rural	Shed	9.3	44.2														1			
PBL_017_r10	278281	6216638	Rural	Garage	16.7	105.7														1			
PBL_017_t01	278259	6216644	Rural	Tank	2.7	5.7														1			
PBL_017_t02	278259	6216642	Rural	Tank	2.7	5.7														1			
PBL_017_t03	278238	6216630	Rural	Tank	2.7	5.7														1			
PBL_017_t04	278169	6216654	Rural	Tank	5.7	25.3														1			
PBL_025_h01	278069	6216687	House		20.8	239.5	1	1					1			1		1	1				
PBL_025_p01	278049	6216670	Pool		9.8	36.0																	
PBL_025_r01	278064	6216657	Rural	Shed	19.1	215.0														1			
PBL_025_r02	278091	6216631	Rural	Shed	24.9	521.8														1			
PBL_025_r03	278091	6216669	Rural	Shed	6.5	41.3														1			
PBL_025_r04	278045	6216693	Rural	Shed	9.6	56.2														1			
PBL_025_t01	278050	6216700	Rural	Tank	7.7	46.0														1			
PBL_025_t02	278050	6216638	Rural	Tank	3.0	7.2														1			
PBL_025_t03	278048	6216635	Rural	Tank	3.0	7.2														1			
PCA_001_h01	277693	6214828	House		25.8	324.6	1	1				1				1		1	1				
PCA_001_r01	277713	6214814	Rural	Garage	9.2	69.7														1			
PCA_001_r02	277690	6214839	Rural	Pergola	7.0	25.0														1			
PCA_001_r03	277705	6214822	Rural	Awning	6.2	16.7														1			
PCA_001_r04	277708	6214818	Rural	Awning	5.4	8.1														1			
PCA_002_h01	277754	6214811	House		34.3	481.1	1		1			1				1		1	1				
PCA_002_p01	277760	6214826	Pool		9.4	40.4																	
PCA_002_r01	277737	6214831	Rural	Garage	9.8	71.6														1			
PCA_002_r02	277751	6214821	Rural	Pergola	8.7	39.7														1			
PCA_003_h01	277821	6214805	House		35.3	482.4	2				1	1				1		1	1				

Table D.04 - Details of the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Type	Description	Maximum Structure Plan Length (m)	Planar Area (m2)	Houses Number of Storeys	Houses				House Wall Type			House Roof Type		House Footing Type			Other Structures			
								Single Storey with Length less than 30 metres	Single Storey with Length greater than 30 metres	Double Storey with Length less than 30 metres	Double Storey with Length greater than 30 metres	Brick or Brick Veneer	Weatherboard	Fibro	Tiled	Metal Sheet	Slab on Ground	Suspended on Piered Footings	Suspended on Strip Footings	Rural	Public Amenities	Public Utilities	Commerical
								H1	H2	H3	H4									R	PA	PU	C
PCA_003_p01	277806	6214821	Pool		6.8	23.1																	
PCA_003_r01	277815	6214810	Rural	Pergola	7.0	18.8														1			
PCA_004_h01	277904	6214804	House		20.6	321.8	2			1		1			1		1						
PCA_004_r01	277962	6214834	Rural	Shed	14.3	92.2														1			
PCA_004_t01	277884	6214825	Rural	Tank	8.7	59.3														1			
PCA_006_h01	277853	6214694	House		26.8	310.4	1	1				1	1			1		1	1				
PCA_007_h01	277813	6214707	House		27.4	408.4	1	1				1				1	1						
PCA_007_p01	277823	6214695	Pool		9.0	35.4																	
PCA_007_r01	277804	6214687	Rural	Shed	12.2	86.7														1			
PCA_008_h01	277770	6214730	House		27.8	507.3	1	1				1				1	1						
PCA_008_r01	277783	6214691	Rural	Shed	10.3	75.0														1			
PCA_009_h01	277719	6214738	House		31.2	810.5	1		1			1				1	1						
PCA_009_p01	277734	6214723	Pool		9.6	50.8																	
PCA_009_p02	277738	6214724	Pool		1.6	2.0																	
PCA_009_r01	277739	6214738	Rural	Shed	4.8	10.8														1			
PSC_001_h01	277548	6214624	House		28.8	456.0	1	1				1				1	1						
PSC_002_h01	277556	6214660	House		26.3	368.1	1	1				1			1		1						
PSC_002_r01	277562	6214677	Rural	Garage	10.8	78.8														1			
PSC_002_r02	277547	6214672	Rural	Pergola	8.7	50.8														1			
PSC_002_r03	277550	6214666	Rural	Pergola	3.9	10.7														1			
PSC_002_r04	277522	6214682	Rural	Garage	11.5	85.2														1			
PSC_002_r05	277521	6214672	Rural	Carport	8.0	48.1														1			
PSC_002_r06	277510	6214656	Rural	Shed	5.8	17.2														1			
PSC_003_h01	277568	6214722	House		31.4	364.3	1		1			1				1	1						
PSC_003_r01	277544	6214708	Rural	Garage	15.1	130.3														1			
PSC_003_r02	277535	6214714	Rural	Shed	4.5	12.5														1			
PSC_003_r03	277534	6214731	Rural	Shed	3.1	5.9														1			
PSC_005_h01	277612	6214834	House		44.5	730.8	1		1			1				1		1	1				
PSC_005_p01	277604	6214833	Pool		6.9	19.3																	
PSC_005_r01	277613	6214853	Rural	Garage	10.8	93.7														1			
PSC_006_h01	277633	6214889	House		43.2	627.9	1		1			1				1		1					
PSC_006_p01	277622	6214886	Pool		9.1	31.5																	
PSC_006_r01	277602	6214883	Rural	Garage	11.6	95.4														1			
PSC_006_r02	277624	6214874	Rural	Pergola	8.8	30.2														1			
PSC_006_r03	277628	6214889	Rural	Pergola	4.2	16.9														1			
PSC_006_r04	277622	6214908	Rural	Pergola	7.8	24.9														1			
PSC_007_h01	277645	6214940	House		26.0	444.8	1	1				1				1	1						
PSC_007_p01	277628	6214954	Pool		9.1	31.5																	

Table D.04 - Details of the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Type	Description	Maximum Structure Plan Length (m)	Planar Area (m2)	Houses Number of Storeys	Houses				House Wall Type			House Roof Type		House Footing Type			Other Structures			
								Single Storey with Length less than 30 metres	Single Storey with Length greater than 30 metres	Double Storey with Length less than 30 metres	Double Storey with Length greater than 30 metres	Brick or Brick Veneer	Weatherboard	Fibro	Tiled	Metal Sheet	Slab on Ground	Suspended on Piered Footings	Suspended on Strip Footings	Rural	Public Amenities	Public Utilities	Commerical
								H1	H2	H3	H4									R	PA	PU	C
PSC_007_r01	277645	6214922	Rural	Garage	9.0	74.6	2													1			
PSC_007_r02	277619	6214955	Rural	Poolhouse	11.9	96.2														1			
PSC_007_r03	277642	6214925	Rural	Awning	12.8	44.8														1			
PSC_007_r04	277650	6214921	Rural	Awning	6.6	17.0														1			
PSC_007_r05	277629	6214941	Rural	Pergola	9.0	42.1														1			
PSC_007_r06	277631	6214961	Rural	Shed	4.3	11.1														1			
PSC_008_h01	277663	6215000	House		29.7	409.5	1	1				1			1		1						
PSC_008_p01	277646	6215013	Pool		8.7	30.3																	
PSC_008_r01	277659	6215002	Rural	Pergola	12.9	75.2														1			
PSC_008_r02	277640	6215020	Rural	Shed	4.8	24.2														1			
PSC_009_h01	277677	6215052	House		16.1	221.1	2			1		1				1	1						
PSC_009_r01	277674	6215039	Rural	Garage	9.8	69.8														1			
PSC_009_r02	277670	6215057	Rural	Pergola	8.5	30.0														1			
PSC_009_r03	277638	6215073	Rural	Shed	2.1	4.1														1			
PSC_009_t01	277656	6215030	Rural	Tank	2.4	4.6														1			
PSC_010_h01	277694	6215100	House		31.5	403.1	1		1			1				1	1						
PSC_010_p01	277672	6215111	Pool		9.7	33.2																	
PSC_010_r01	277677	6215090	Rural	Garage	9.2	72.2														1			
PSC_010_r02	277687	6215103	Rural	Pergola	12.0	75.8														1			
PSC_010_r03	277672	6215094	Rural	Tank	2.2	3.9														1			
PSC_011_h01	277700	6215138	House		24.7	366.3	1	1				1				1		1	1				
PSC_011_p01	277676	6215152	Pool		9.7	47.6																	
PSC_011_r01	277701	6215146	Rural	Pergola	15.7	56.9														1			
PSC_011_r02	277685	6215154	Rural	Shed	9.0	47.8														1			
PSC_011_r03	277679	6215159	Rural	Awning	6.1	19.3														1			
PSC_012_h01	277709	6215196	House		30.7	475.8	1		1			1				1	1						
PSC_012_p01	277685	6215202	Pool		11.2	38.9																	
PSC_012_r01	277716	6215174	Rural	Garage	7.1	44.1														1			
PSC_013_h01	277722	6215234	House		28.8	423.4	2			1		1				1		1	1				
PSC_014_h01	277761	6215295	House		28.9	463.3	2			1		1				1		1	1				
PSC_014_r01	277742	6215271	Rural	Garage	10.5	74.7														1			
PSC_014_r02	277738	6215288	Rural	Gazebo	8.8	68.7														1			
PSC_015_h01	277709	6215321	House		40.8	455.3	1		1			1				1	1						
PSC_016_h01	277722	6215386	House		23.3	359.1	1	1					1			1		1	1				
PSC_016_r01	277712	6215370	Rural	Garage	7.2	47.3														1			
PSC_016_r02	277712	6215376	Rural	Awning	5.6	17.3														1			
PSC_016_r03	277718	6215414	Rural	Shed	3.8	6.4														1			
PSC_016_r04	277716	6215424	Rural	Shed	6.7	44.1														1			

Table D.04 - Details of the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Type	Description	Maximum Structure Plan Length (m)	Planar Area (m2)	Houses Number of Storeys	Houses				House Wall Type			House Roof Type		House Footing Type			Other Structures			
								Single Storey with Length less than 30 metres (H1)	Single Storey with Length greater than 30 metres (H2)	Double Storey with Length less than 30 metres (H3)	Double Storey with Length greater than 30 metres (H4)	Brick or Brick Veneer	Weatherboard	Fibro	Tiled	Metal Sheet	Slab on Ground	Suspended on Piered Footings	Suspended on Strip Footings	Rural (R)	Public Amenities (PA)	Public Utilities (PU)	Commerical (C)
PSC_017_h01	277770	6215377	House		33.9	423.2	1		1			1			1		1						
PSC_017_r01	277751	6215364	Rural	Garage	18.7	124.4														1			
PSC_018_h01	277815	6215349	House		29.1	585.3	1	1				1				1	1						
PSC_020_h01	278000	6215430	House		31.0	262.2	1		1				1			1		1	1				
PSC_020_h02	278011	6215439	House		28.0	181.1	1	1					1			1		1	1				
PSC_021_h01	277975	6215371	House		25.9	345.4	1	1				1				1		1	1				
PSC_021_r01	277982	6215354	Rural	Garage	7.9	58.8														1			
PSC_022_h01	277778	6215153	House		32.6	462.7	2				1	1				1	1						
PSC_022_r01	277759	6215117	Rural	Tank	5.4	23.2														1			
PSC_023_h01	277835	6215145	House		28.4	518.8	1	1				1				1		1	1				
PSC_023_r01	277820	6215098	Rural	Shed	8.8	76.3														1			
PSC_024_h01	277762	6215064	House		32.8	587.8	1		1				1			1	1						
PSC_024_r01	277776	6215047	Rural	Garage	13.1	95.7														1			
PSC_025_h01	277658	6214761	House		32.1	362.2	1		1			1				1	1						
PSC_025_p01	277674	6214762	Pool		14.6	77.3																	
PSC_025_r01	277654	6214738	Rural	Garage	9.6	60.4														1			
PSC_025_r02	277659	6214729	Rural	Garage	7.2	48.7														1			
PSC_025_r03	277685	6214721	Rural	Shed	3.4	8.9														1			
PSC_026_h01	277653	6214695	House		30.0	543.7	1	1				1			1			1	1				
PSC_027_h01	277648	6214652	House		35.8	466.4	1		1			1				1	1						
PSC_027_p01	277672	6214660	Pool		8.5	28.0																	
PSC_027_r01	277653	6214651	Rural	Pergola	6.4	32.4														1			
PSC_027_r02	277667	6214638	Rural	Shed	3.8	11.4														1			
PSC_027_r03	277678	6214661	Rural	Shed	5.5	17.3														1			
PSC_090_pu01	278547	6216190	Public Utility	Shed	5.2	22.5																1	
PSC_090_pu02	278540	6216186	Public Utility	Tank	8.5	57.5																1	
PSC_090_pu03	278542	6216177	Public Utility	Tank	8.5	57.5																1	
PSC_090_pu04	278544	6216168	Public Utility	Tank	8.5	57.5																1	
PSC_090_pu05	278551	6216187	Public Utility	Tank	3.3	8.5																1	
PSC_090_pu06	278547	6216186	Public Utility	Tank	3.3	8.5																1	
PSC_090_pu07	278548	6216182	Public Utility	Tank	3.3	8.5																1	
PSC_090_pu08	278549	6216178	Public Utility	Tank	3.3	8.5																1	
PSC_090_pu09	278550	6216175	Public Utility	Tank	3.3	8.5																1	
PSC_090_pu10	278551	6216171	Public Utility	Tank	3.3	8.5																1	
PSC_090_pu11	278542	6216218	Public Utility	Tank	8.5	57.5																1	
PSC_090_pu12	278535	6216210	Public Utility	Tank	8.5	57.5																1	
PSC_090_pu13	278567	6216240	Public Utility	Shed	3.0	3.6																1	
PSC_091_r01	278472	6216406	Rural	Shed	9.2	84.9														1			

Table D.04 - Details of the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Type	Description	Maximum Structure Plan Length (m)	Planar Area (m2)		Houses				House Wall Type			House Roof Type		House Footing Type			Other Structures			
							Houses Number of Storeys	Single Storey with Length less than 30 metres	Single Storey with Length greater than 30 metres	Double Storey with Length less than 30 metres	Double Storey with Length greater than 30 metres	Brick or Brick Veneer	Weatherboard	Fibro	Tiled	Metal Sheet	Slab on Ground	Suspended on Piered Footings	Suspended on Strip Footings	Rural	Public Amenities	Public Utilities	Commerical
								H1	H2	H3	H4									R	PA	PU	C
PSC_091_r02	278492	6216419	Rural	Shed	11.5	59.0														1			
PSC_092_h01	278429	6216451	House		13.1	91.5	1	1					1			1		1	1				
PSC_092_t01	278423	6216459	Rural	Tank	2.2	4.0														1			
PTH_001_h01	278017	6214640	House		23.0	216.7	2			1			1			1		1	1				
PTH_001_p01	278006	6214654	Pool		6.7	20.4																	
PTH_001_r01	278020	6214658	Rural	Garage	14.1	148.1														1			
PTH_001_r02	278036	6214612	Rural	Shed	6.7	29.0														1			
PTH_001_r03	277992	6214667	Rural	Shed	3.1	7.7														1			
PTH_031_r01	278352	6215105	Rural	Shed	18.9	178.8														1			
PTH_031_r02	278374	6215090	Rural	Shed	14.7	180.7														1			
PTH_031_r03	278394	6215056	Rural	Shed	19.0	169.9														1			
PTH_031_r04	278415	6215040	Rural	Shed	3.9	12.6														1			
PTH_031_r05	278422	6215034	Rural	Shed	11.0	53.8														1			
PTH_031_r06	278430	6215072	Rural	Shed	11.6	105.8														1			
PTH_031_r07	278422	6215061	Rural	Shed	11.1	47.5														1			
PTH_031_r08	278412	6215066	Rural	Shed	5.3	24.0														1			
PTH_031_r09	278382	6215087	Rural	Awning	14.7	77.1														1			
PTH_031_t01	278420	6215073	Rural	Tank	5.7	25.4														1			
PTH_031_t02	278404	6215056	Rural	Tank	2.6	5.3														1			
PTH_031_t04	278370	6215103	Rural	Tank	2.6	5.3														1			
PTH_055_h01	278604	6214939	House		22.9	290.9	1	1				1	1			1		1	1				
PTH_055_r01	278577	6214930	Rural	Shed	7.1	49.5														1			
PTH_080_r01	278661	6214817	Rural	Shed	3.1	9.4														1			
TAD_005_r04	277365	6215596	Rural	Shed	11.5	51.3														1			
TAD_010_h01	277370	6215244	House		26.8	341.7	1	1				1			1		1						
TTH_023_h01	277472	6214622	House		33.6	453.0	1		1				1			1		1	1				
TTH_023_r01	277493	6214643	Rural	Garage	9.2	82.2														1			
V04a	277559	6214316	Public Amenity	Aged Care	60.6	1893.5															1		
V04ag	277716	6214247	Public Amenity	Aged Care	6.3	28.8															1		
V04b	277653	6214267	Public Amenity	Aged Care	49.4	878.1															1		
V04bh	277595	6214334	Public Amenity	Aged Care	7.3	23.4															1		
V05a	278182	6214426	House		23.7	282.4	1	1				1			1			1	1				
V05c	278168	6214410	Rural	Tank	7.9	49.4														1			
V05d	278188	6214436	Rural	Carport	4.8	18.7														1			
V05e	278172	6214403	Rural	Shed	2.6	6.4														1			
V05f	278179	6214423	Rural	Pergola	3.7	10.2														1			
V05g	278188	6214408	Rural	Shed	9.4	43.8														1			
V05h	278166	6214431	Rural	Tank	2.2	4.0														1			

Table D.04 - Details of the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Type	Description	Maximum Structure Plan Length (m)	Planar Area (m2)	Houses Number of Storeys	Houses				House Wall Type			House Roof Type		House Footing Type			Other Structures			
								Single Storey with Length less than 30 metres	Single Storey with Length greater than 30 metres	Double Storey with Length less than 30 metres	Double Storey with Length greater than 30 metres	Brick or Brick Veneer	Weatherboard	Fibro	Tiled	Metal Sheet	Slab on Ground	Suspended on Piered Footings	Suspended on Strip Footings	Rural	Public Amenities	Public Utilities	Commerical
								H1	H2	H3	H4									R	PA	PU	C
V06a	278230	6214365	House		23.1	339.8	1	1					1			1		1	1				
V06b	278237	6214343	Rural	Shed	6.1	25.5														1			
V06c	278229	6214311	Rural	Shed	20.2	189.7														1			
V06e	278242	6214307	Rural	Tank	3.0	7.2														1			
V06h	278230	6214351	Rural	Well	4.0	12.5														1			
V06k	278249	6214396	Rural	Tank	7.1	39.6														1			
V15a	278592	6214524	House		43.1	630.8	1		1			1			1		1						
V15b	278554	6214493	Rural	Shed	23.3	200.1														1			
V15c	278564	6214487	Rural	Shed	19.4	97.1														1			
V15d	278560	6214512	Rural	Tank	7.9	49.2														1			
V15e	278585	6214532	Rural	Carport	8.2	54.8														1			
V15f	278576	6214518	Rural	Pergola	16.9	116.9														1			
V15g	278560	6214523	Rural	Tank	2.6	5.4														1			
							No.	32	18	8	4	47	17	0	8	54	31	33	31	145	4	13	0

Table D.05 - Predicted subsidence effects for the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Structure Type	Predicted total subsidence after LW W1 (mm)	Predicted total subsidence after LW W2 (mm)	Predicted total tilt after LW W1 (mm/m)	Predicted total tilt after LW W2 (mm/m)	Predicted total hogging curvature after LW W1 (1/km)	Predicted total hogging curvature after LW W2 (1/km)	Predicted total sagging curvature after LW W1 (1/km)	Predicted total sagging curvature after LW W2 (1/km)	Predicted mean total tensile strain (mm/m)	Predicted 95% CL for total tensile strain (mm/m)	Predicted mean total comp. strain (mm/m)	Predicted 95% CL for total comp. strain (mm/m)	Predicted Probability of Nil or Category R0 Impact for Houses (%)	Predicted Probability of Category R1 or R2 Impact for Houses (%)	Predicted Probability of Category R3 and R4 Impact for Houses (%)	Predicted Probability of Category R5 Impact for Houses (%)
PAT_001_h01	277728	6214984	House	100	150	1.0	1.0	< 0.01	0.01	< 0.01	< 0.01	0.3	0.7	-0.1	-0.4	85.2	12.2	2.3	0.3
PAT_001_r01	277733	6214967	Rural	100	150	1.0	1.0	< 0.01	0.01	< 0.01	< 0.01	0.3	0.8	-0.1	-0.4	-	-	-	-
PAT_001_r02	277736	6214966	Rural	100	150	1.0	1.0	< 0.01	0.01	< 0.01	< 0.01	0.3	0.8	-0.1	-0.4	-	-	-	-
PAT_001_t01	277735	6215023	Rural	100	150	1.0	1.0	< 0.01	0.01	< 0.01	< 0.01	0.3	0.8	-0.1	-0.4	-	-	-	-
PAT_002_h01	277767	6214977	House	150	200	1.0	2.0	0.01	0.02	< 0.01	< 0.01	0.3	0.8	-0.1	-0.5	81.6	14.9	3.1	0.3
PAT_003_h01	277798	6214965	House	200	275	1.5	2.5	0.02	0.02	< 0.01	< 0.01	0.3	0.8	-0.2	-0.6	71.6	19.1	7.9	1.3
PAT_003_r01	277817	6214963	Rural	200	300	2.0	2.5	0.02	0.02	< 0.01	< 0.01	0.3	0.8	-0.2	-0.7	-	-	-	-
PAT_004_h01	277861	6214965	House	325	450	2.0	3.5	0.02	0.02	0.02	0.02	0.3	0.8	-0.3	-1.1	81.5	12.9	5.4	0.2
PAT_006_h01	277976	6215004	House	375	650	2.0	2.0	0.01	0.01	0.04	0.04	0.3	1.0	-0.4	-1.6	75.5	17.0	7.2	0.3
PAT_006_r01	277957	6215034	Rural	375	650	1.0	2.0	0.01	0.01	0.04	0.04	0.3	0.9	-0.6	-2.1	-	-	-	-
PAT_006_r02	277943	6215027	Rural	375	625	1.0	2.5	0.01	0.01	0.04	0.04	0.4	1.0	-0.7	-2.3	-	-	-	-
PAT_006_r03	277943	6215034	Rural	375	625	1.0	2.5	0.01	0.01	0.04	0.04	0.4	1.0	-0.7	-2.3	-	-	-	-
PAT_006_r04	277947	6215032	Rural	375	650	1.0	2.5	0.01	0.01	0.04	0.04	0.3	1.0	-0.6	-2.3	-	-	-	-
PAT_006_r06	277989	6215035	Rural	375	675	2.0	1.0	0.01	0.01	0.04	0.04	0.4	1.2	-0.3	-1.2	-	-	-	-
PAT_006_r07	277987	6215046	Rural	375	675	2.0	1.5	0.01	0.01	0.04	0.04	0.4	1.2	-0.3	-1.2	-	-	-	-
PAT_006_r08	277937	6215048	Rural	375	625	1.0	3.0	0.01	0.01	0.04	0.04	0.4	1.0	-0.7	-2.3	-	-	-	-
PAT_008_h01	277827	6214897	House	250	325	2.0	3.0	0.02	0.02	< 0.01	< 0.01	0.3	0.8	-0.2	-0.8	71.8	19.0	7.9	1.3
PAT_009_h01	277789	6214893	House	150	225	1.5	2.0	0.01	0.02	< 0.01	< 0.01	0.3	0.8	-0.1	-0.6	80.1	16.1	3.5	0.3
PAT_010_h01	277710	6214894	House	90	125	0.5	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	87.7	10.3	1.7	0.3
PAT_010_r01	277725	6214908	Rural	90	125	0.5	1.0	< 0.01	0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	-	-	-	-
PBG_001_h01	277919	6215363	House	425	700	2.0	3.5	0.02	0.02	0.05	0.05	0.4	1.0	-0.7	-2.4	71.7	19.4	8.6	0.4
PBG_001_h02	277931	6215333	House	425	700	1.5	3.0	0.02	0.02	0.05	0.05	0.4	1.0	-0.7	-2.4	71.7	19.3	8.5	0.4
PBG_002_h01	277970	6215317	House	425	700	2.5	2.0	0.02	0.02	0.05	0.05	0.4	1.2	-0.4	-1.3	54.2	28.4	13.6	3.8
PBG_003_h01	278008	6215272	House	375	700	2.5	0.5	0.02	0.02	0.03	0.04	0.6	1.6	-0.2	-0.5	62.0	24.5	11.1	2.4
PBG_003_r01	278010	6215301	Rural	375	700	2.5	0.5	0.02	0.02	0.03	0.03	0.6	1.7	-0.2	-0.5	-	-	-	-
PBG_004_h01	277977	6215195	House	400	700	2.5	2.0	0.01	0.01	0.04	0.04	0.4	1.3	-0.3	-1.3	56.5	27.2	12.9	3.4
PBG_004_r01	277998	6215151	Rural	375	675	2.5	0.5	0.01	0.01	0.04	0.04	0.5	1.5	-0.2	-0.8	-	-	-	-
PBG_005_h01	277942	6215241	House	425	700	1.5	3.0	0.02	0.02	0.05	0.05	0.3	1.0	-0.7	-2.3	66.4	26.2	7.0	0.5
PBG_005_r01	277935	6215223	Rural	425	675	1.0	3.0	0.01	0.01	0.05	0.05	0.4	1.0	-0.7	-2.4	-	-	-	-
PBG_006_h01	277908	6215244	House	425	650	2.5	3.5	0.02	0.02	0.05	0.05	0.4	1.0	-0.7	-2.2	72.4	18.9	8.3	0.4
PBG_007_h01	277888	6215276	House	425	625	2.5	3.5	0.02	0.02	0.05	0.05	0.3	0.8	-0.6	-1.8	66.0	26.4	7.1	0.5
PBG_008_h01	277849	6215290	House	375	525	2.5	4.0	0.02	0.03	0.03	0.03	0.3	0.8	-0.3	-1.1	72.7	21.8	5.3	0.3
PBL_002_p01	278479	6216590	Pool	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PBL_013_h01	278472	6216600	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	95.5	4.3	0.2	0.1
PBL_013_r01	278477	6216595	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PBL_013_r02	278468	6216580	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PBL_013_r03	278472	6216571	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PBL_013_r04	278466	6216569	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PBL_013_r05	278492	6216561	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PBL_013_r06	278470	6216573	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PBL_013_r07	278436	6216625	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PBL_013_t01	278472	6216564	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PBL_013_t02	278472	6216562	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PBL_013_t03	278483	6216602	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PBL_017_h01	278267	6216649	House	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	96.6	2.7	0.5	0.1
PBL_017_r02	278265	6216641	Rural	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.3	-	-	-	-
PBL_017_r03	278294	6216607	Rural	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PBL_017_r04	278232	6216634	Rural	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.2	-0.7	-	-	-	-
PBL_017_r06	278190	6216666	Rural	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.4	1.1	-0.4	-1.5	-	-	-	-
PBL_017_r07	278191	6216673	Rural	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.4	1.1	-0.4	-1.5	-	-	-	-
PBL_017_r08	278182	6216670	Rural	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.4	1.1	-0.4	-1.5	-	-	-	-
PBL_017_r09	278175	6216672	Rural	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.4	1.1	-0.4	-1.5	-	-	-	-
PBL_017_r10	278282	6216639	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PBL_017_t01	278259	6216644	Rural	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.3	-	-	-	-
PBL_017_t02	278259	6216642	Rural	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.3	-	-	-	-
PBL_017_t03	278238	6216630	Rural	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.4	-0.1	-0.6	-	-	-	-
PBL_017_t04	278169	6216654	Rural	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.4	1.0	-0.3	-1.4	-	-	-	-
PBL_025_h01	278066	6216685	House	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	97.0	2.5	0.4	0.1
PBL_025_p01	278049	6216671	Pool	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
PBL_025_r01	278062	6216657	Rural	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
PBL_025_r02	278088	6216630	Rural	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
PBL_025_r03	278090	6216669	Rural	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
PBL_025_r04	278044	6216693	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
PBL_025_t01	278050	6216700	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
PBL_025_t02	278050	6216638	Rural	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-

Table D.05 - Predicted subsidence effects for the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Structure Type	Predicted total subsidence after LW W1 (mm)	Predicted total subsidence after LW W2 (mm)	Predicted total tilt after LW W1 (mm/m)	Predicted total tilt after LW W2 (mm/m)	Predicted total hogging curvature after LW W1 (1/km)	Predicted total hogging curvature after LW W2 (1/km)	Predicted total sagging curvature after LW W1 (1/km)	Predicted total sagging curvature after LW W2 (1/km)	Predicted mean total tensile strain (mm/m)	Predicted 95% CL for total tensile strain (mm/m)	Predicted mean total comp. strain (mm/m)	Predicted 95% CL for total comp. strain (mm/m)	Predicted Probability of Nil or Category R0 Impact for Houses (%)	Predicted Probability of Category R1 or R2 Impact for Houses (%)	Predicted Probability of Category R3 and R4 Impact for Houses (%)	Predicted Probability of Category R5 Impact for Houses (%)
PBL_025_t03	278048	6216635	Rural	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
PCA_001_h01	277693	6214830	House	70	90	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	88.0	9.2	2.6	0.3
PCA_001_r01	277712	6214816	Rural	80	100	0.5	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	-	-	-	-
PCA_001_r02	277689	6214841	Rural	70	90	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	-	-	-	-
PCA_001_r03	277706	6214823	Rural	70	90	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	-	-	-	-
PCA_001_r04	277706	6214819	Rural	70	90	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	-	-	-	-
PCA_002_h01	277754	6214814	House	125	150	1.0	1.5	0.01	0.01	< 0.01	< 0.01	0.3	0.8	-0.1	-0.4	82.1	13.0	4.5	0.5
PCA_002_p01	277760	6214826	Pool	125	150	1.0	1.0	0.01	0.01	< 0.01	< 0.01	0.3	0.8	-0.1	-0.5	-	-	-	-
PCA_002_r01	277736	6214831	Rural	90	125	1.0	1.0	< 0.01	0.01	< 0.01	< 0.01	0.3	0.7	-0.1	-0.4	-	-	-	-
PCA_002_r02	277752	6214824	Rural	100	125	1.0	1.0	< 0.01	0.01	< 0.01	< 0.01	0.3	0.8	-0.1	-0.4	-	-	-	-
PCA_003_h01	277819	6214808	House	200	250	2.0	2.5	0.02	0.02	< 0.01	< 0.01	0.3	0.8	-0.2	-0.7	73.9	17.8	7.1	1.2
PCA_003_p01	277806	6214820	Pool	175	200	1.5	2.0	0.02	0.02	< 0.01	< 0.01	0.3	0.8	-0.2	-0.6	-	-	-	-
PCA_003_r01	277815	6214810	Rural	175	200	1.5	2.0	0.02	0.02	< 0.01	< 0.01	0.3	0.8	-0.2	-0.6	-	-	-	-
PCA_004_h01	277902	6214805	House	350	425	2.0	3.0	< 0.01	0.01	0.04	0.04	0.3	0.8	-0.5	-1.5	69.9	23.8	6.1	0.3
PCA_004_r01	277962	6214836	Rural	375	525	1.0	2.0	0.01	0.01	0.04	0.04	0.3	1.0	-0.6	-2.1	-	-	-	-
PCA_004_t01	277884	6214825	Rural	325	400	2.0	3.0	0.01	0.02	0.03	0.03	0.2	0.7	-0.4	-1.3	-	-	-	-
PCA_006_h01	277851	6214693	House	200	225	2.0	2.0	0.01	0.01	0.01	0.01	0.2	0.7	-0.2	-0.7	80.5	13.9	5.0	0.6
PCA_007_h01	277814	6214710	House	150	175	1.5	1.5	0.01	0.01	< 0.01	< 0.01	0.3	0.7	-0.1	-0.5	83.7	13.3	2.6	0.3
PCA_007_p01	277822	6214695	Pool	125	150	1.5	1.5	0.01	0.01	< 0.01	< 0.01	0.3	0.7	-0.2	-0.5	-	-	-	-
PCA_007_r01	277804	6214687	Rural	100	125	1.0	1.5	0.01	0.01	< 0.01	< 0.01	0.3	0.7	-0.1	-0.5	-	-	-	-
PCA_008_h01	277770	6214734	House	100	125	1.0	1.0	< 0.01	0.01	< 0.01	< 0.01	0.3	0.7	-0.1	-0.4	85.9	11.7	2.1	0.3
PCA_008_r01	277782	6214691	Rural	90	100	1.0	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.3	0.7	-0.1	-0.4	-	-	-	-
PCA_009_h01	277717	6214741	House	80	90	0.5	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	88.7	9.5	1.5	0.3
PCA_009_p01	277733	6214723	Pool	70	80	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	-	-	-	-
PCA_009_p02	277738	6214724	Pool	70	90	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	-	-	-	-
PCA_009_r01	277739	6214738	Rural	80	90	0.5	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	-	-	-	-
PSC_001_h01	277550	6214622	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	94.0	5.4	0.5	0.1
PSC_002_h01	277552	6214664	House	20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	94.3	5.2	0.4	0.1
PSC_002_r01	277561	6214677	Rural	20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	-	-	-	-
PSC_002_r02	277547	6214672	Rural	20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	-	-	-	-
PSC_002_r03	277550	6214666	Rural	20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	-	-	-	-
PSC_002_r04	277521	6214683	Rural	20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	-	-	-	-
PSC_002_r05	277520	6214672	Rural	20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	-	-	-	-
PSC_002_r06	277511	6214656	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	-	-	-	-
PSC_003_h01	277569	6214723	House	30	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	93.7	5.7	0.5	0.1
PSC_003_r01	277543	6214708	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	-	-	-	-
PSC_003_r02	277535	6214714	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	-	-	-	-
PSC_003_r03	277533	6214730	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	-	-	-	-
PSC_005_h01	277612	6214832	House	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	92.7	6.0	1.2	0.2
PSC_005_p01	277604	6214834	Pool	40	50	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_005_r01	277612	6214854	Rural	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_006_h01	277633	6214889	House	50	70	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	92.1	6.4	1.3	0.2
PSC_006_p01	277622	6214886	Pool	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_006_r01	277603	6214884	Rural	40	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_006_r02	277622	6214872	Rural	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_006_r03	277627	6214890	Rural	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_006_r04	277621	6214908	Rural	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_007_h01	277644	6214938	House	60	80	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	92.0	7.0	0.9	0.2
PSC_007_p01	277629	6214954	Pool	50	70	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_007_r01	277645	6214922	Rural	60	80	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_007_r02	277618	6214954	Rural	50	70	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_007_r03	277642	6214926	Rural	60	80	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_007_r04	277651	6214921	Rural	60	80	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_007_r05	277627	6214942	Rural	50	70	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_007_r06	277630	6214961	Rural	50	70	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_008_h01	277665	6215000	House	70	90	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	90.6	8.0	1.1	0.2
PSC_008_p01	277645	6215012	Pool	60	80	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_008_r01	277659	6215002	Rural	60	80	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.3	-	-	-	-
PSC_008_r02	277640	6215020	Rural	60	80	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_009_h01	277676	6215053	House	70	100	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	89.3	9.1	1.4	0.2
PSC_009_r01	277673	6215039	Rural	70	100	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	-	-	-	-
PSC_009_r02	277669	6215057	Rural	60	90	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	-	-	-	-
PSC_009_r03	277638	6215073	Rural	60	80	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.3	-	-	-	-
PSC_009_t01	277656	6215030	Rural	60	80	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.3	-	-	-	-
PSC_010_h01	277692	6215101	House	80	125	0.5	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	87.5	10.5	1.8	0.3

Table D.05 - Predicted subsidence effects for the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Structure Type	Predicted total subsidence after LW W1 (mm)	Predicted total subsidence after LW W2 (mm)	Predicted total tilt after LW W1 (mm/m)	Predicted total tilt after LW W2 (mm/m)	Predicted total hogging curvature after LW W1 (1/km)	Predicted total hogging curvature after LW W2 (1/km)	Predicted total sagging curvature after LW W1 (1/km)	Predicted total sagging curvature after LW W2 (1/km)	Predicted mean total tensile strain (mm/m)	Predicted 95% CL for total tensile strain (mm/m)	Predicted mean total comp. strain (mm/m)	Predicted 95% CL for total comp. strain (mm/m)	Predicted Probability of Nil or Category R0 Impact for Houses (%)	Predicted Probability of Category R1 or R2 Impact for Houses (%)	Predicted Probability of Category R3 and R4 Impact for Houses (%)	Predicted Probability of Category R5 Impact for Houses (%)
PSC_010_p01	277672	6215111	Pool	70	100	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	-	-	-	-
PSC_010_r01	277675	6215091	Rural	70	100	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	-	-	-	-
PSC_010_r02	277686	6215103	Rural	80	100	0.5	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	-	-	-	-
PSC_010_r03	277672	6215094	Rural	70	100	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	-	-	-	-
PSC_011_h01	277704	6215140	House	90	125	0.5	1.0	< 0.01	0.01	< 0.01	< 0.01	0.2	0.8	-0.1	-0.4	84.0	11.8	3.8	0.4
PSC_011_p01	277675	6215151	Pool	70	100	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	-	-	-	-
PSC_011_r01	277701	6215150	Rural	80	125	0.5	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.8	-0.1	-0.4	-	-	-	-
PSC_011_r02	277685	6215155	Rural	80	100	0.5	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	-	-	-	-
PSC_011_r03	277678	6215158	Rural	70	100	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.1	-0.4	-	-	-	-
PSC_012_h01	277705	6215195	House	100	150	1.0	1.0	< 0.01	0.01	< 0.01	< 0.01	0.3	0.8	-0.1	-0.4	85.5	12.0	2.2	0.3
PSC_012_p01	277686	6215201	Pool	80	100	0.5	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.8	-0.1	-0.4	-	-	-	-
PSC_012_r01	277716	6215174	Rural	100	125	1.0	1.0	< 0.01	0.01	< 0.01	< 0.01	0.3	0.8	-0.1	-0.4	-	-	-	-
PSC_013_h01	277723	6215233	House	125	150	1.0	1.5	0.01	0.01	< 0.01	< 0.01	0.3	0.8	-0.1	-0.4	80.6	13.8	5.0	0.6
PSC_014_h01	277762	6215295	House	175	225	1.5	2.0	0.02	0.02	< 0.01	< 0.01	0.3	0.9	-0.1	-0.5	72.0	18.9	7.8	1.3
PSC_014_r01	277741	6215271	Rural	125	175	1.0	1.5	0.01	0.02	< 0.01	< 0.01	0.3	0.9	-0.1	-0.4	-	-	-	-
PSC_014_r02	277738	6215289	Rural	125	175	1.0	1.5	0.01	0.02	< 0.01	< 0.01	0.3	0.9	-0.1	-0.4	-	-	-	-
PSC_015_h01	277709	6215322	House	100	150	1.0	1.5	0.01	0.01	< 0.01	< 0.01	0.3	0.8	-0.1	-0.4	84.1	13.0	2.5	0.3
PSC_016_h01	277722	6215384	House	125	175	1.0	1.5	0.01	0.02	< 0.01	< 0.01	0.3	0.8	-0.1	-0.4	86.5	9.5	3.9	0.2
PSC_016_r01	277711	6215371	Rural	100	150	1.0	1.0	0.01	0.01	< 0.01	< 0.01	0.3	0.8	-0.1	-0.4	-	-	-	-
PSC_016_r02	277711	6215375	Rural	100	125	1.0	1.0	< 0.01	0.01	< 0.01	< 0.01	0.3	0.8	-0.1	-0.4	-	-	-	-
PSC_016_r03	277718	6215415	Rural	100	150	1.0	1.0	0.01	0.01	< 0.01	< 0.01	0.3	0.8	-0.1	-0.4	-	-	-	-
PSC_016_r04	277715	6215423	Rural	100	150	1.0	1.5	0.01	0.01	< 0.01	< 0.01	0.3	0.8	-0.1	-0.4	-	-	-	-
PSC_017_h01	277770	6215374	House	200	275	2.0	2.5	0.02	0.03	< 0.01	< 0.01	0.3	0.9	-0.1	-0.5	74.7	20.2	4.8	0.3
PSC_017_r01	277751	6215363	Rural	150	200	1.5	2.0	0.01	0.02	< 0.01	< 0.01	0.3	0.9	-0.1	-0.5	-	-	-	-
PSC_018_h01	277820	6215346	House	300	400	2.5	3.5	0.02	0.03	< 0.01	< 0.01	0.3	0.9	-0.2	-0.8	73.5	21.1	5.1	0.3
PSC_020_h01	278004	6215429	House	400	700	2.5	0.5	0.02	0.02	0.04	0.04	0.6	1.7	-0.2	-0.5	73.9	18.0	7.8	0.3
PSC_020_h02	278009	6215441	House	375	700	2.5	0.5	0.02	0.02	0.03	0.03	0.7	1.7	-0.1	-0.5	76.9	16.0	6.8	0.3
PSC_021_h01	277971	6215372	House	425	700	2.5	1.5	0.02	0.02	0.05	0.05	0.4	1.3	-0.3	-1.2	54.0	28.5	13.7	3.8
PSC_021_r01	277982	6215354	Rural	425	700	2.5	1.0	0.02	0.02	0.05	0.05	0.5	1.4	-0.3	-0.9	-	-	-	-
PSC_022_h01	277777	6215154	House	175	250	1.5	2.5	0.02	0.02	< 0.01	< 0.01	0.3	0.9	-0.1	-0.6	77.4	18.2	4.2	0.3
PSC_022_r01	277759	6215117	Rural	125	200	1.0	1.5	0.01	0.02	< 0.01	< 0.01	0.3	0.9	-0.1	-0.5	-	-	-	-
PSC_023_h01	277833	6215140	House	300	425	2.5	3.5	0.02	0.03	< 0.01	< 0.01	0.3	0.9	-0.3	-0.9	69.3	20.5	8.7	1.5
PSC_023_r01	277820	6215097	Rural	225	325	2.0	3.0	0.02	0.03	< 0.01	< 0.01	0.3	0.9	-0.2	-0.8	-	-	-	-
PSC_024_h01	277765	6215063	House	150	200	1.0	2.0	0.01	0.02	< 0.01	< 0.01	0.3	0.8	-0.1	-0.5	85.4	10.2	4.2	0.2
PSC_024_r01	277775	6215048	Rural	150	225	1.5	2.0	0.01	0.02	< 0.01	< 0.01	0.3	0.8	-0.1	-0.6	-	-	-	-
PSC_025_h01	277658	6214760	House	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	92.8	6.3	0.7	0.2
PSC_025_p01	277673	6214762	Pool	60	70	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_025_r01	277653	6214738	Rural	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_025_r02	277659	6214729	Rural	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_025_r03	277684	6214720	Rural	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_026_h01	277658	6214692	House	40	50	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	92.9	5.9	1.1	0.2
PSC_027_h01	277647	6214652	House	30	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	93.1	6.1	0.6	0.2
PSC_027_p01	277671	6214660	Pool	40	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	-	-	-	-
PSC_027_r01	277655	6214653	Rural	30	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	-	-	-	-
PSC_027_r02	277667	6214638	Rural	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	-	-	-	-
PSC_027_r03	277677	6214662	Rural	40	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	-	-	-	-
PSC_090_pu01	278547	6216190	Public Utility	< 20	80	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSC_090_pu02	278540	6216186	Public Utility	< 20	80	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSC_090_pu03	278542	6216178	Public Utility	< 20	80	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSC_090_pu04	278544	6216168	Public Utility	< 20	80	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSC_090_pu05	278551	6216187	Public Utility	< 20	80	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSC_090_pu06	278547	6216186	Public Utility	< 20	80	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSC_090_pu07	278548	6216182	Public Utility	< 20	80	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSC_090_pu08	278549	6216178	Public Utility	< 20	80	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSC_090_pu09	278550	6216175	Public Utility	< 20	80	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSC_090_pu10	278551	6216171	Public Utility	< 20	80	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSC_090_pu11	278542	6216218	Public Utility	< 20	80	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSC_090_pu12	278535	6216210	Public Utility	< 20	80	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSC_090_pu13	278567	6216240	Public Utility	< 20	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSC_091_r01	278473	6216407	Rural	< 20	40	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSC_091_r02	278492	6216420	Rural	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PSC_092_h01	278429	6216451	House	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	93.0	5.1	1.8	0.1
PSC_092_t01	278423	6216459	Rural	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_001_h01	278018	6214641	House	175	225	2.0	2.0	0.02	0.02	0.02	0.02	0.3	0.7	-0.1	-0.6	83.7	11.4	4.7	0.2
PTH_001_p01	278006	6214654	Pool	200	225	2.0	2.0	0.02	0.02	0.02	0.02	0.2	0.7	-0.2	-0.7	-	-	-	-

Table D.05 - Predicted subsidence effects for the structures within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Structure Type	Predicted total subsidence after LW W1 (mm)	Predicted total subsidence after LW W2 (mm)	Predicted total tilt after LW W1 (mm/m)	Predicted total tilt after LW W2 (mm/m)	Predicted total hogging curvature after LW W1 (1/km)	Predicted total hogging curvature after LW W2 (1/km)	Predicted total sagging curvature after LW W1 (1/km)	Predicted total sagging curvature after LW W2 (1/km)	Predicted mean total tensile strain (mm/m)	Predicted 95% CL for total tensile strain (mm/m)	Predicted mean total comp. strain (mm/m)	Predicted 95% CL for total comp. strain (mm/m)	Predicted Probability of Nil or Category R0 Impact for Houses (%)	Predicted Probability of Category R1 or R2 Impact for Houses (%)	Predicted Probability of Category R3 and R4 Impact for Houses (%)	Predicted Probability of Category R5 Impact for Houses (%)
PTH_001_r01	278019	6214660	Rural	200	250	2.0	2.0	0.02	0.02	0.02	0.02	0.3	0.8	-0.2	-0.6	-	-	-	-
PTH_001_r02	278035	6214611	Rural	100	150	1.5	1.5	0.02	0.02	< 0.01	< 0.01	0.2	0.6	-0.1	-0.4	-	-	-	-
PTH_001_r03	277992	6214667	Rural	225	250	2.0	2.0	0.02	0.02	0.02	0.02	0.2	0.7	-0.2	-1.0	-	-	-	-
PTH_031_r01	278350	6215104	Rural	40	475	< 0.5	5.0	< 0.01	0.06	< 0.01	0.01	0.4	1.1	-0.1	-0.4	-	-	-	-
PTH_031_r02	278376	6215091	Rural	30	350	< 0.5	4.0	< 0.01	0.06	< 0.01	< 0.01	0.4	1.1	-0.1	-0.2	-	-	-	-
PTH_031_r03	278393	6215056	Rural	30	275	< 0.5	3.0	< 0.01	0.06	< 0.01	< 0.01	0.4	1.1	-0.1	-0.2	-	-	-	-
PTH_031_r04	278415	6215039	Rural	30	225	< 0.5	2.0	< 0.01	0.03	< 0.01	< 0.01	0.4	1.0	-0.1	-0.2	-	-	-	-
PTH_031_r05	278421	6215034	Rural	30	200	< 0.5	2.0	< 0.01	0.03	< 0.01	< 0.01	0.4	0.9	-0.1	-0.2	-	-	-	-
PTH_031_r06	278429	6215072	Rural	30	200	< 0.5	1.5	< 0.01	0.02	< 0.01	< 0.01	0.3	0.9	-0.1	-0.2	-	-	-	-
PTH_031_r07	278422	6215060	Rural	30	200	< 0.5	1.5	< 0.01	0.03	< 0.01	< 0.01	0.4	0.9	-0.1	-0.2	-	-	-	-
PTH_031_r08	278412	6215066	Rural	30	225	< 0.5	2.0	< 0.01	0.04	< 0.01	< 0.01	0.4	1.0	-0.1	-0.2	-	-	-	-
PTH_031_r09	278384	6215086	Rural	30	300	< 0.5	3.5	< 0.01	0.06	< 0.01	< 0.01	0.4	1.1	-0.1	-0.2	-	-	-	-
PTH_031_t01	278420	6215073	Rural	30	200	< 0.5	1.5	< 0.01	0.03	< 0.01	< 0.01	0.4	0.9	-0.1	-0.2	-	-	-	-
PTH_031_t02	278404	6215056	Rural	30	225	< 0.5	2.5	< 0.01	0.04	< 0.01	< 0.01	0.4	1.0	-0.1	-0.2	-	-	-	-
PTH_031_t04	278370	6215103	Rural	30	350	< 0.5	4.0	< 0.01	0.06	< 0.01	< 0.01	0.4	1.1	-0.1	-0.2	-	-	-	-
PTH_055_h01	278604	6214938	House	< 20	70	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	92.7	6.0	1.2	0.2
PTH_055_r01	278577	6214931	Rural	< 20	70	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
PTH_080_r01	278660	6214816	Rural	< 20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
TAD_005_r04	277364	6215597	Rural	20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	-	-	-	-
TAD_010_h01	277367	6215243	House	20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	95.0	4.6	0.3	0.1
TTH_023_h01	277469	6214622	House	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	96.4	2.9	0.6	0.1
TTH_023_r01	277494	6214643	Rural	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	-	-	-	-
V04a	277559	6214316	Public Amenity	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V04ag	277715	6214247	Public Amenity	20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V04b	277653	6214268	Public Amenity	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V04bh	277594	6214334	Public Amenity	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V05a	278181	6214427	House	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	92.7	6.0	1.2	0.2
V05c	278168	6214410	Rural	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V05d	278190	6214436	Rural	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V05e	278172	6214403	Rural	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V05f	278179	6214423	Rural	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V05g	278188	6214408	Rural	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V05h	278166	6214432	Rural	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V06a	278228	6214365	House	80	80	0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	93.6	4.7	1.6	0.1
V06b	278237	6214343	Rural	80	90	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V06c	278229	6214311	Rural	100	125	1.0	1.0	0.01	0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V06e	278242	6214307	Rural	100	125	1.0	1.0	0.01	0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V06h	278230	6214351	Rural	80	90	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V06k	278249	6214396	Rural	60	70	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	-	-	-	-
V15a	278588	6214526	House	60	60	1.0	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	87.4	10.5	1.8	0.3
V15b	278552	6214492	Rural	80	80	1.0	1.0	0.01	0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
V15c	278563	6214486	Rural	80	80	1.0	1.0	0.01	0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
V15d	278560	6214512	Rural	60	60	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
V15e	278585	6214535	Rural	40	50	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
V15f	278572	6214516	Rural	60	60	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
V15g	278560	6214523	Rural	50	60	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	-	-	-	-
			Maximum	**425**	**700**	**2.5**	**5.0**	**0.02**	**0.06**	**0.05**	**0.05**	**0.7**	**1.7**	**-0.7**	**-2.4**				

Table D.06 - Predicted subsidence effects for the dams within the Study Area

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Maximum Dimension (m)	Plan Area (m2)	Predicted total subsidence after LW W1 (mm)	Predicted total subsidence after LW W2 (mm)	Predicted total tilt after LW W1 (mm/m)	Predicted total tilt after LW W2 (mm/m)	Predicted total hogging curvature after LW W1 (1/km)	Predicted total hogging curvature after LW W2 (1/km)	Predicted total sagging curvature after LW W1 (1/km)	Predicted total sagging curvature after LW W2 (1/km)	Predicted mean total tensile strain (mm/m)	Predicted 95% CL for total tensile strain (mm/m)	Predicted mean total comp. strain (mm/m)	Predicted 95% CL for total comp. strain (mm/m)	Predicted Change in Freeboard after LW W1 (mm)	Predicted Change in Freeboard after LW W2 (mm)
PSC_004_d01	277590	6214768	35	454.7	40	50	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	< 50	< 50
PSC_019_d01	277857	6215418	80	3669.2	425	625	2.5	4.0	0.02	0.03	0.05	0.05	0.3	0.8	-0.4	-1.3	100	150
PSC_080_d01	278221	6215832	53	1377.0	70	750	< 0.5	5.0	< 0.01	0.02	< 0.01	0.11	0.4	1.1	-0.8	-2.7	< 50	< 50
PSC_090_d01	278513	6216093	120	5671.4	30	125	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	< 50	< 50
PSC_100_d01	277570	6214996	20	197.4	40	50	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.1	-0.3	< 50	< 50
PSR_010_d03	278740	6215573	53	1478.7	< 20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	< 50	< 50
PTH_031_d01	278350	6214905	72	3134.1	50	525	< 0.5	4.5	< 0.01	0.05	< 0.01	0.08	0.3	0.9	-0.1	-0.4	< 50	150
PTH_031_d02	278390	6214848	23	126.6	30	175	< 0.5	2.5	< 0.01	0.03	< 0.01	< 0.01	0.3	0.7	-0.1	-0.2	< 50	< 50
PTH_055_d01	278547	6215155	108	3834.4	20	125	< 0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.4	-0.1	-0.2	< 50	< 50
PTH_080_d01	278583	6214761	161	15038.8	20	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	< 50	< 50
PTH_105_d01	278720	6215094	139	7279.1	< 20	50	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.3	-0.1	-0.2	< 50	< 50
TAD_005_d01	277334	6215659	54	1895.1	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.1	-0.3	< 50	< 50
V04ax	277913	6214240	4	13.8	50	50	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.7	-0.2	-0.9	< 50	< 50
V04ay	277900	6214265	5	36.2	40	50	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.6	-0.2	-0.8	< 50	< 50
V04az	277878	6214309	15	38.0	40	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.5	-0.2	-0.6	< 50	< 50
V04ba	277787	6214438	17	96.6	20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.4	< 50	< 50
V04bd	277758	6214505	26	483.2	20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	< 50	< 50
V04be	277727	6214523	3	88.5	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	< 50	< 50
V06f	278188	6214326	20	296.4	80	90	0.5	0.5	< 0.01	< 0.01	< 0.01	< 0.01	0.2	0.4	-0.1	-0.3	< 50	< 50
				Maximum	**425**	**750**	**2.5**	**5.0**	**0.02**	**0.05**	**0.05**	**0.11**	**0.4**	**1.1**	**-0.8**	**-2.7**	**100**	**150**

Table D.07 - Predicted subsidence effects for the Aboriginal heritage sites within the Study Area

Site Reference	Location	Type	Predicted total subsidence after LW W1 (mm)	Predicted total subsidence after LW W2 (mm)	Predicted total tilt after LW W1 (mm/m)	Predicted total tilt after LW W2 (mm/m)	Predicted total hogging curvature after LW W1 (1/km)	Predicted total hogging curvature after LW W2 (1/km)	Predicted total sagging curvature after LW W1 (1/km)	Predicted total sagging curvature after LW W2 (1/km)	Stream	Predicted total upsidence after LW W2 (mm)	Predicted total closure after LW W2 (mm)
52-2-2068	250 m north-east of LW W2	Grinding Grooves	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Stonequarry Creek	20	30
52-2-2069	180 m east of LW W2	Open Site	20	90	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	-	-	-
52-2-2070	270 m east of LW W2	Open Site	< 20	50	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	-	-	-
52-2-2071	100 m north-east of LW W2	Open Site	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Stonequarry Creek	30	40
52-2-2072	120 m north-east of LW W2	Open Site	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Stonequarry Creek	40	40
52-2-2073	320 m north-east of LW W2	Open Site	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	-	-	-
52-2-2100	Directly above LW W2	Modified Tree	90	725	0.5	1.0	< 0.01	0.02	< 0.01	0.02	-	-	-
52-2-4159	570 m west of LW W1	PAD	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Matthews Creek	< 20	< 20
52-2-4213	370 m west of LW W1	Rock Shelter	20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Matthews Creek	30	70
52-2-4214	370 m west of LW W1	Rock Shelter	20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Matthews Creek	30	70
52-2-4385	250 m west of LW W1	Rock Shelter	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Cedar Creek	60	90
52-2-4386	180 m west of LW W1	Rock Shelter	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Matthews Creek	60	100
52-2-4387	180 m west of LW W1	Rock Shelter	50	70	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Matthews Creek	70	150
52-2-4388	250 m west of LW W1	Rock Shelter	40	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Matthews Creek	60	125
52-2-4389	320 m west of LW W1	Rock Shelter	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Tributary 1 to Matthews Creek	30	60
52-2-4390	340 m west of LW W1	Rock Shelter	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Matthews Creek	40	70
52-2-4391	370 m west of LW W1	Rock Shelter	20	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Matthews Creek	30	70
52-2-4392	170 m west of LW W1	Rock Shelter	50	60	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Matthews Creek	80	150
52-2-4393	280 m west of LW W1	Rock Shelter	30	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Matthews Creek	50	100
52-2-4430	210 m west of LW W1	Rock Shelter and Grinding Grooves	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Cedar Creek	50	80
52-2-4431	240 m west of LW W1	Rock Shelter	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Cedar Creek	50	80
CC1	240 m west of LW W1	Rock Shelter	40	40	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Cedar Creek	70	150
CC2	240 m west of LW W1	Rock Shelter	30	30	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Cedar Creek	60	80
CC3	210 m west of LW W1	Rock Shelter	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Cedar Creek	50	70
CCT1	220 m north-west of LW W1	Rock Shelter	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Tributary to Cedar Creek	20	50
SQC1	90 m north-east of LW W2	Open Site	< 20	20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Stonequarry Creek	30	30
MCR 2014-5	470 m west of LW W1	Rock Shelter	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01	Matthews Creek	30	40
		Maximum	**90**	**725**	**0.5**	**1.0**	**< 0.01**	**0.02**	**< 0.01**	**0.02**		**80**	**150**

APPENDIX E. DRAWINGS

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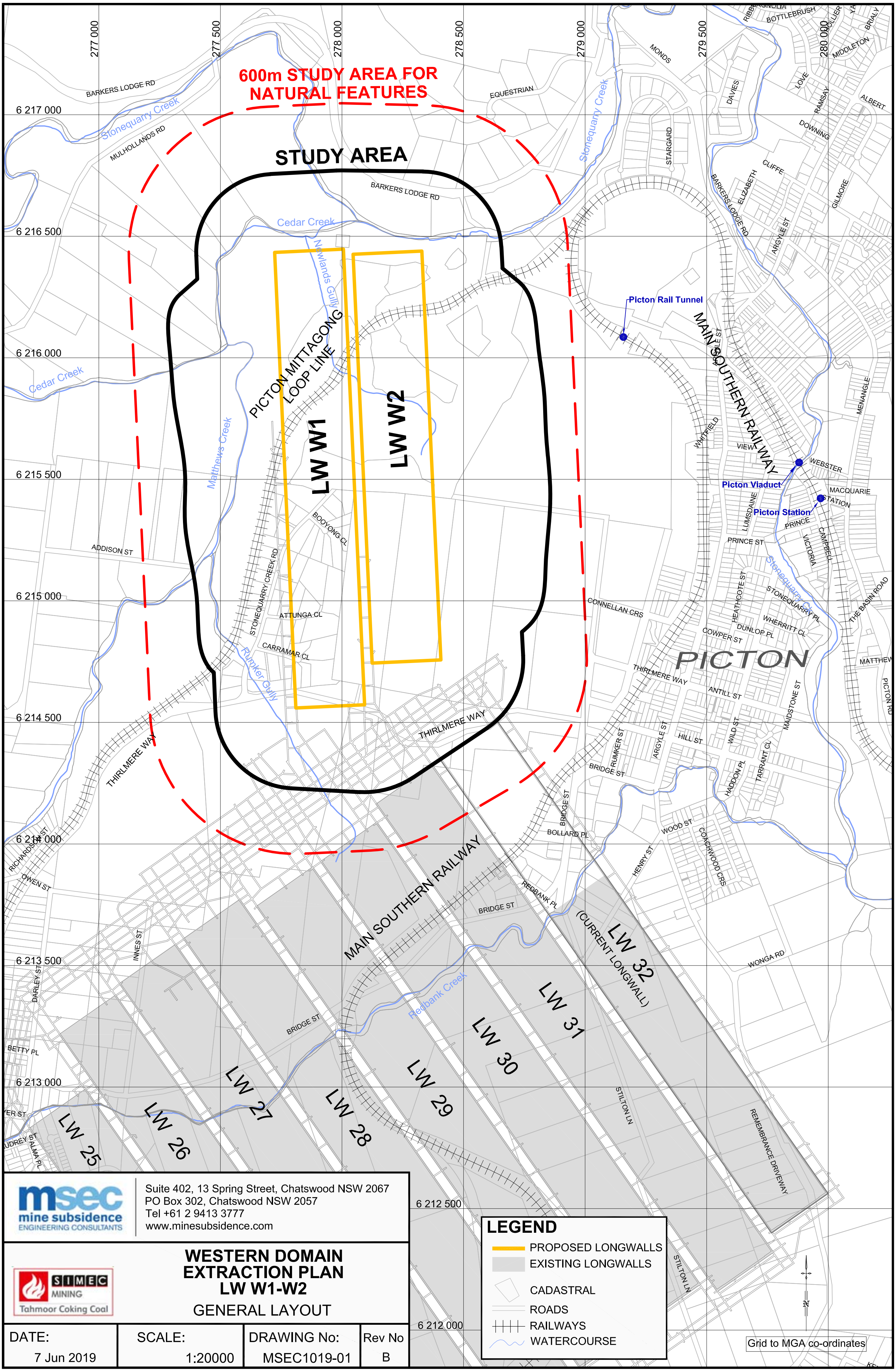

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WESTERN DOMAIN EXTRACTION PLAN LW W1-W2

GENERAL LAYOUT

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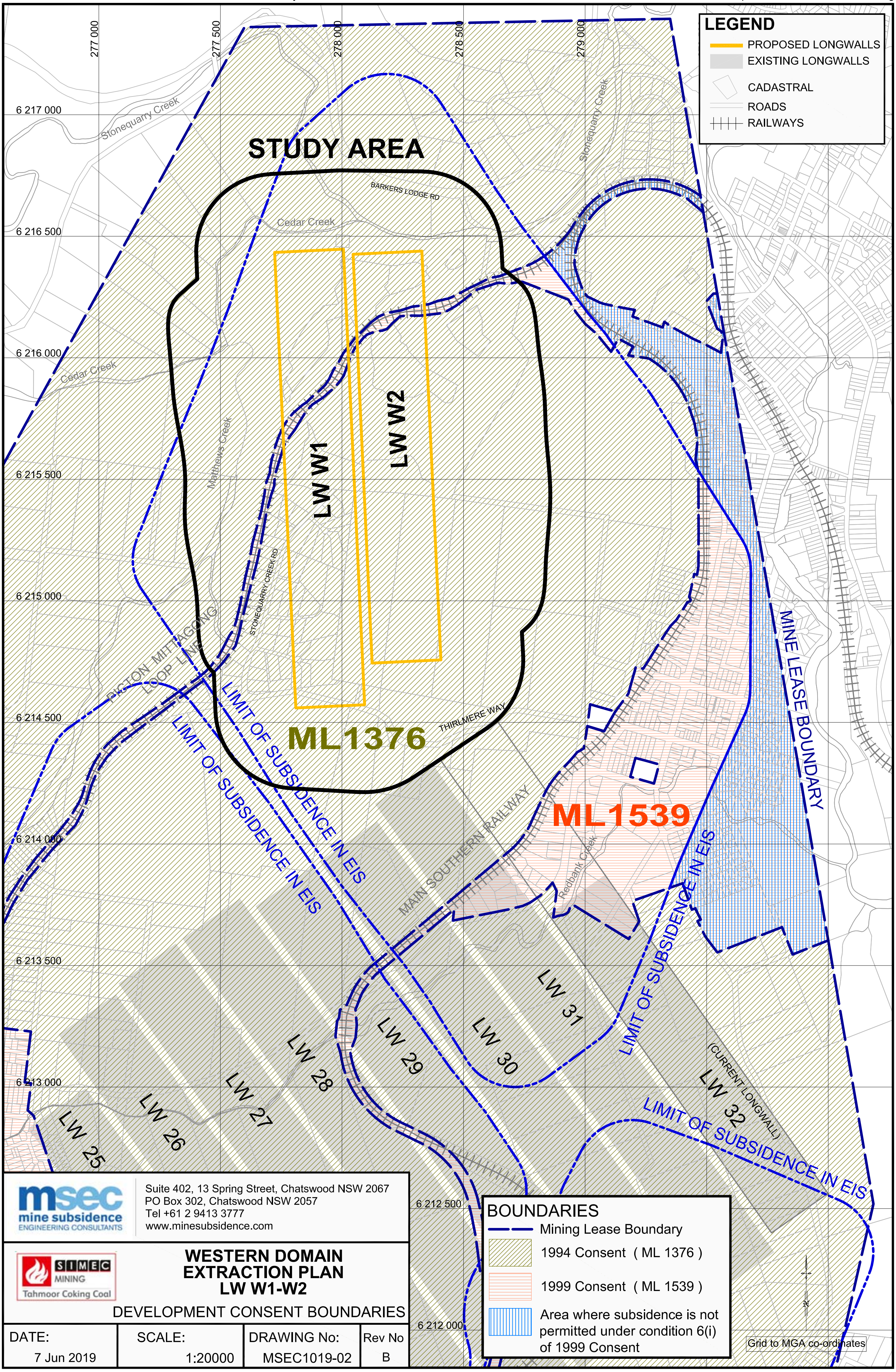

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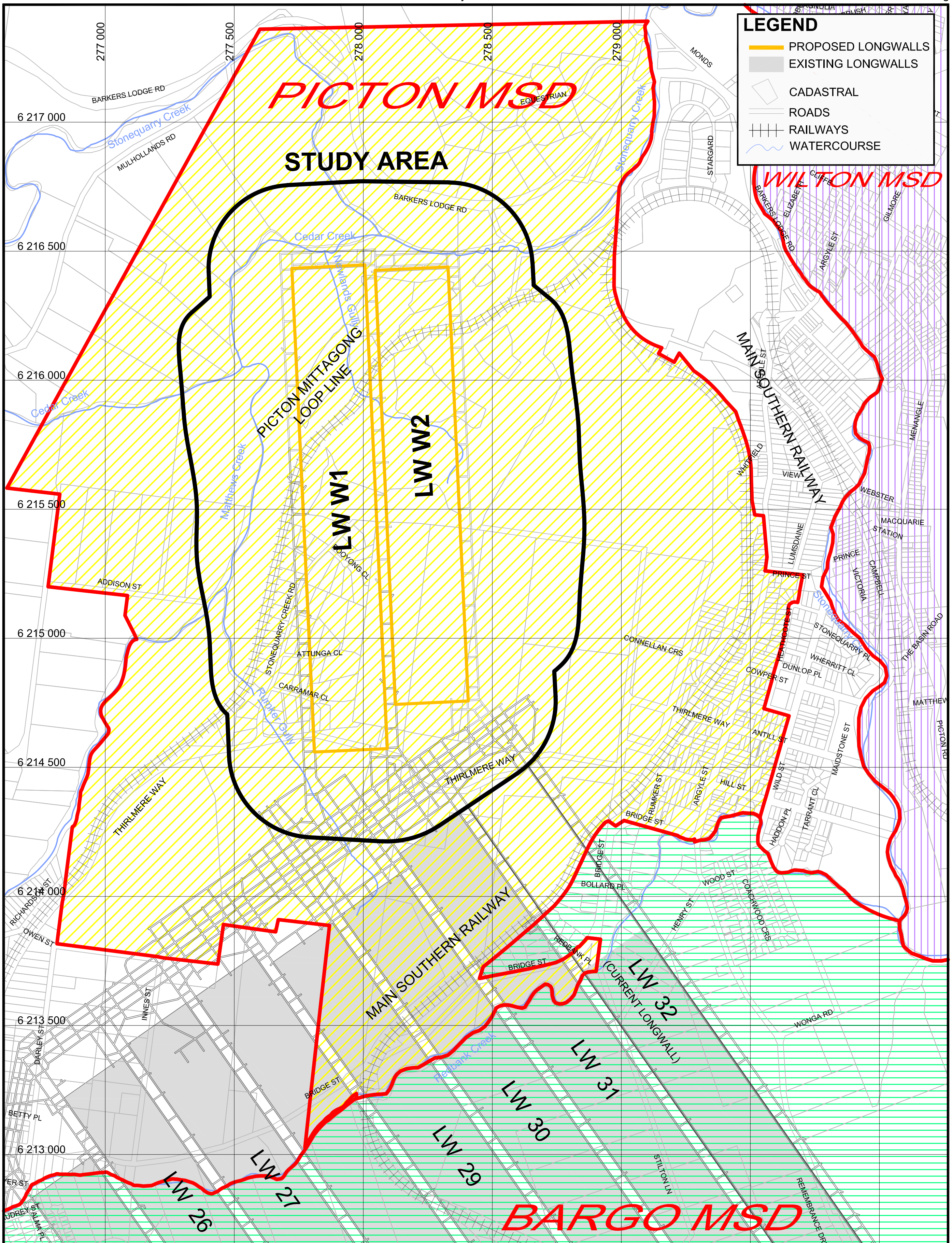

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MINE SUBSIDENCE DISTRICTS

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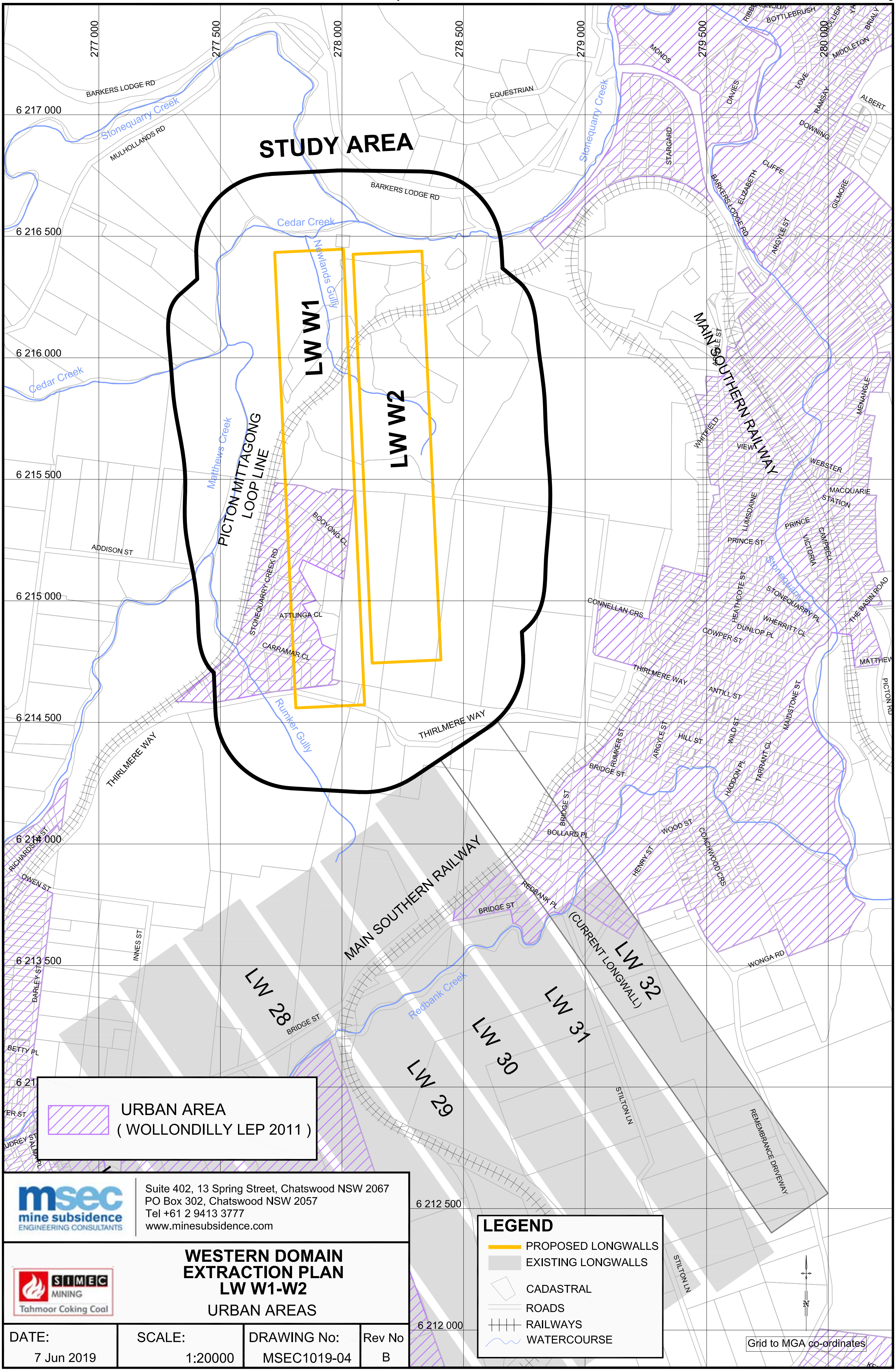

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WESTERN DOMAIN EXTRACTION PLAN LW W1-W2

URBAN AREAS

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WESTERN DOMAIN EXTRACTION PLAN LW W1-W2

SURFACE LEVEL CONTOURS

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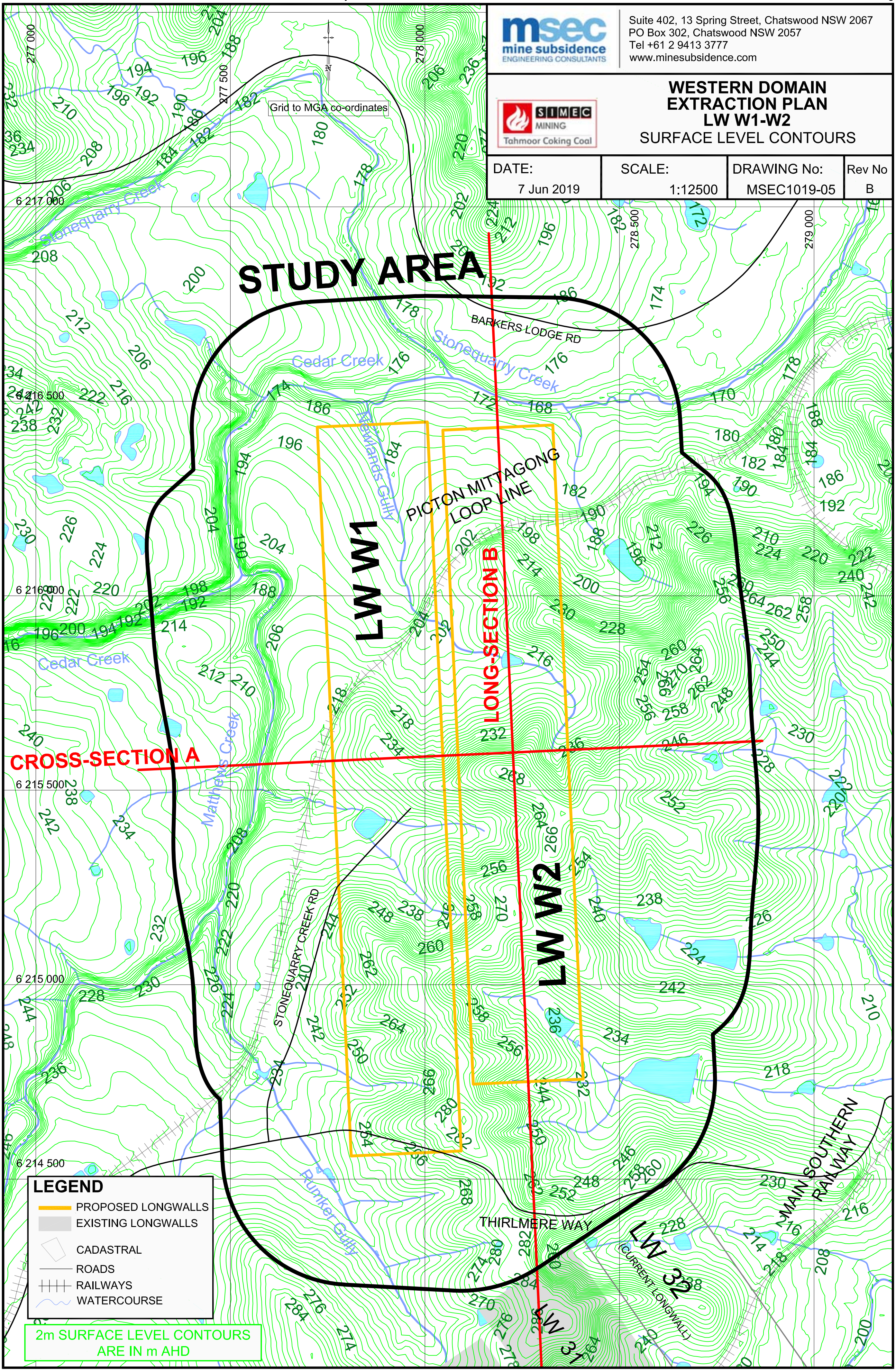

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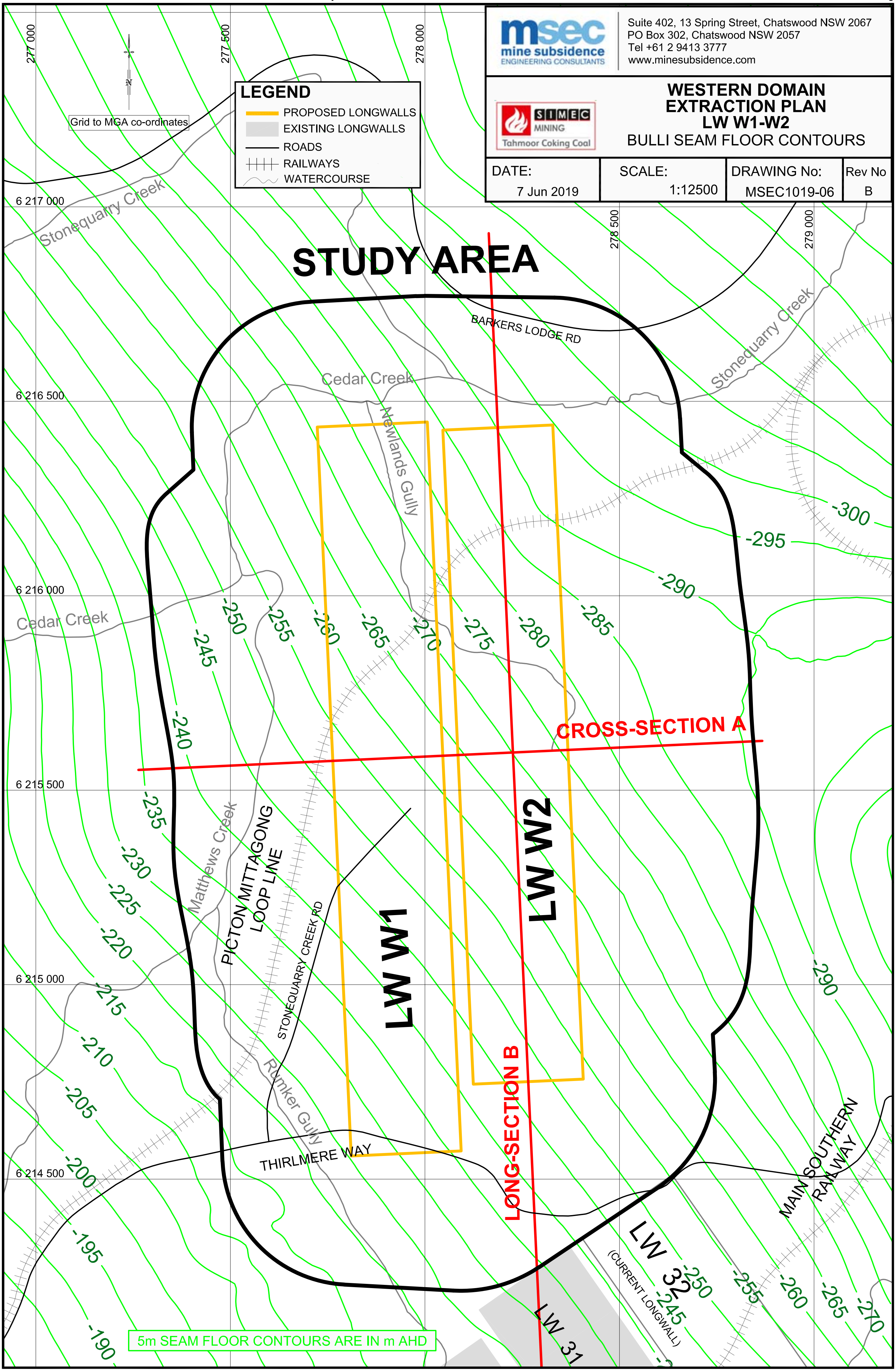

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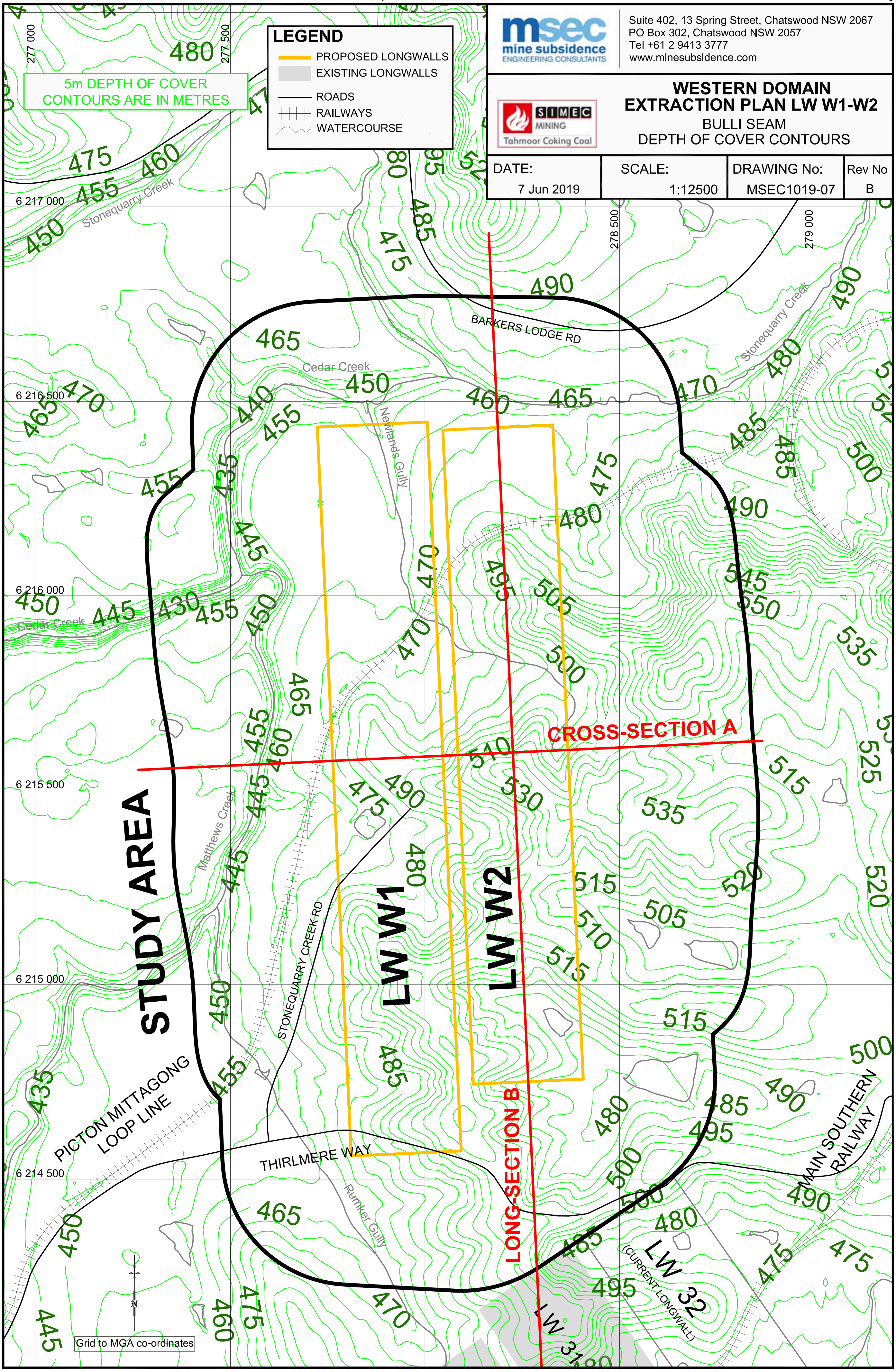

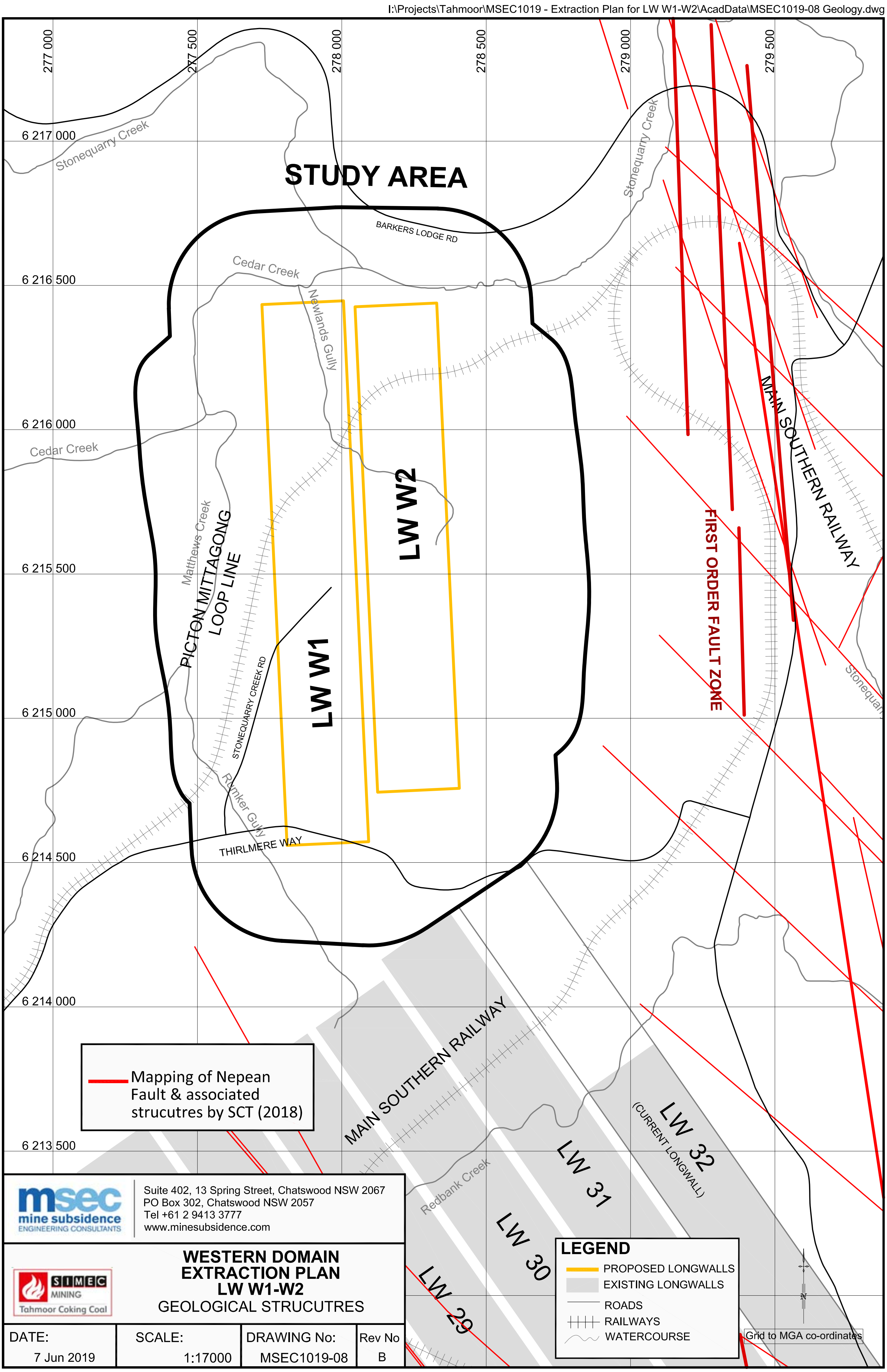
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277 000
277 500
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6 217 000
6 216 500
6 216 000
6 215 500
6 215 000
6 214 500
6 214 000
6 213 500
STUDY AREA
Stonequarry Creek
BARKERS LODGE RD
Cedar Creek
Newlands Gully
LW W2
LW W1
Matthews Creek
PICTON MITTAGONG LOOP LINE
STONEQUARRY CREEK RD
Rumker Gully
THIRLMERE WAY
FIRST ORDER FAULT ZONE
MAIN SOUTHERN RAILWAY
Mapping of Nepean Fault & associated strucutres by SCT (2018)
Redbank Creek
LW 32 (CURRENT LONGWALL)
LW 31
LW 30
LW 29
LEGEND
PROPOSED LONGWALLS
EXISTING LONGWALLS
ROADS
RAILWAYS
WATERCOURSE
Grid to MGA co-ordinates
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GEOLOGICAL STRUCUTRES
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Rev No B

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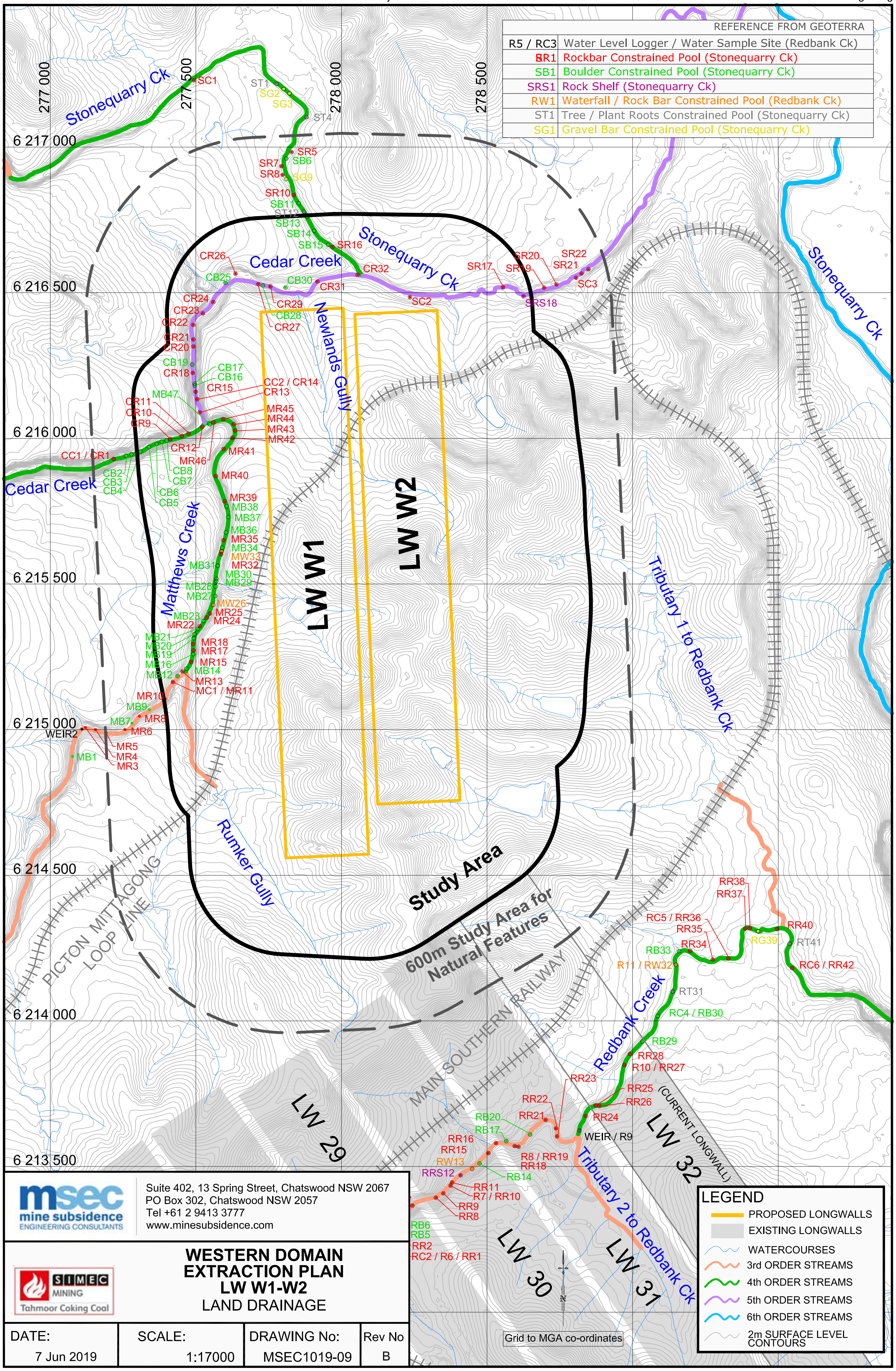

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WESTERN DOMAIN EXTRACTION PLAN LW W1-W2
LAND DRAINAGE

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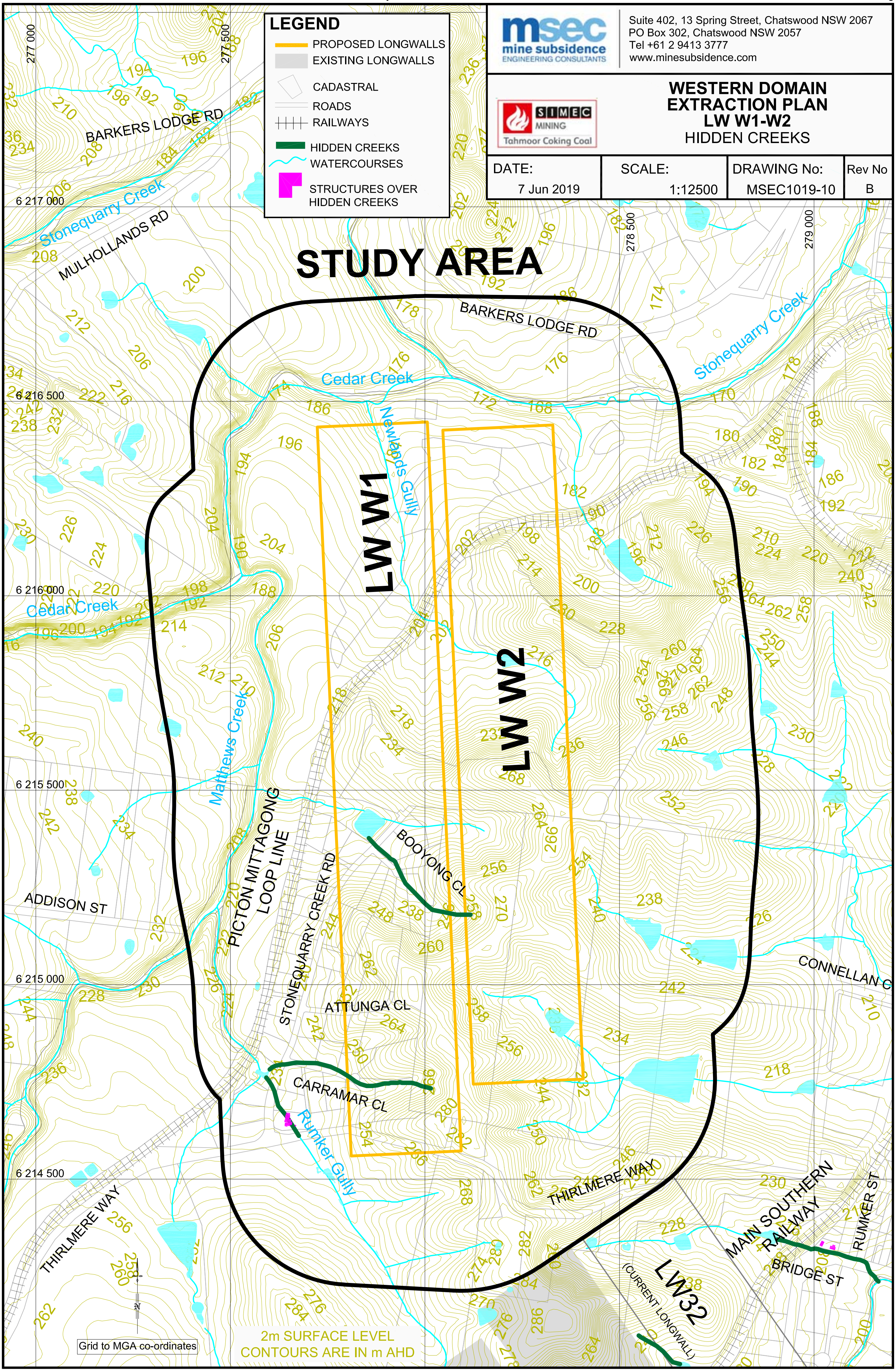

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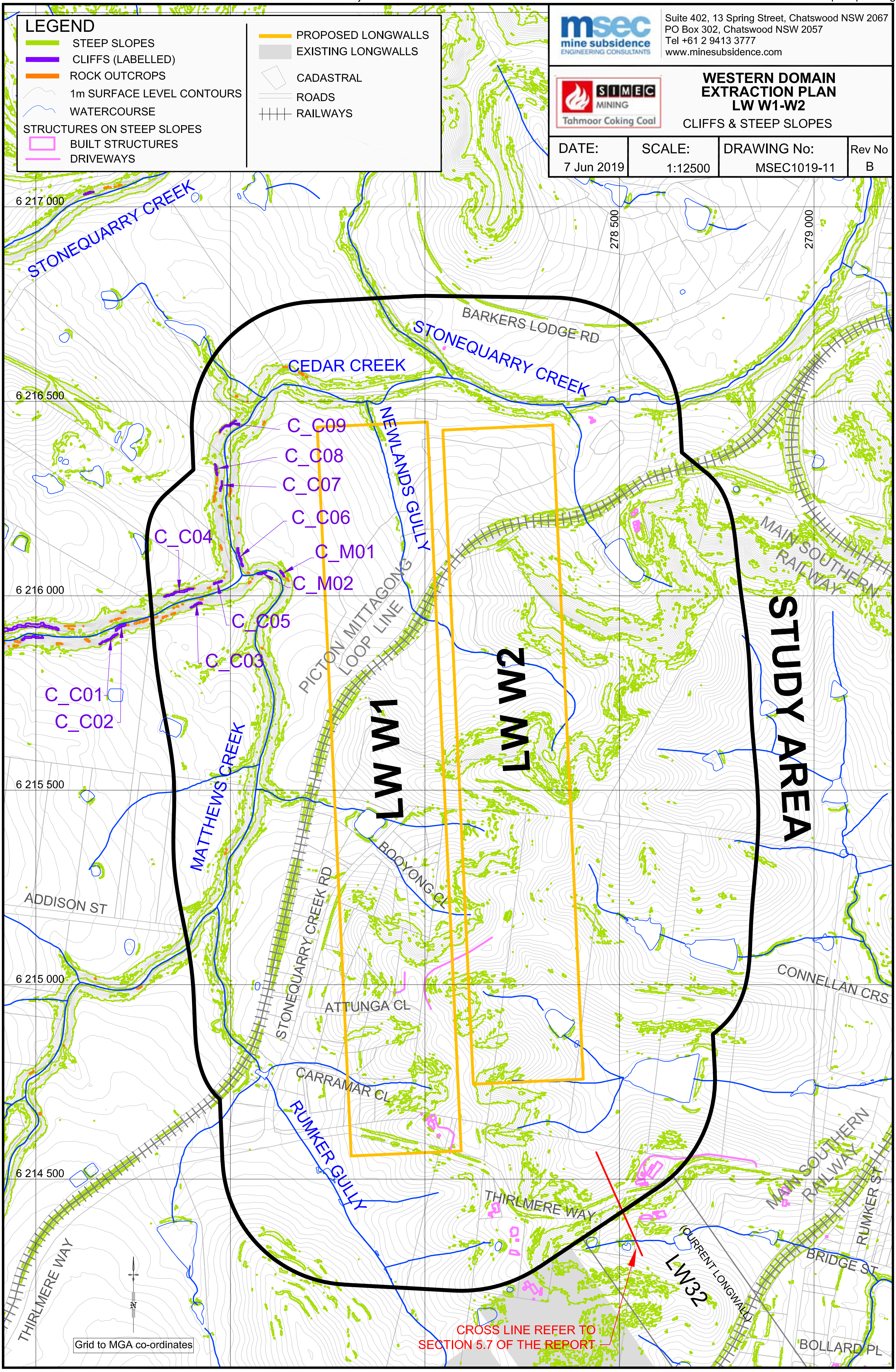

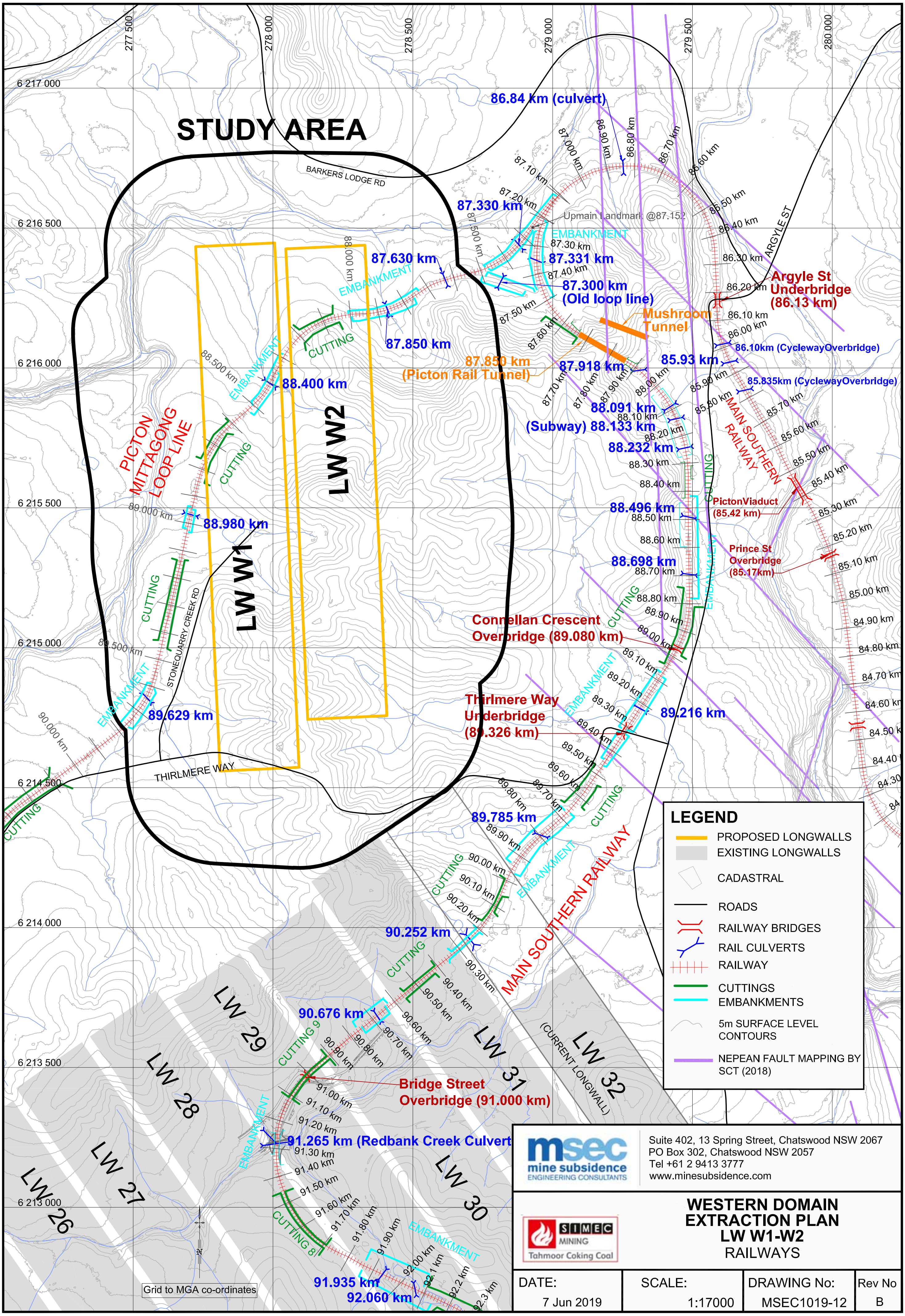

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WESTERN DOMAIN EXTRACTION PLAN LW W1-W2
RAILWAYS

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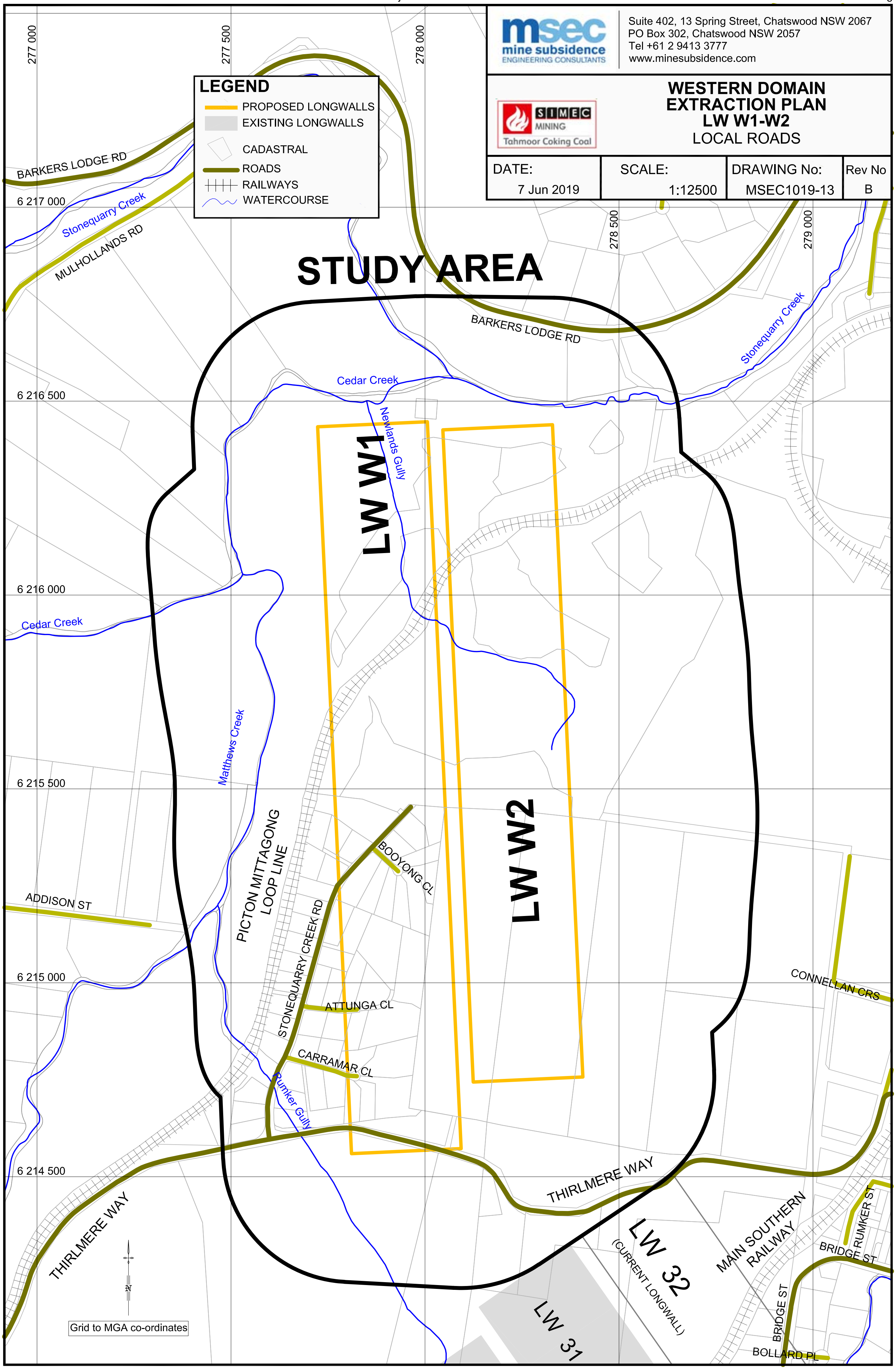

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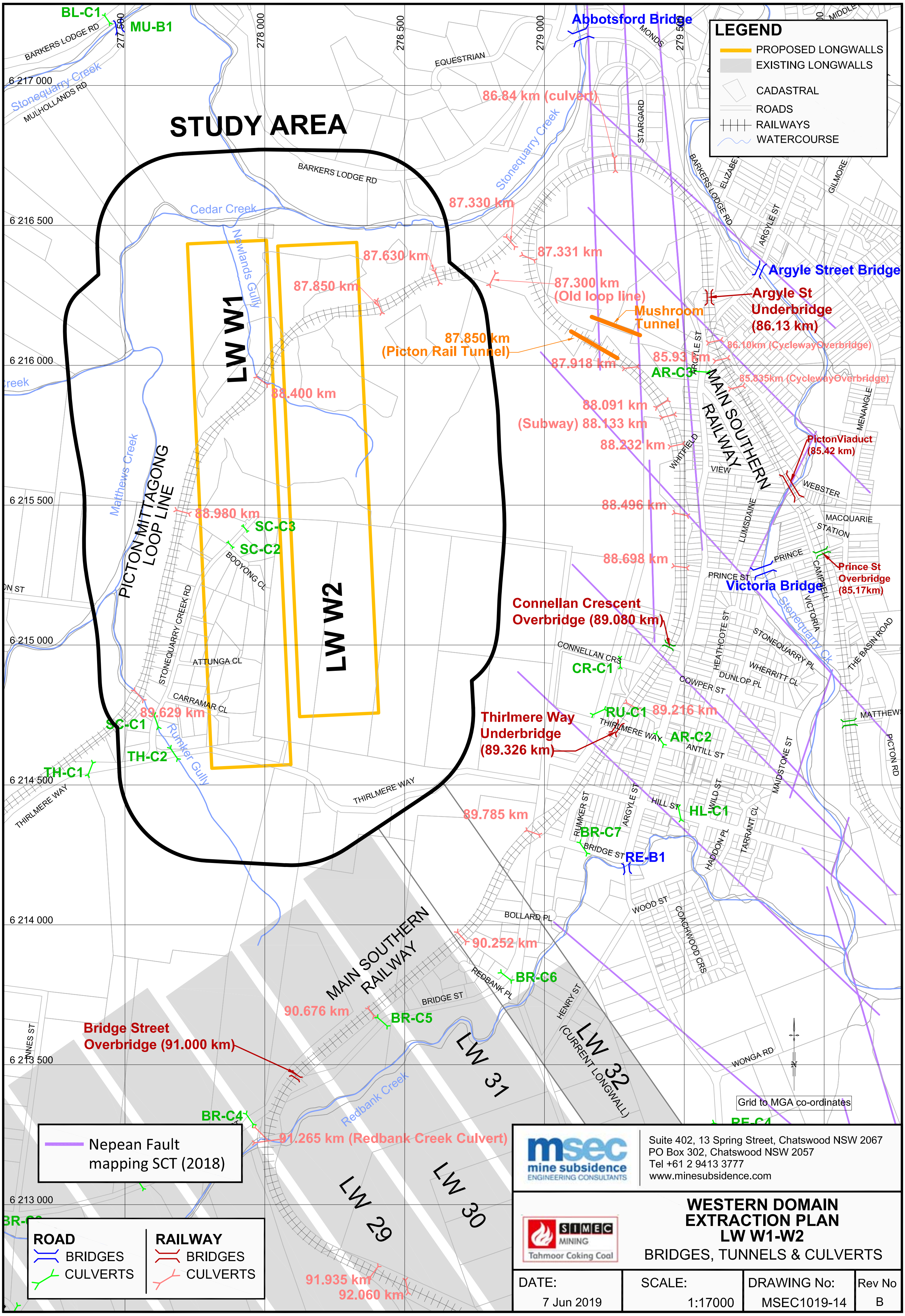

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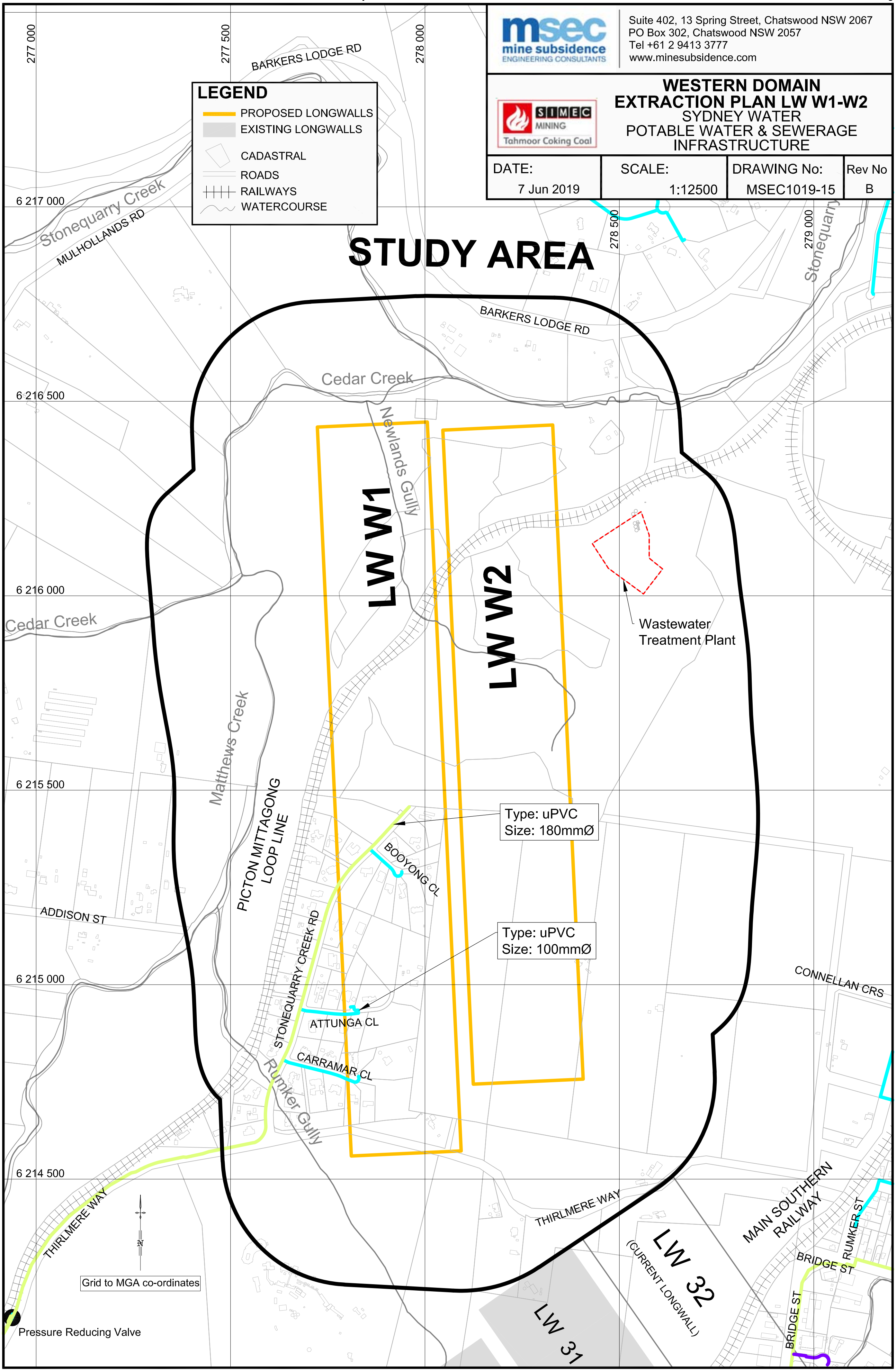

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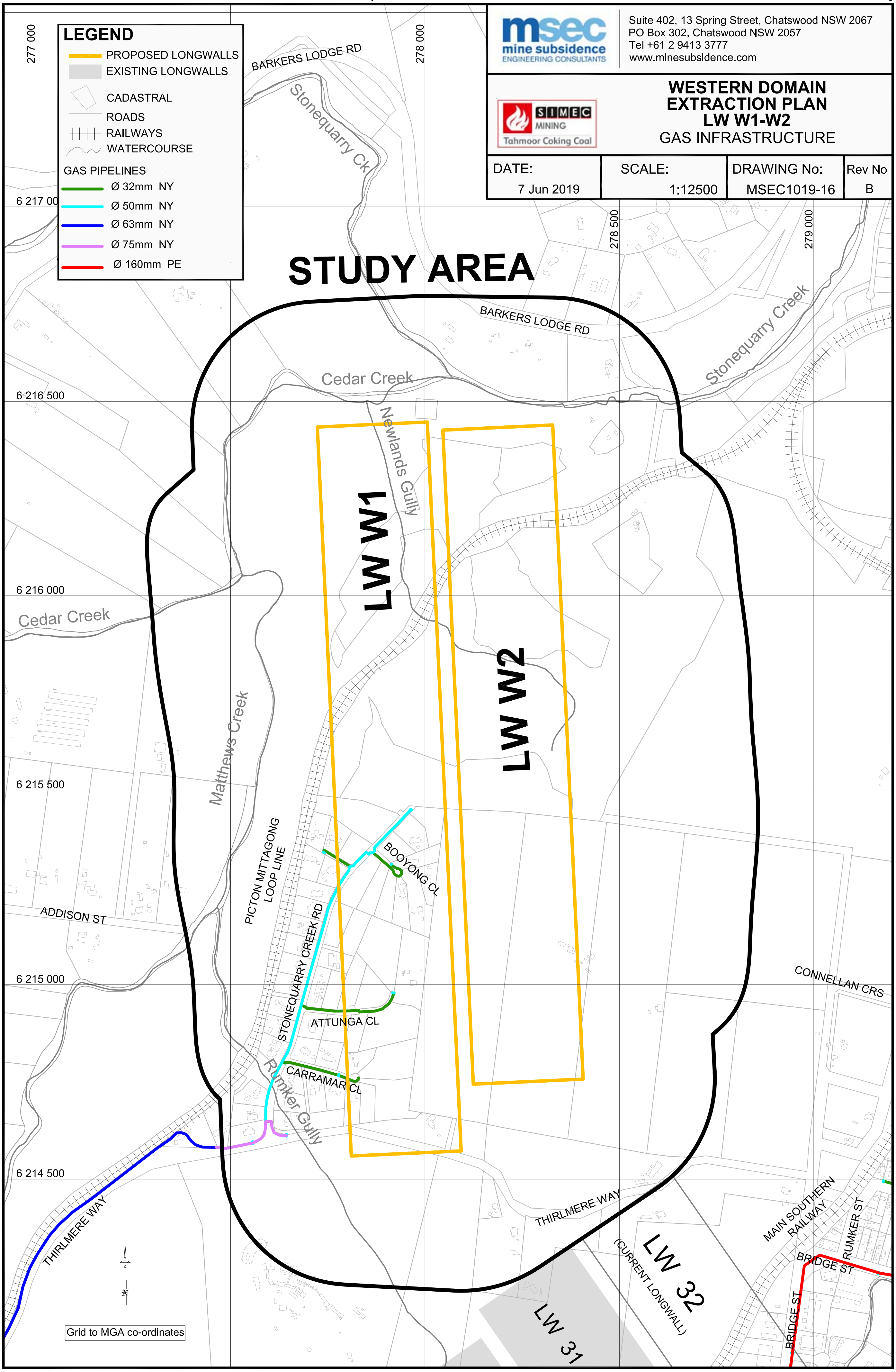

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WESTERN DOMAIN EXTRACTION PLAN LW W1-W2

GAS INFRASTRUCTURE

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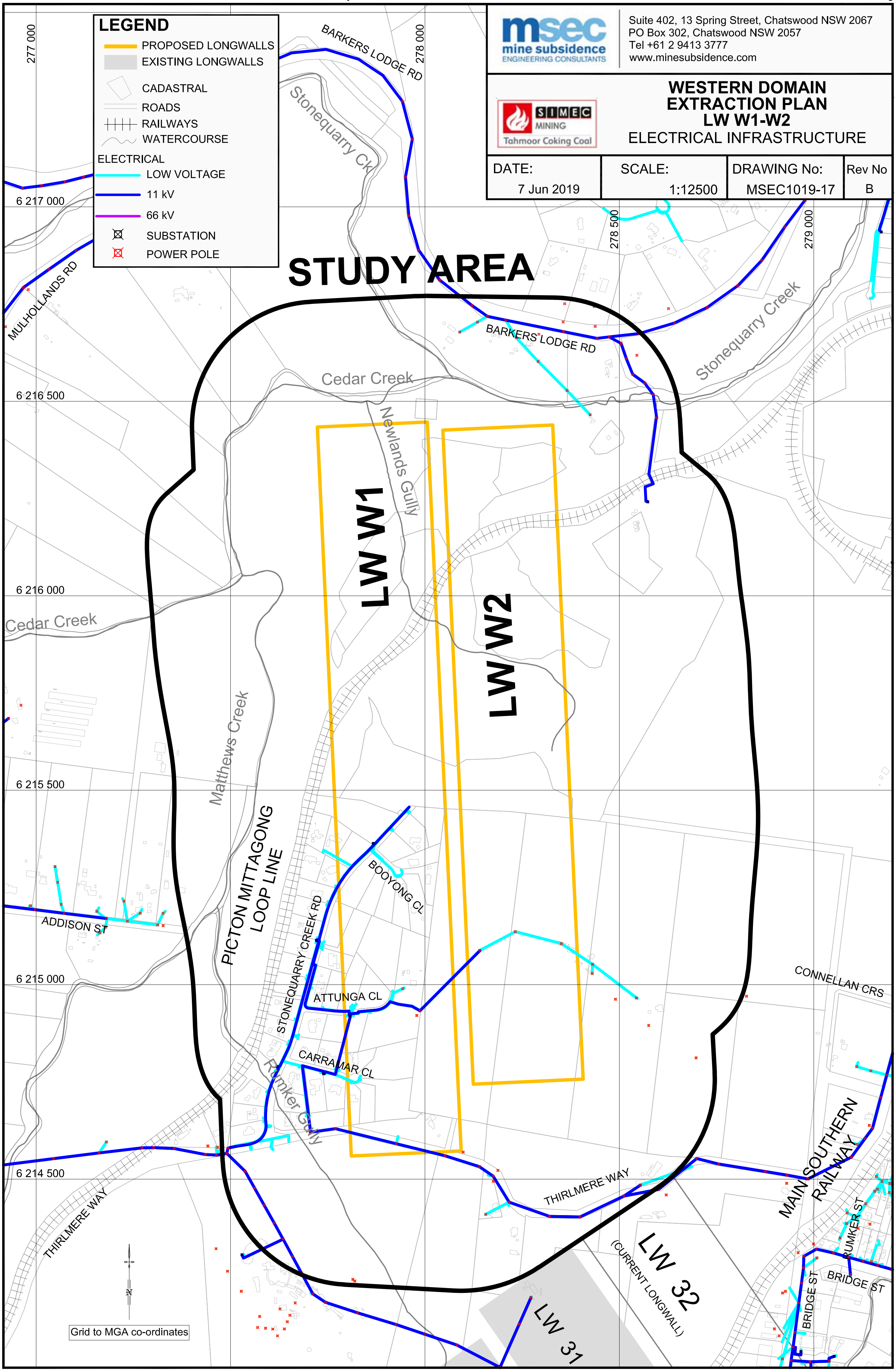

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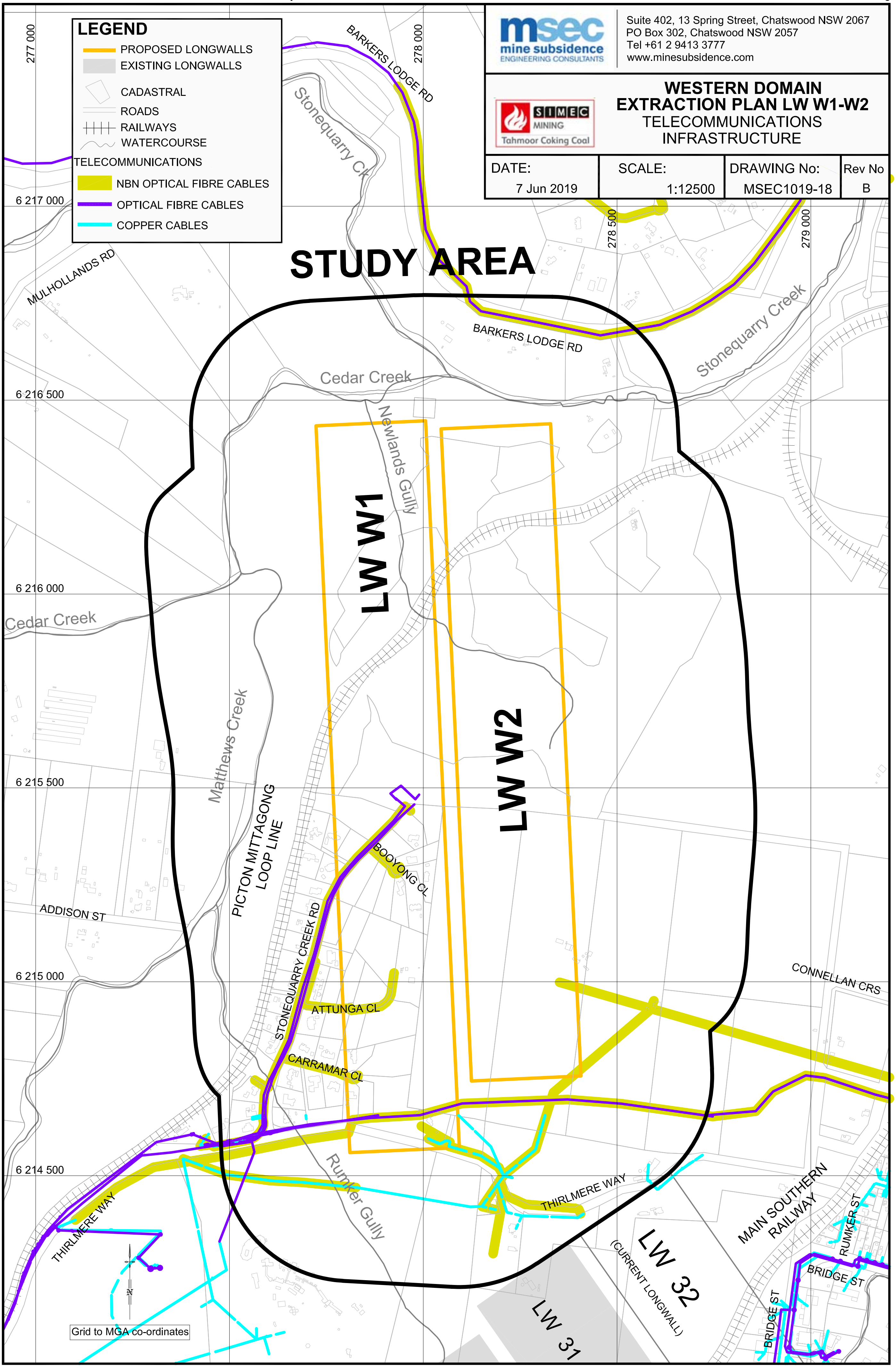

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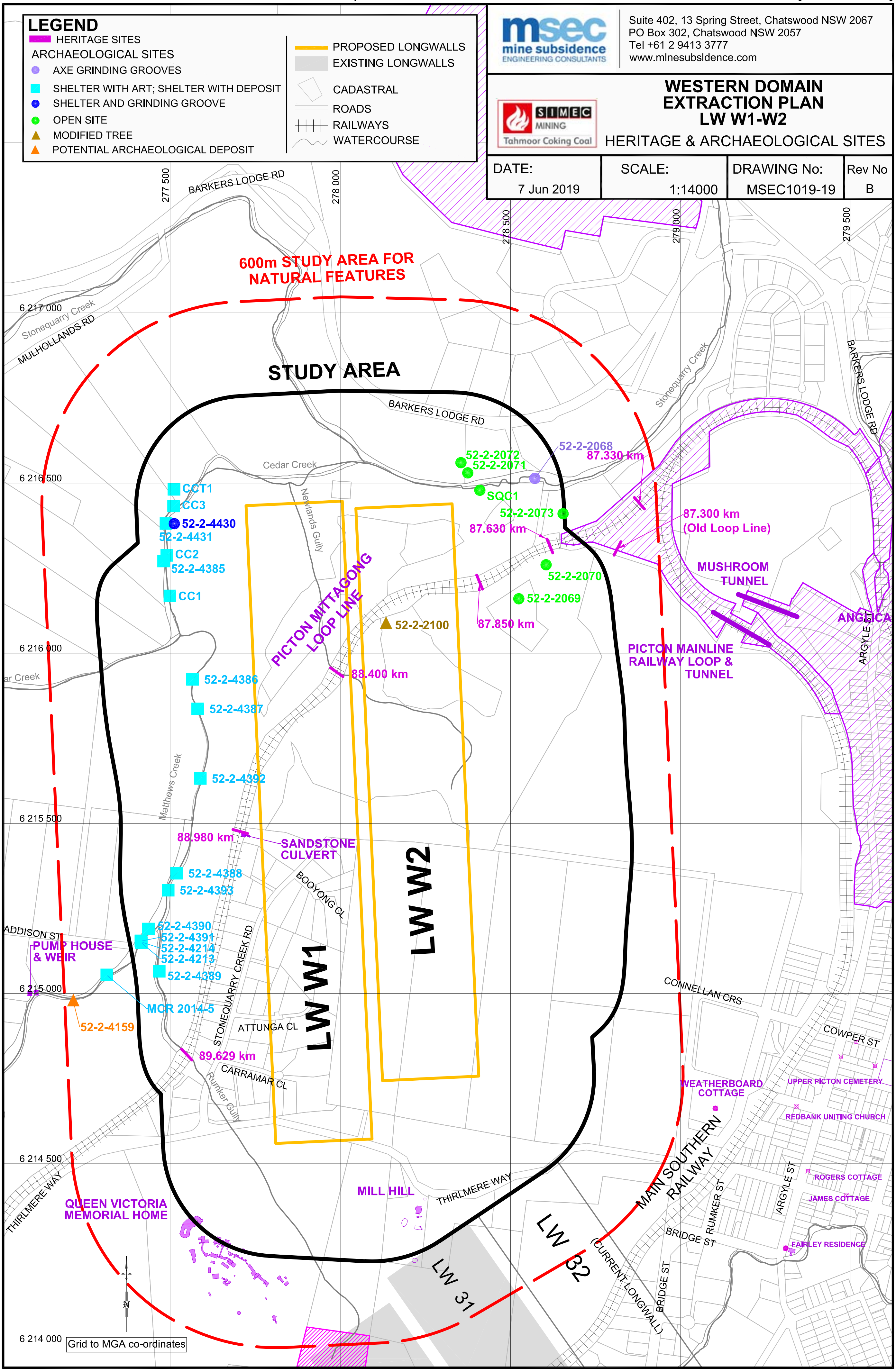

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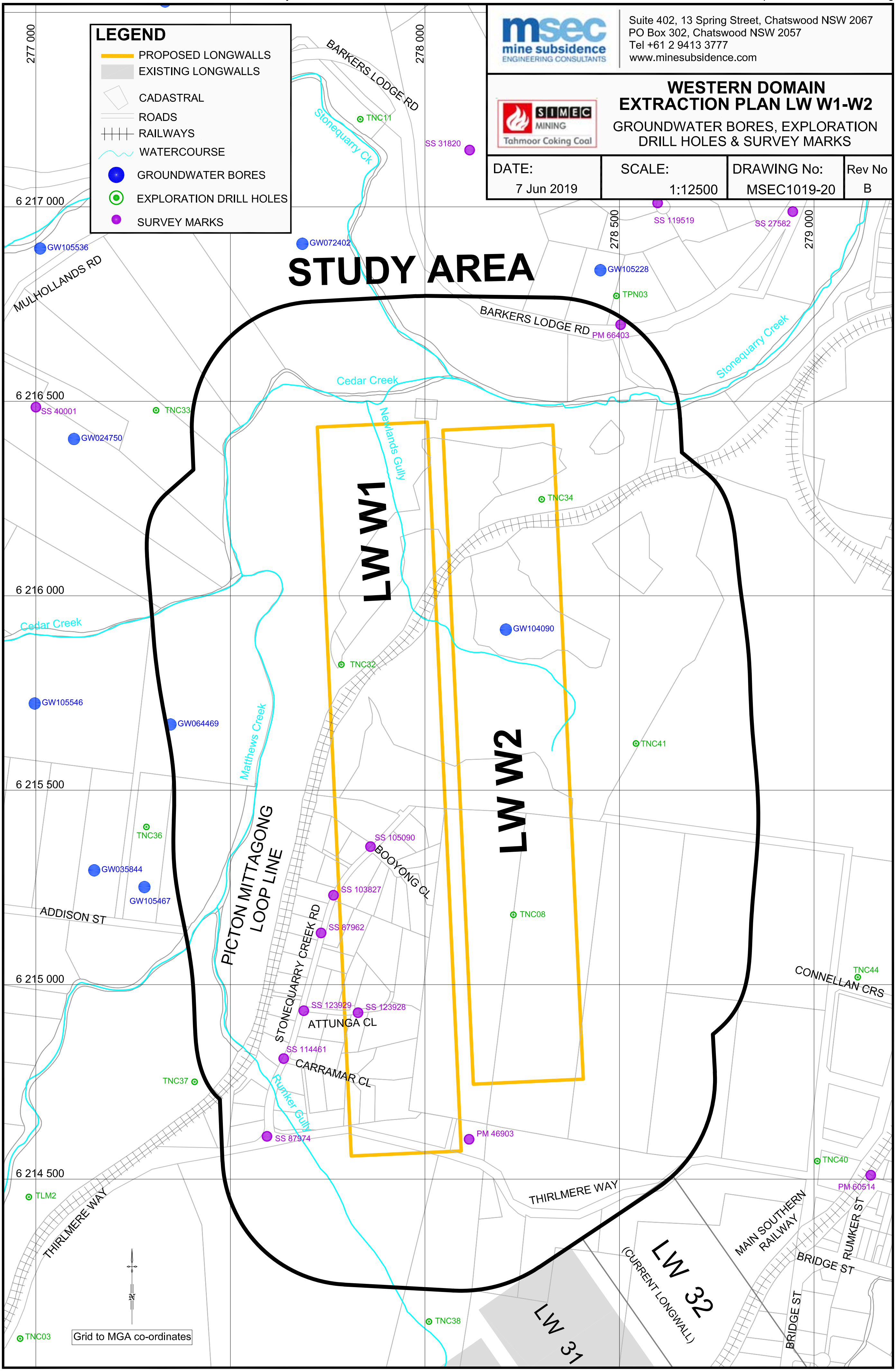

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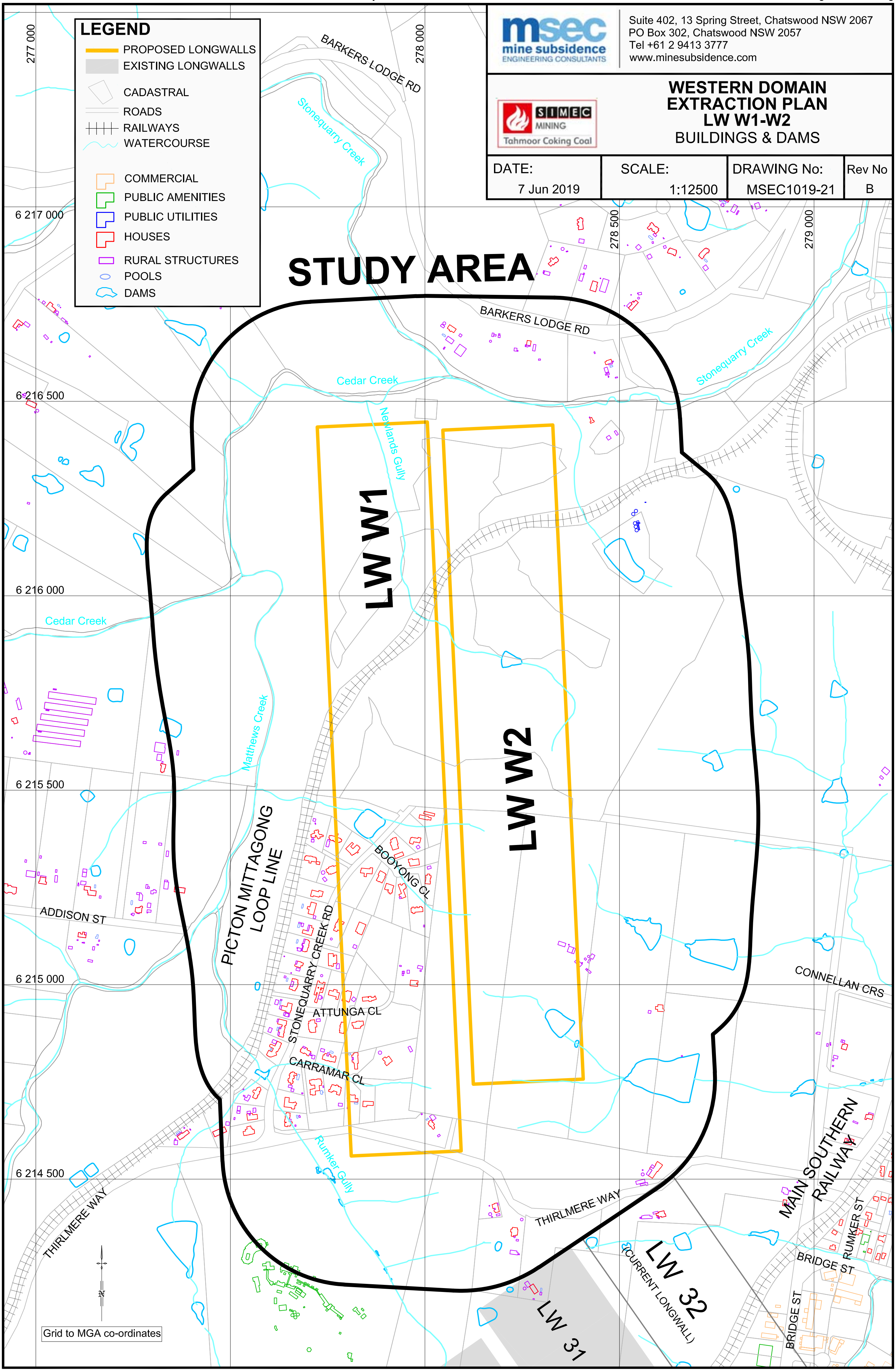

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BUILDINGS & DAMS

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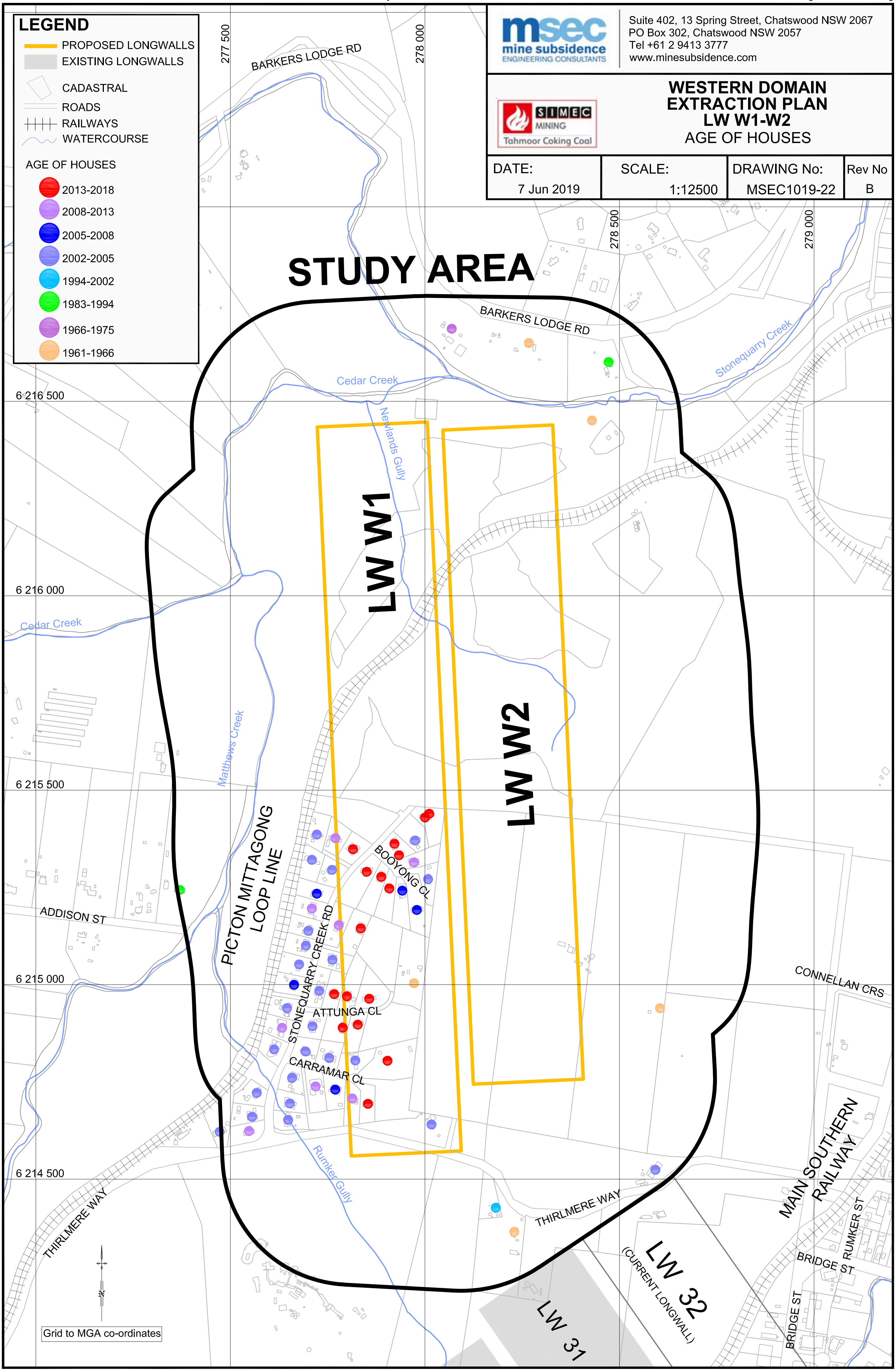

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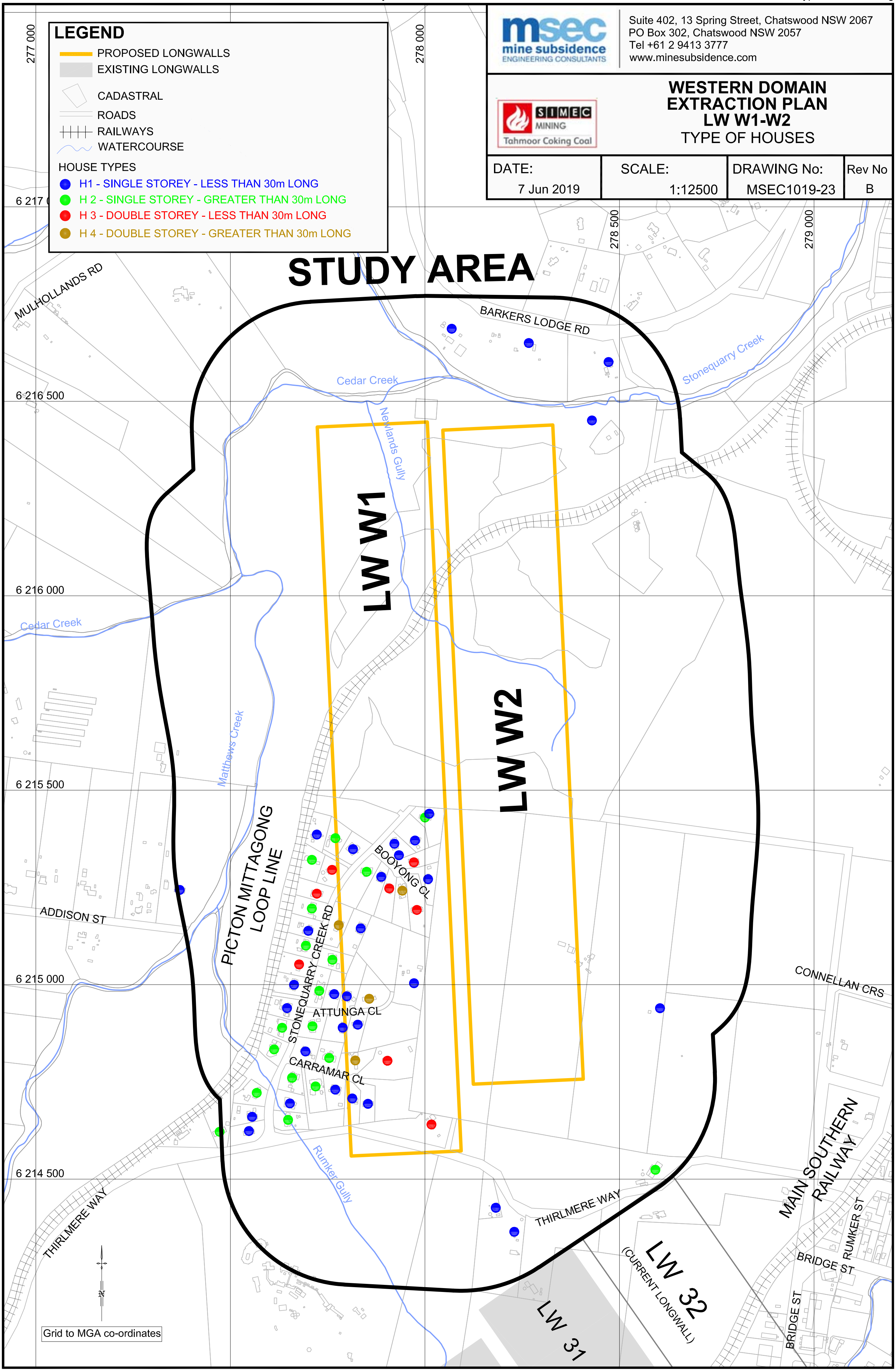

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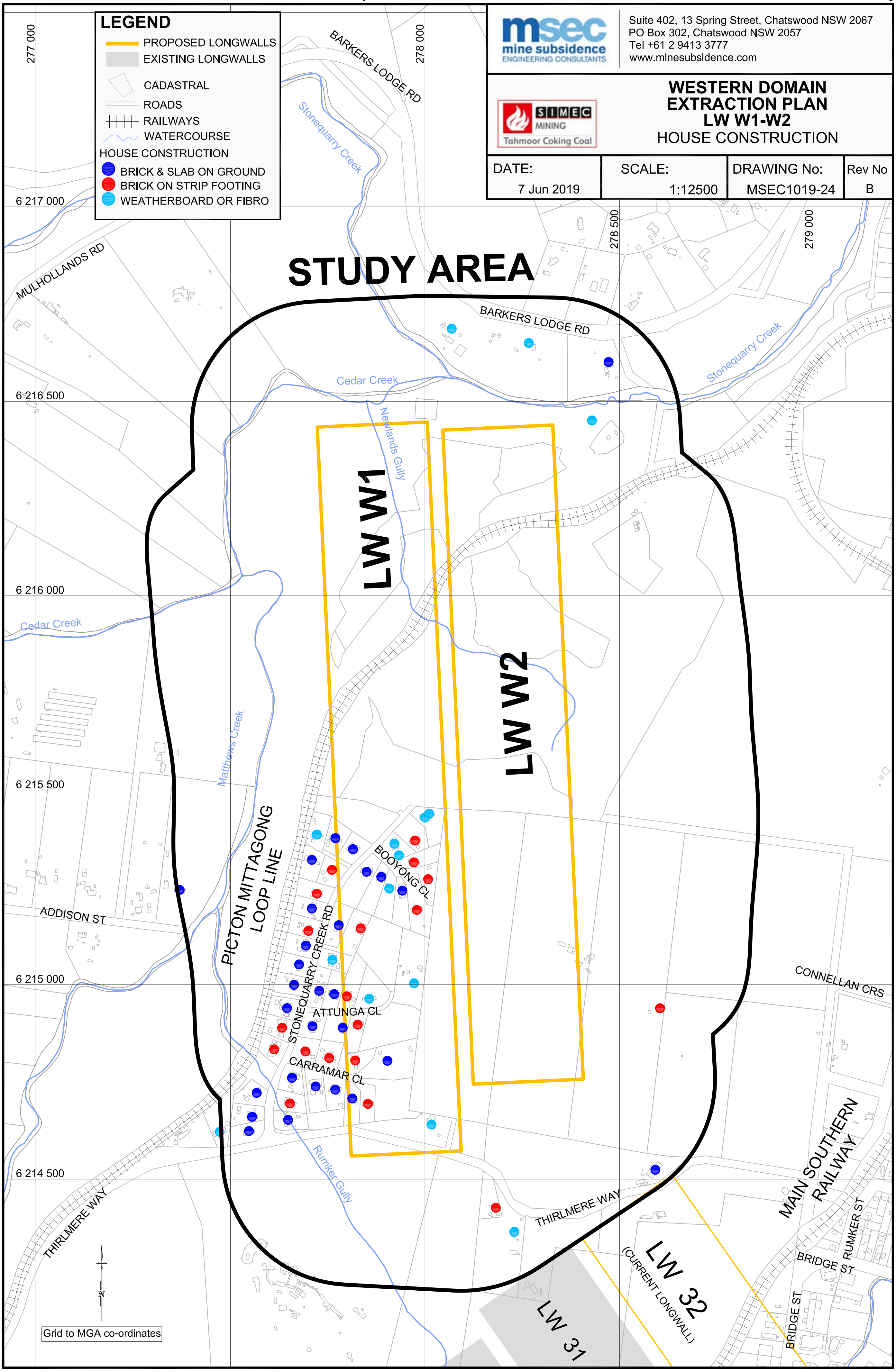
WESTERN DOMAIN EXTRACTION PLAN LW W1-W2
TYPE OF HOUSES

DATE:	SCALE:	DRAWING No:	Rev No
7 Jun 2019	1:12500	MSEC1019-23	B


LEGEND
PROPOSED LONGWALLS
EXISTING LONGWALLS
CADASTRAL
ROADS
RAILWAYS
WATERCOURSE
HOUSE CONSTRUCTION
BRICK & SLAB ON GROUND
BRICK ON STRIP FOOTING
WEATHERBOARD OR FIBRO
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SIMEC MINING Tahmoor Coking Coal
WESTERN DOMAIN
EXTRACTION PLAN
LW W1-W2
HOUSE CONSTRUCTION
DATE: 7 Jun 2019
SCALE: 1:12500
DRAWING No: MSEC1019-24
Rev No B
STUDY AREA
277 000
278 000
278 500
279 000
6 217 000
6 216 500
6 216 000
6 215 500
6 215 000
6 214 500
BARKERS LODGE RD
Stonequarry Creek
MULHOLLANDS RD
Cedar Creek
Newlands Gully
LW W1
LW W2
Matthews Creek
PICTON MITTAGONG LOOP LINE
ADDISON ST
BOOYONG CL
STONEQUARRY CREEK RD
ATTUNGA CL
CARRAMAR CL
Rumker Gully
CONNELLAN CRS
MAIN SOUTHERN RAILWAY
THIRLMERE WAY
LW 32 (CURRENT LONGWALL)
LW 31
RUMKER ST
BRIDGE ST
Grid to MGA co-ordinates

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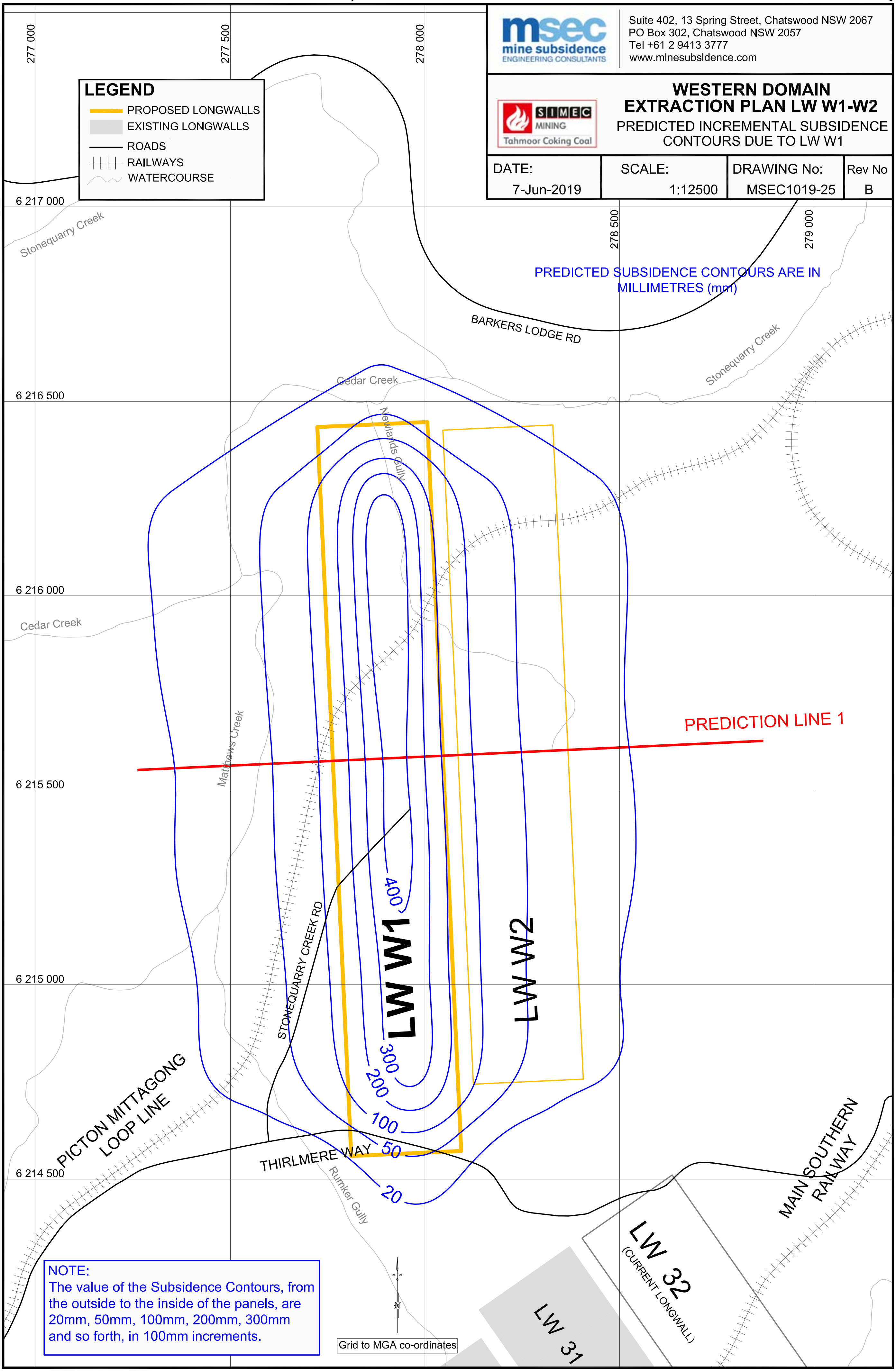

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WESTERN DOMAIN
EXTRACTION PLAN LW W1-W2
PREDICTED INCREMENTAL SUBSIDENCE CONTOURS DUE TO LW W1

DATE:	SCALE:	DRAWING No:	Rev No
7-Jun-2019	1:12500	MSEC1019-25	B

NOTE:
The value of the Subsidence Contours, from the outside to the inside of the panels, are 20mm, 50mm, 100mm, 200mm, 300mm and so forth, in 100mm increments.

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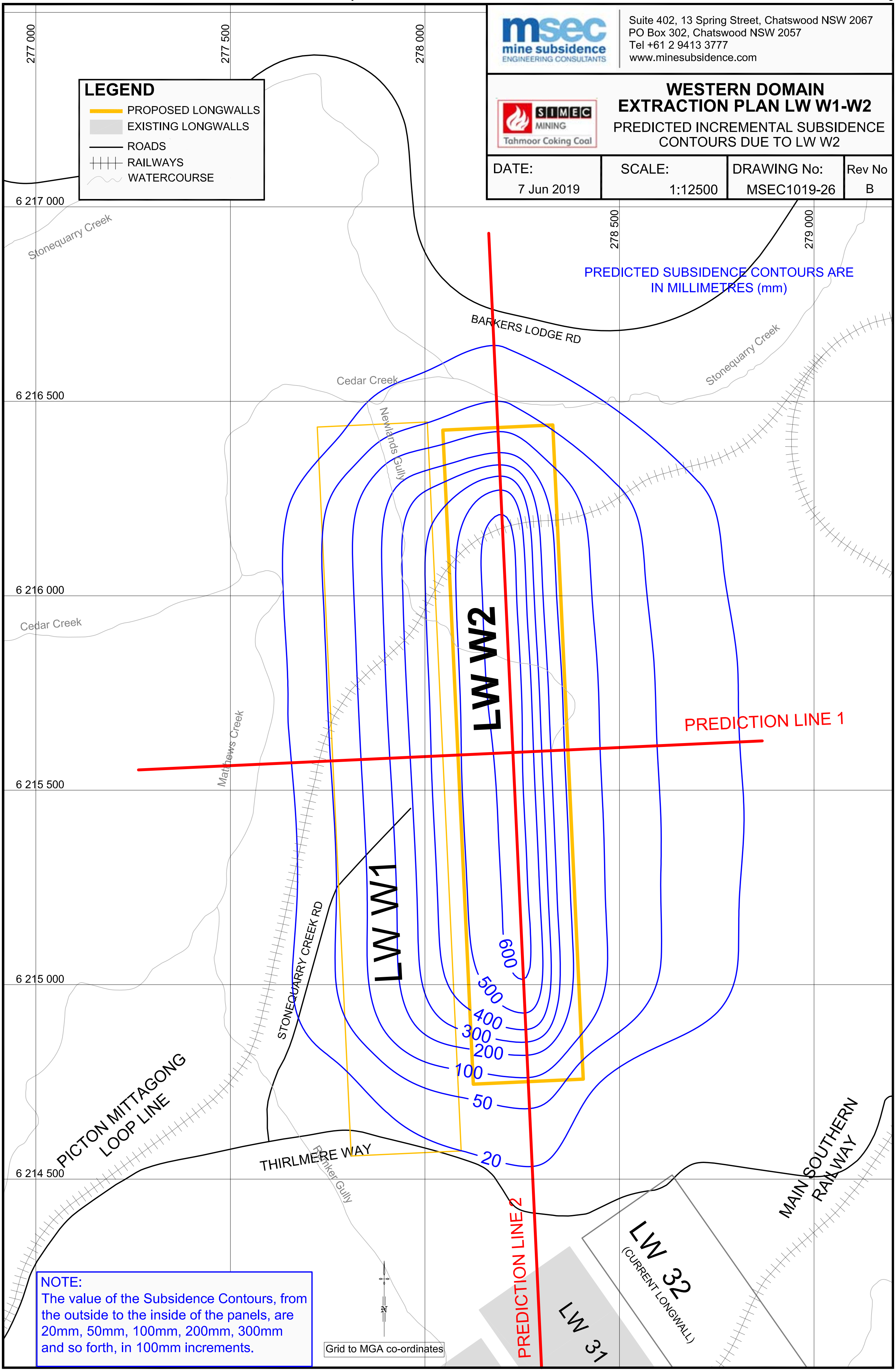
WESTERN DOMAIN EXTRACTION PLAN LW W1-W2

PREDICTED INCREMENTAL SUBSIDENCE CONTOURS DUE TO LW W2

DATE:	SCALE:	DRAWING No:	Rev No
7 Jun 2019	1:12500	MSEC1019-26	B



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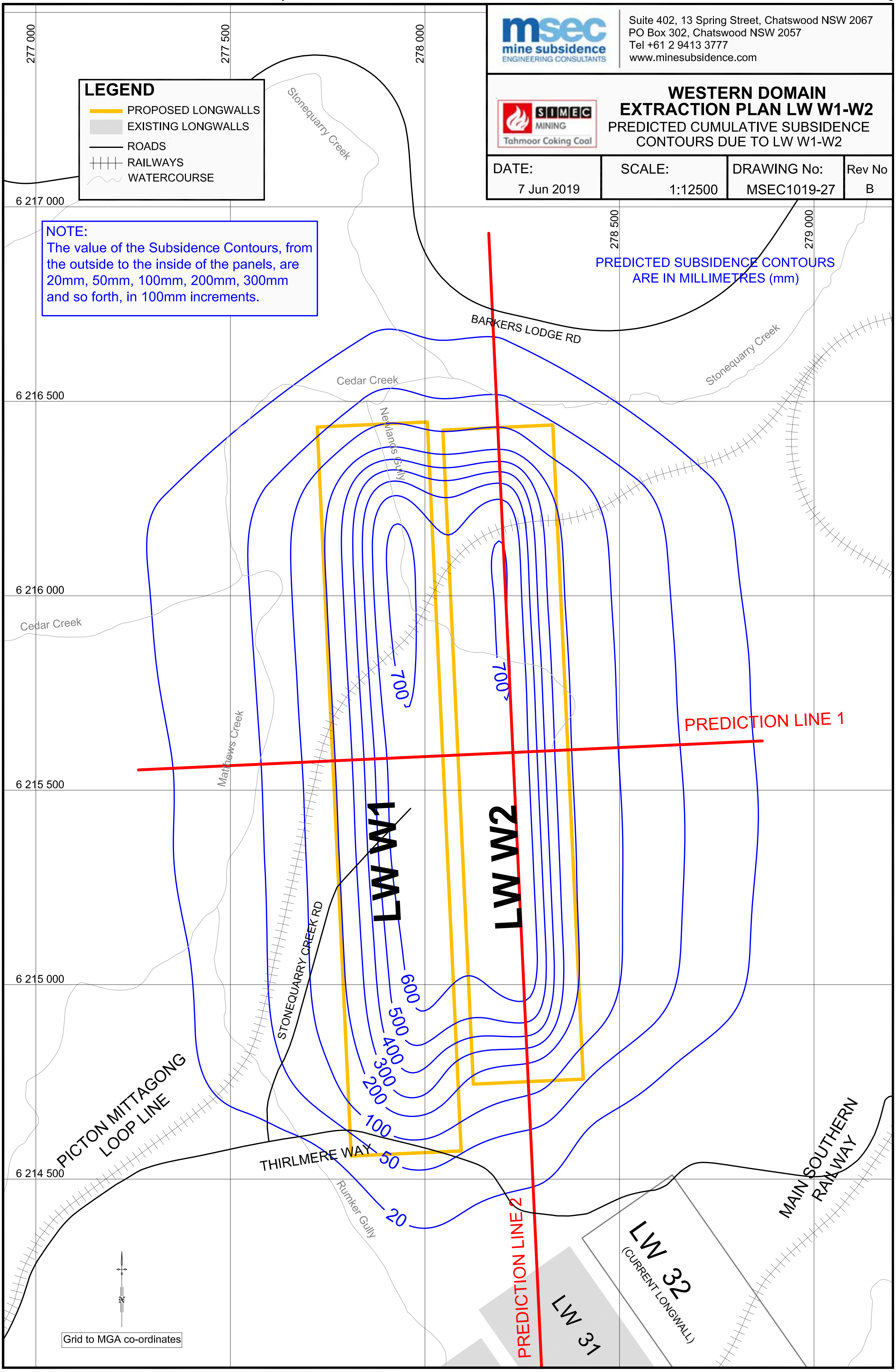

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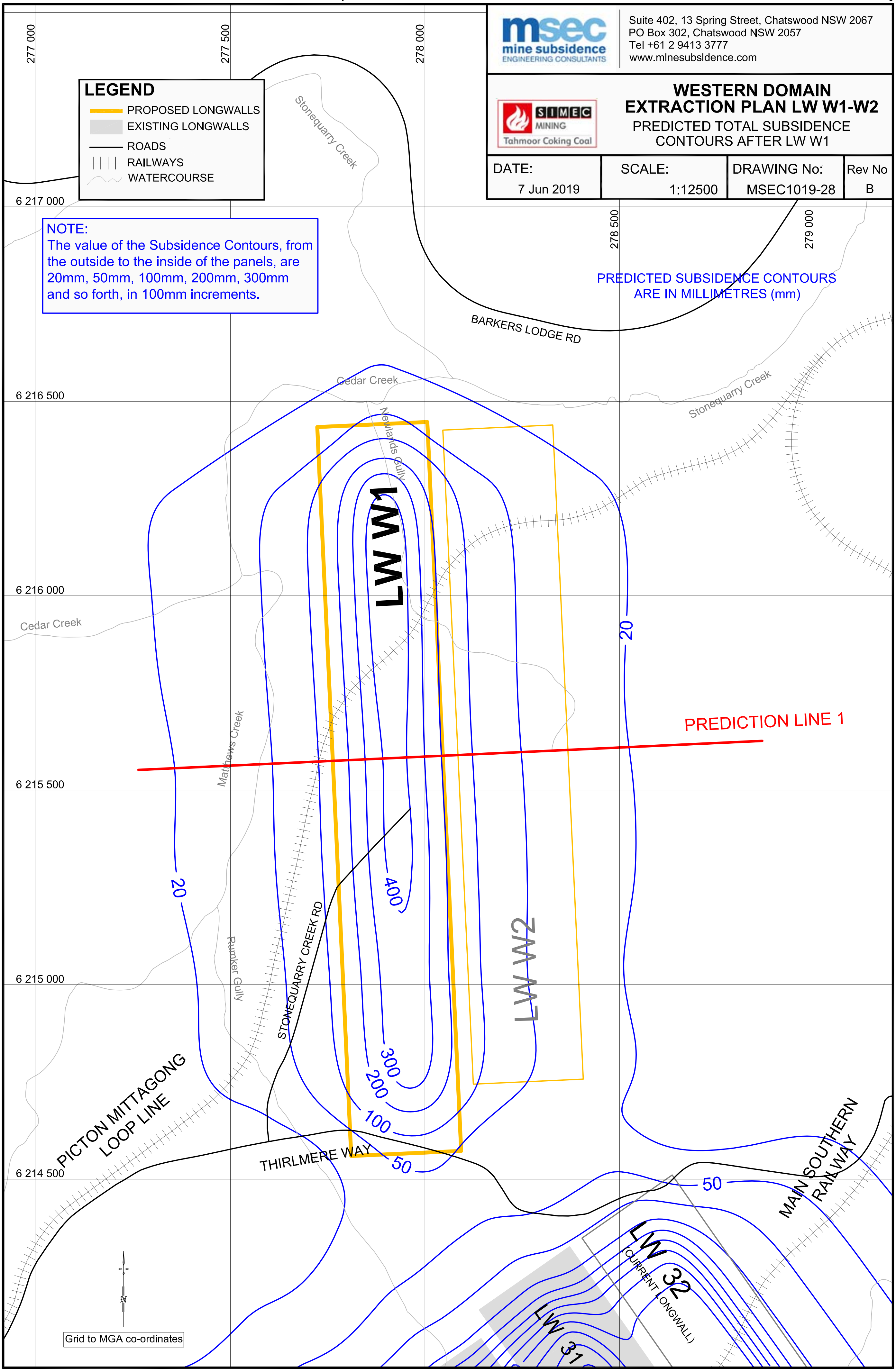

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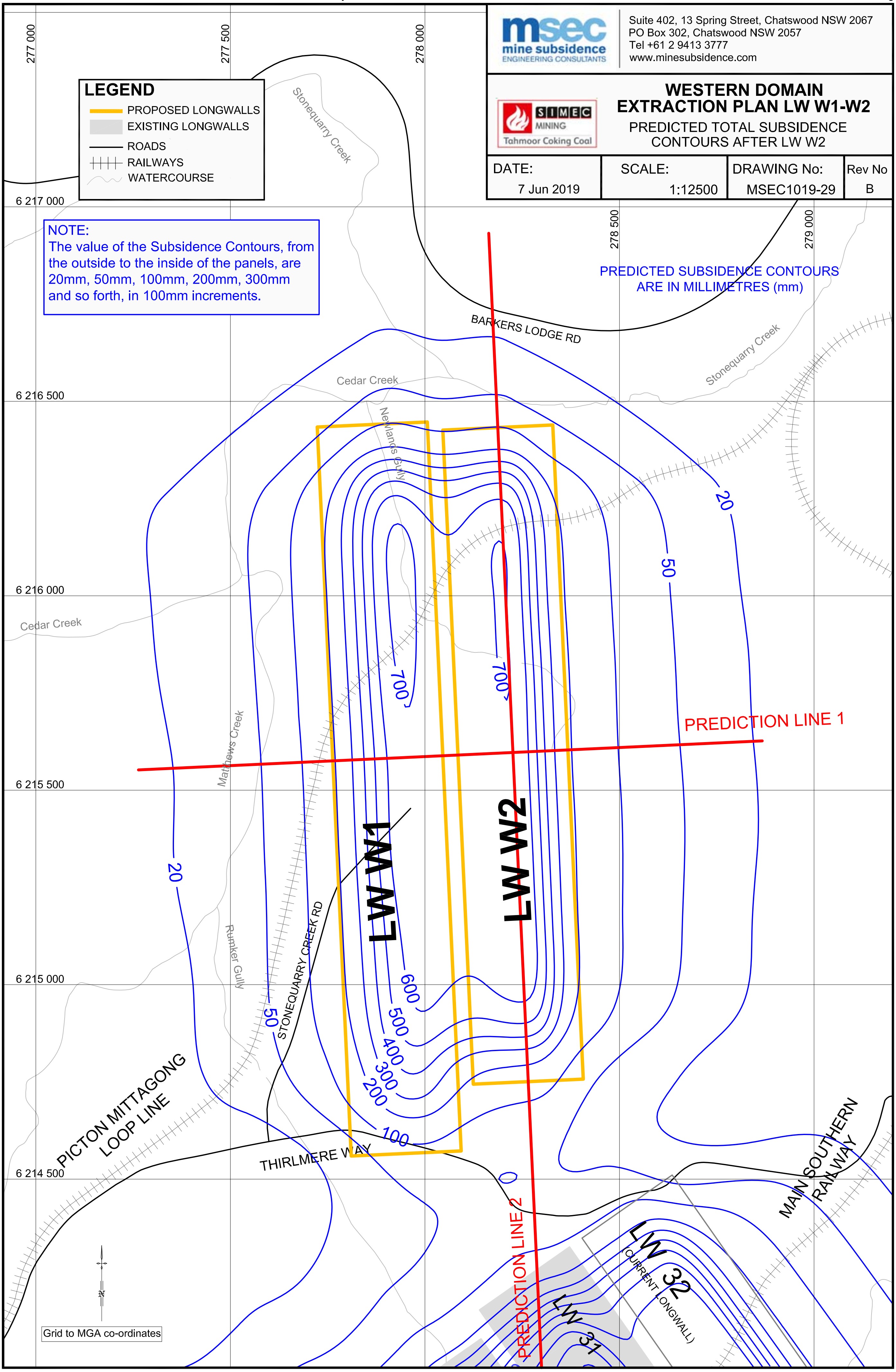

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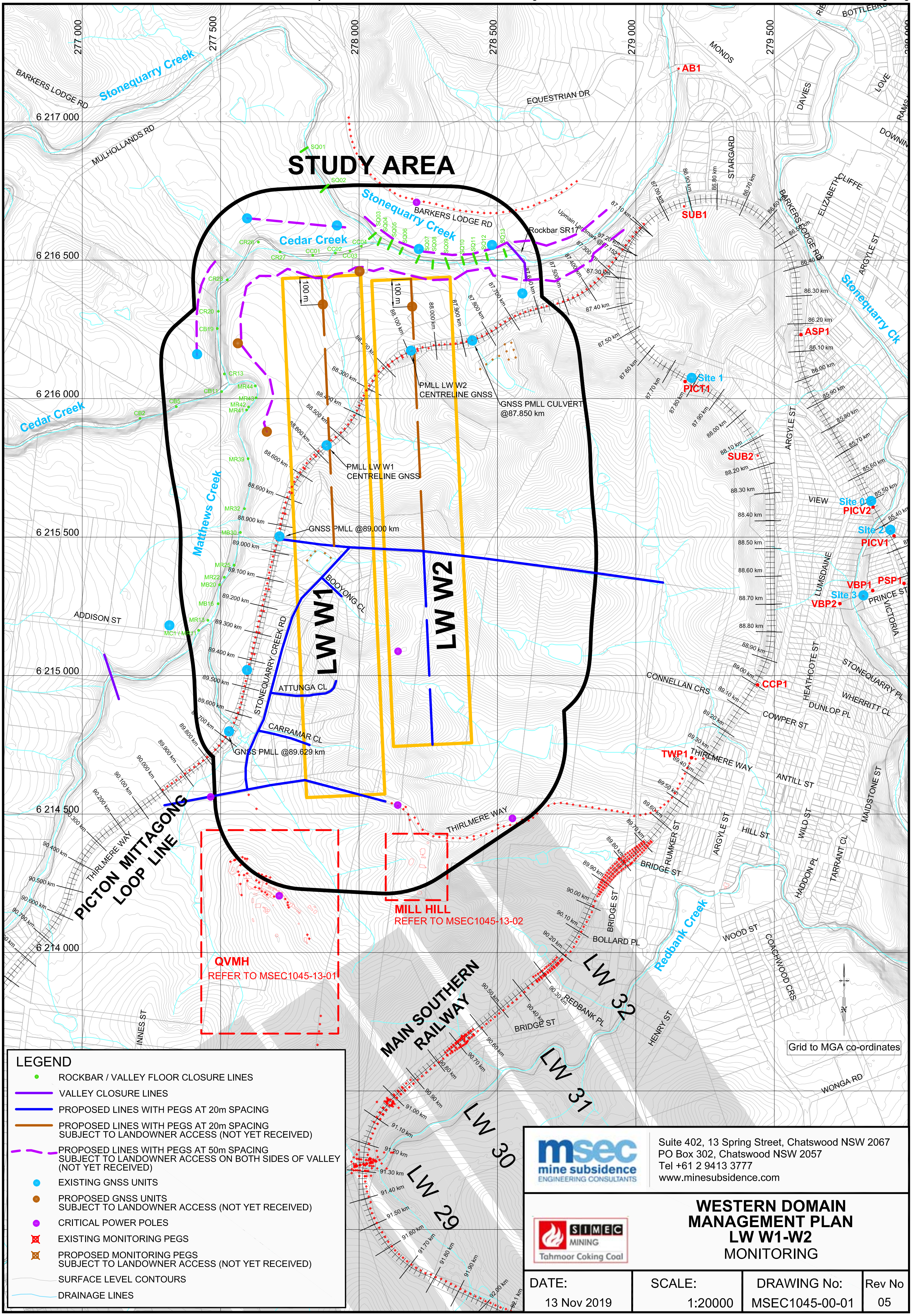

LEGEND

- ROCKBAR / VALLEY FLOOR CLOSURE LINES
- VALLEY CLOSURE LINES
- PROPOSED LINES WITH PEGS AT 20m SPACING
- PROPOSED LINES WITH PEGS AT 20m SPACING SUBJECT TO LANDOWNER ACCESS (NOT YET RECEIVED)
- PROPOSED LINES WITH PEGS AT 50m SPACING SUBJECT TO LANDOWNER ACCESS ON BOTH SIDES OF VALLEY (NOT YET RECEIVED)
- EXISTING GNSS UNITS
- PROPOSED GNSS UNITS SUBJECT TO LANDOWNER ACCESS (NOT YET RECEIVED)
- CRITICAL POWER POLES
- EXISTING MONITORING PEGS
- PROPOSED MONITORING PEGS SUBJECT TO LANDOWNER ACCESS (NOT YET RECEIVED)
- SURFACE LEVEL CONTOURS
- DRAINAGE LINES

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WESTERN DOMAIN MANAGEMENT PLAN LW W1-W2 MONITORING

DATE:	SCALE:	DRAWING No:	Rev No
13 Nov 2019	1:20000	MSEC1045-00-01	05