METROPOLITAN COAL LONGWALLS 305-307

SUBSIDENCE REPORT




Peabody

METROPOLITAN COAL PROJECT:

Metropolitan Mine – Longwalls 305 to 307

Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Extraction Plan

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Report produced to:- Support the Extraction Plan for submission to the Department of Planning, Industry and Environment (DPIE).

Associated reports:-

MSEC285 (Revision C) – Metropolitan Colliery - The Prediction of Subsidence Parameters and the Assessment of Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Proposed Extraction of Longwalls 20 to 44 at Metropolitan Colliery in Support of a Part 3A Application.

MSEC403 (May 2009) – Metropolitan Colliery – Preferred Project Layout (Longwalls 20 to 27 and 301 to 317) Technical discussion on Proposed Modification of Longwall Layout Orientation.

MSEC487 (Revision A, August 2013) – Metropolitan Mine – Longwalls 23 to 27 Subsidence Predictions and Impact Assessments for the Natural and Built Features in support of the Extraction Plan.

MSEC736-02 (Revision A, April 2015) – Metropolitan Colliery – Proposed Longwalls 301 to 317 – Technical Discussion on Proposed Modification of Preferred Project Layout.

MSEC846 (Revision A, October 2016) – Metropolitan Mine – Longwalls 301 to 303 – Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Extraction Plan.

MSEC984 (Revision A, September 2018) – Metropolitan Mine – Longwalls 301 to 303 – Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Extraction Plan.

MSEC958 (Revision C, October 2018) – Metropolitan Coal – Report on Subsidence Predictions and Impact Assessments in support of a Request for a Revised Longwalls 305 to 307 to 306 Layout.

MSEC1020-02 (February 2019) – Metropolitan LW303 – Updated Predictions and Trigger Action Response Plan for the Eastern Tributary

MSEC1009 (Revision B, March 2019) – Metropolitan Coal – Report on Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Extraction Plan.

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

Introduction to Longwall Mining and Subsidence (Revision A)

General Discussion of Mine Subsidence Ground Movements (Revision A)

Mine Subsidence Damage to Building Structures (Revision A)

Metropolitan Coal proposes to continue its underground coal mining operations within the Bulli Seam at Metropolitan Colliery, which is located in the Southern Coalfield of New South Wales. Metropolitan Coal proposes to extract the next longwalls in the current series, referred to as Longwalls 305 to 307.

Metropolitan Coal was granted Project Approval 08_0149 by the Minister for Planning on the 22nd June 2009. The Project Approval included a layout for Longwalls 301 to 317 referred to as the Preferred Project Layout. Longwalls 305 to 307 based on the *Preferred Project Layout* comprised a 163 m panel width (void) with 45 m pillars (solid) beyond 500 m from the Woronora Reservoir, and a 138 m panel width (void) with 70 m pillars (solid) within 500 m of the Woronora Reservoir.

In April 2015, Metropolitan Coal received approval from the Department of Planning, Industry and Environment (DPIE) for changes to Longwalls 301 to 317, by rotating them in an anti-clockwise direction by approximately six degrees.

The Metropolitan Coal Longwalls 301-303 Extraction Plan (September 2018) describes the amendments that have been made to the Longwalls 301-303 layout from 2016 to 2018. In particular, the Longwalls 301-303 Extraction Plan (September 2018) sought approval for the secondary extraction of Longwall 303 at a length of 1,600 m, which included shortening of the finishing end of Longwall 303 by 98 m adjacent to the Eastern Tributary. In November 2018, the DPIE approved secondary extraction of the first 1,143 m of Longwall 303. Metropolitan Coal has applied for approval for an additional 182 m of secondary extraction in Longwall 303 for a total length of 1,325 m. MSEC prepared the letter Report No. MSEC1020-02 (February 2019) in support of the application.

In April 2019, Metropolitan Coal submitted an application to the DPIE to extract Longwall 304 to a void length of 1,286 m. MSEC prepared the letter Report No. MSEC1009 (March 2019) in support of the application. Approval for the extraction of Longwall 304 was granted on 16 July 2019.

MSEC has prepared this report to support the Longwalls 305 to 307 Extraction Plan.

A comparison of predicted subsidence effects and impact assessments has been made for the natural and built features resulting from extraction of Longwalls 305 to 307 (including the effects of the previous LW301 to LW304), based on the Extraction Plan Layout, with the Preferred Project Layout for these longwalls at Metropolitan Colliery.

The main changes made to the longwalls for the Extraction Plan Layout compared with the Preferred Project Layout include an approximate 6 degree anti-clockwise rotation, a reduction in longwall lengths and a narrowing of the pillar widths of Longwalls 301-304.

The changes from the Preferred Project Layout generally result in a reduction in predicted subsidence parameters where the longwalls have been shortened, and an increase in predicted subsidence parameters where pillar widths have been reduced. Where there is an increase in the predicted subsidence parameters, based on the Extraction Plan Layout, the magnitudes of the maximum predicted subsidence parameters are similar to the maxima predicted elsewhere above the Preferred Project Layout. As a result, the overall impact assessments for the natural and built features based on the Extraction Plan Layout are unchanged, or reduce compared to those based on the Preferred Project Layout.

The management and monitoring plans that have been developed for natural and built features have been updated for Longwalls 305 to 307.

Monitoring and management strategies have been revised for the following built features as part of the Extraction Plan process for Longwalls 305 to 307, in consideration of the results of additional assessments and consultation with the infrastructure owners:

- NSW Health - Garrawarra;
- Sydney Water – water and sewer pipelines;
- Roads and Maritime Services - M1 Princes Motorway and bridges;
- Wollongong City Council - Old Princes Highway;
- Wollongong City Council - Waterfall Cemetery;
- Telstra - telecommunication infrastructure;
- Optus - telecommunication infrastructure;
- Vocus - telecommunication infrastructure;
- Axicom - telecommunication infrastructure;
- Sydney Trains - Illawarra Railway and infrastructure;
- TransGrid – 330 kV transmission line infrastructure; and
- Endeavour Energy – 132 kV transmission line infrastructure and other high voltage powerline infrastructure.

The monitoring and management strategies for built features aim to achieve the performance measure of safe, serviceable and repairable (unless the owner, authority and Subsidence Advisory NSW agree otherwise in writing).

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Tables

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Figures

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

Drawings

Drawings referred to in this report are included in Appendix E at the end of this report.

1.1. Background

Metropolitan Coal is a wholly owned subsidiary of Peabody Energy Pty Limited (Peabody) and operates Metropolitan Colliery (the Colliery), which is located in the Southern Coalfield of New South Wales (NSW). Metropolitan Coal has extracted Longwalls 1 to 27, 301 to 303, at the Colliery, and it is currently mining Longwall 304.

Metropolitan Coal submitted the Metropolitan Coal Project Environmental Assessment for the extraction of Longwalls 20 to 44 at the Colliery in 2008 (Helensburgh Coal Pty Ltd, 2008). Mine Subsidence Engineering Consultants (MSEC) prepared Report No. MSEC285 (Rev. C) that provided the subsidence predictions and impact assessments for these longwalls in support of the Environmental Assessment.

Metropolitan Coal submitted the Metropolitan Coal Project Preferred Project Report (Helensburgh Coal, 2009), with changes to the layout used in the Environmental Assessment. MSEC prepared Report No. MSEC403 that provided an assessment of the Preferred Project Layout in support of the Preferred Project Report. The longwalls based on the *Preferred Project Layout* comprised 163 m panel widths (void) with 45 m pillars (solid) beyond 500 m from the Woronora Reservoir, and 138 m panel widths (void) with 70 m pillars (solid) within 500 m of the Woronora Reservoir. The Minister for Planning granted Peabody approval for Preferred Project Layout on the 22nd June 2009 (Project Approval 08_0149).

Metropolitan Coal subsequently modified the northern series of longwalls, now referred to as Longwalls 301 to 317, by rotating them in an anti-clockwise direction by approximately six degrees. MSEC prepared the letter Report No. MSEC736-02 (Rev. A) that provided the updated subsidence predictions and impact assessments in support of the application. Metropolitan Coal received approval from the Department of Planning, Industry and Environment (DPIE) for the orientation change in April 2015.

The Metropolitan Coal Longwalls 301-303 Extraction Plan (September 2018) describes the amendments that have been made to the Longwalls 301-303 layout from 2016 to 2018. In particular, the Longwalls 301-303 Extraction Plan (September 2018) sought approval for the secondary extraction of Longwall 303 at a length of 1,600 m, which included shortening of the finishing end of Longwall 303 by 98 m adjacent to the Eastern Tributary. In November 2018, the DPIE approved secondary extraction of the first 1,143 m of Longwall 303. This approval allows Metropolitan Coal to seek further approval for any additional secondary extraction beyond 1,143 m in Longwall 303. Metropolitan Coal has applied for approval for an additional 182 m of secondary extraction in Longwall 303 for a total length of 1,325 m. MSEC prepared the letter Report No. MSEC1020-02 (February 2019) in support of the application.

In April 2019, Metropolitan Coal submitted an application to the DPIE to extract Longwall 304 to a void length of 1,286 m. MSEC prepared the letter Report No. MSEC1009 (March 2019) in support of the application. Approval for the extraction of Longwall 304 was granted on 16 July 2019.

MSEC has prepared this report to support the Longwalls 305 to 307 Extraction Plan.

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

Chapter 3 includes overviews of the mine subsidence parameters and the methods that have been used to predict the mine subsidence movements resulting from the extraction of the longwalls.

Chapter 4 provides the maximum predicted subsidence parameters resulting from the extraction of Longwalls 305 to 307 (including the effects of the previous LW301 to LW304) based on the Extraction Plan Layout. Comparisons of these predictions with the maxima based on the Preferred Project Layout are also provided in this chapter.

Chapters 5 through 11 provide the descriptions, predictions and impact assessments for each of the natural and built features within the Study Area based on the Extraction Plan Layout. Comparisons of the predictions for each of these features with those based on the Preferred Project Layout are provided in these chapters. The impact assessments and recommendations have also been provided based on the Extraction Plan Layout.

The comparisons of the Extraction Plan Layout with the Preferred Project Layout is provided in Fig. 1.1.

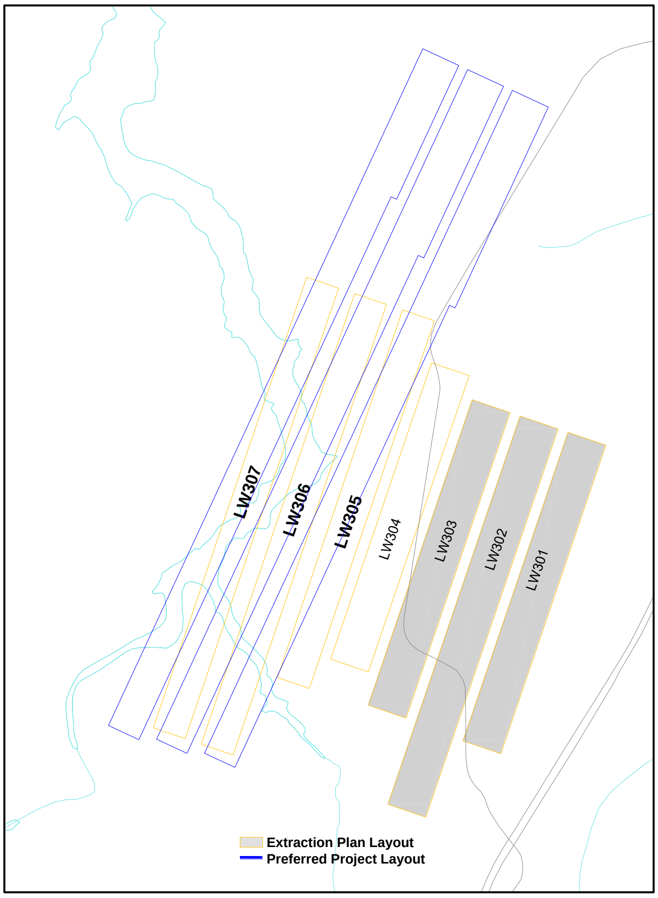

Fig. 1.1 Comparison of the Extraction Plan Layout with the Preferred Project Layout

1.2. Mining Geometry

The layout of Longwalls 305 to 307 is shown in Drawing No. MSEC1057-01 in Appendix E. A summary of the proposed longwall dimensions is provided in Table 1.1.

Table 1.1 Geometry of the Proposed Longwalls 305 to 307 based on the Extraction Plan Layout

Longwall	Overall Void Length Including Installation Heading (m)	Overall Void Width Including First Workings (m)	Overall Tailgate Chain Pillar Width (m)
LW305	1,596	138	45
LW306	1,956	138	70
LW307	1,956	138	70

The lengths of Longwalls 305 to 307 have been shortened at the northern (i.e. commencing) ends from those adopted in the Preferred Project Report. The overall lengths of the longwalls adopted in the Preferred Project Report for the Preferred Project Layout (MSEC403) are 3,003 m for Longwall 305, 3,034 m for Longwall 306 and 3,066 m for Longwall 307. The mining direction of Longwalls 305 to 307 are from the north to the south.

1.3. Surface Topography

The surface level contours in the vicinity of the proposed Longwalls 305 to 307 are shown in Drawing No. MSEC1057-02, which were generated from an airborne laser scan of the area.

A topographical high point is located within the Study Area and to the north east of Longwalls 305 to 307, with a surface level of 300 metres above Australian Height Datum (m AHD). Surface levels above Longwalls 305 to 307 vary from 275 m AHD at the north east corner of Longwall 305 to less than 165 m

AHD in the base of the Woronora Reservoir. The natural surface slopes down towards the Woronora Reservoir.

1.4. Seam Information

The seam floor contours, seam thickness contours and depth of cover contours for the Bulli Seam are shown in Drawings Nos. MSEC1057-03, MSEC1057-04 and MSEC1057-05, respectively.

The depth of cover to the Bulli Seam within the Study Area varies between a minimum of 400 m, in the south of the Study Area, and a maximum of 535 m, to the north east of Longwall 305. The depth of cover directly above Longwalls 305 to 307 varies from 415 m to 525 m.

The seam floor within the Study Area generally dips from the south east to the north west. The seam thickness within the Longwalls 305 to 307 footprint varies between approximately 2.6 m at the northern end and less than 2.9 m at the southern end. The proposed longwalls will extract a minimum height of 2.8 m.

The variations in the surface and seam levels across the mining area are illustrated along Cross-section 1 in Fig. 1.2. The location of this section is shown in Drawings Nos. MSEC1057-02 to MSEC1057-054.

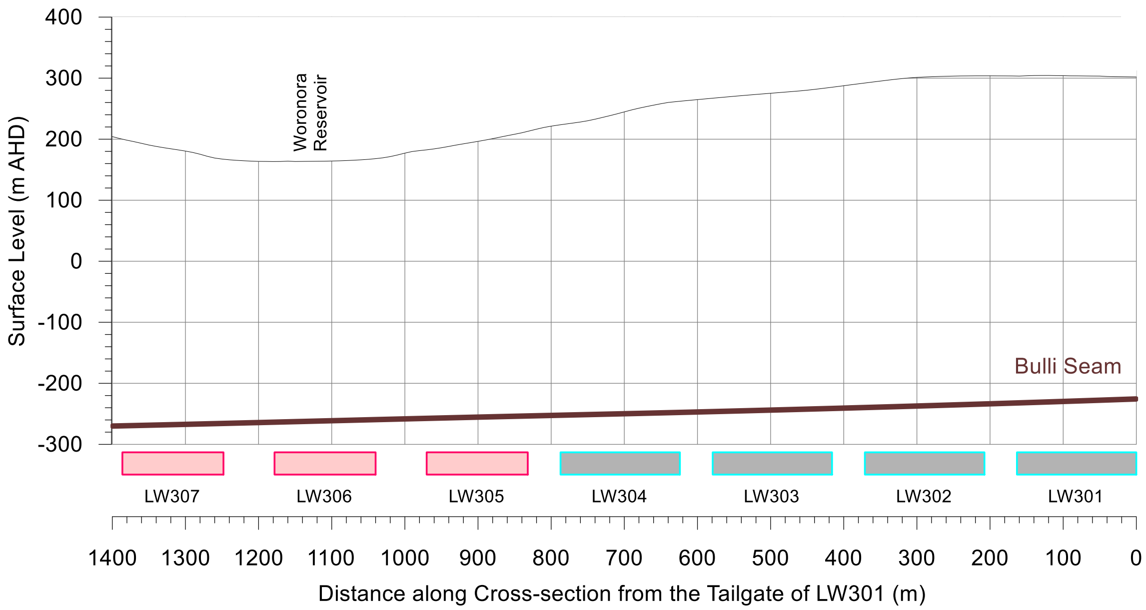

Fig. 1.2 Surface and Seam Levels along Cross-section 1

1.5. Geological Details

The overburden geology mainly comprises sedimentary sandstones, shales and claystones of the Permian and Triassic Periods, which have in some places been intruded by igneous sills. The main geological features mapped at seam level in the area of the longwalls are shown in Drawing No. MSEC1057-06.

Minor discontinuous faulting is located within the Study Area to the south of Longwalls 305 to 307 with probable faulting identified within the southern ends of the longwall footprints and a single probable fault in the northern half of Longwalls 305 and 306. Significant probable faults are located to the east within Longwall 304 (F-0008) and to the north west of Longwall 307. Fault F-0008 is associated with a surface linear that aligns with the Eastern Tributary. Longwalls 20 to 27 extracted through this feature directly under the Eastern Tributary. There are no mapped faults located within the Study Area that extend beneath the surface infrastructure.

The commencing end of Longwalls 305 is approximately 925 m from the Metropolitan Fault. The Metropolitan Fault has a north west to south east strike and dips to the north east.

The stratigraphic section at one borehole location within the Study Area, which was provided by Metropolitan Coal, is shown in Fig. 1.3. The location of the borehole (S225) is shown in Drawing No. MSEC1057-09.

The sandstone and shale units vary in thickness from a few metres to over 160 m. The major sandstone units are interbedded with other rocks and, though shales and claystones are quite extensive in places, the sandstone predominates.

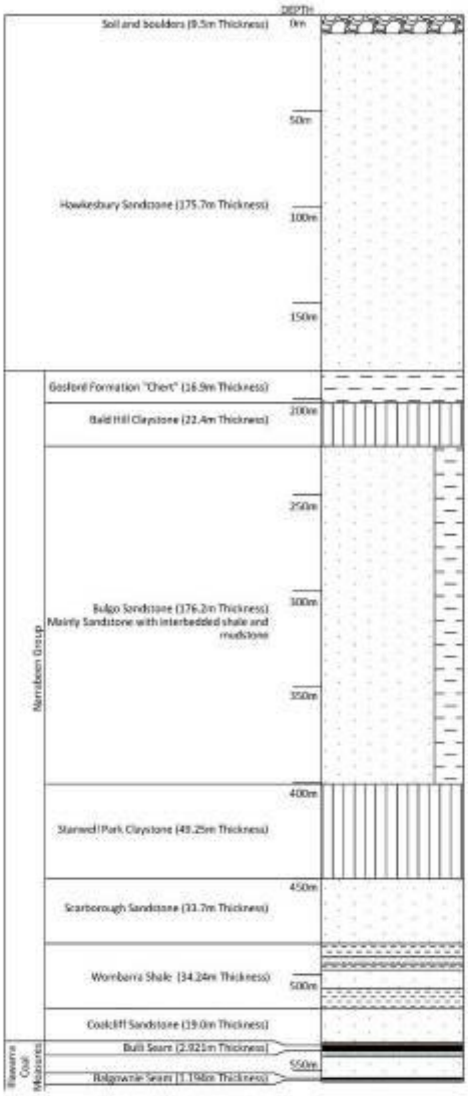

Fig. 1.3 Stratigraphic Section at Borehole S225

The major sedimentary units in the Metropolitan area are, from the top down:-

- Hawkesbury Sandstone; and
- the Narrabeen Group.

The Narrabeen Group contains the Newport Formation (sometimes referred to as the Gosford Formation), the Bald Hill Claystone (also referred to as Chocolate Shale), the Bulgo Sandstone, the Stanwell Park Claystone/Shale, the Scarborough Sandstone, the Wombarra Shale and the Coal Cliff Sandstone.

The surface geology within the Study Area can be seen in Fig. 1.4, which shows the proposed longwalls overlaid on Geological Series Sheet 9029-9129, which is published by the then Department of Industry – Division of Resources and Energy (DRE).

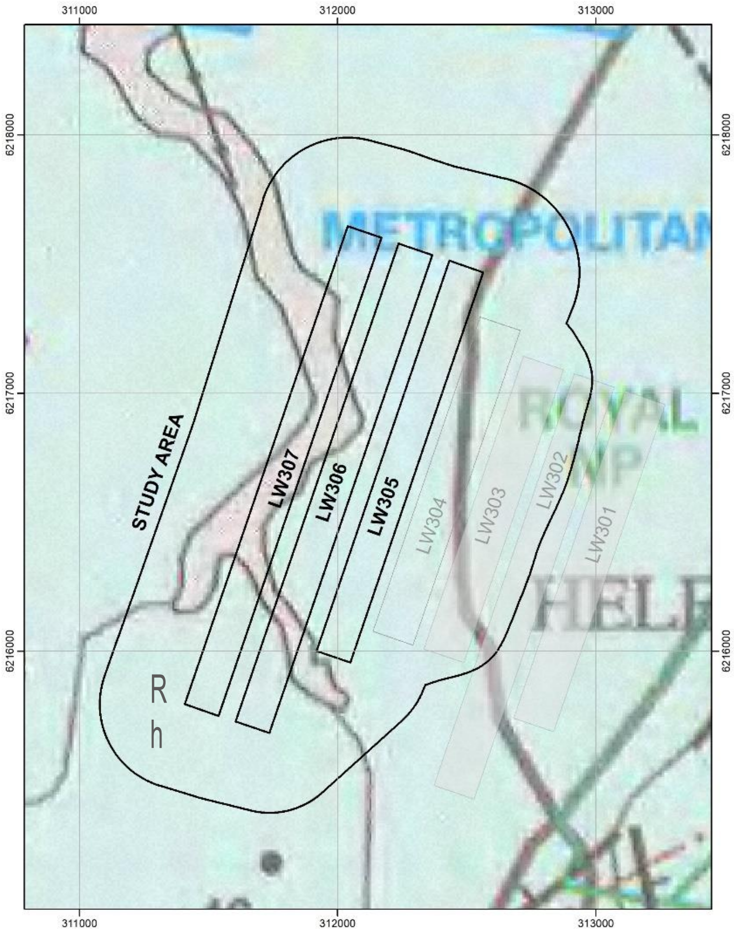

Fig. 1.4 Surface Lithology within the Study Area (DRE Geological Series Sheet 9029-9129)

It can be seen from the above Fig. 1.4 that the surface lithology in the vicinity of the proposed Longwalls 305 to 307 comprises Hawkesbury Sandstone Group (Rh). Quaternary alluvium (Qa) is present within the Woronora Reservoir.

2.1. Definition of the Study Area

The Study Area is defined as the surface area that is likely to be affected by the proposed mining of Longwalls 305 to 307 at Metropolitan Colliery. The surface features included in the Study Area are those features within areas bounded by the following limits:-

- A 35° angle of draw line from the proposed extent of Longwalls 305 to 307; and
- The predicted limit of vertical subsidence, taken as the predicted additional 20 mm subsidence contour resulting from the extraction of the proposed Longwalls 305 to 307.

The depth of cover contours are shown in Drawing No. MSEC1057-05. It can be seen from this drawing that the depth of cover directly above the proposed Longwalls 305 to 307 varies between a minimum of 415 m and a maximum of 525 m. The 35° angle of draw line, therefore, has been determined by drawing a line that is a horizontal distance varying between 290 m and 370 m from Longwalls 305 to 307.

The predicted limit of vertical subsidence, taken as the predicted additional 20 mm subsidence contour, has been determined using the calibrated Incremental Profile Method, which is described in Chapter 3.

The line defining the Study Area, based on the further extent of the 35° angle of draw and the predicted additional 20 mm subsidence contour is shown in Drawing No. MSEC1057-01.

There are features that lie outside the Study Area that are expected to experience either far-field movements, or valley related movements. The surface features which are sensitive to such movements have been identified and have been included in the assessments provided in this report. These features are listed below and details of these are provided in later sections of the report:-

- Portions of the Eastern Tributary;
- M1 Princes Motorway bridges at Old Princes Highway (bridge 2) and Cawleys Road;
- Garrawarra Complex;
- Illawarra Railway;
- Exploration bores; and
- Survey control marks.

The natural features within 600 m of the proposed Longwalls 305 to 307 are also considered in this report. Other natural features located outside the 600 m boundary have also been considered where they are predicted to experience far-field or valley related movements and they could be sensitive to these effects.

2.2. Natural and Built Features within the Study Area

Many 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), numbered APPIN 9029-1S. The proposed Longwalls 305 to 307 has been overlaid on an extract of this CMA map in Fig. 2.1.

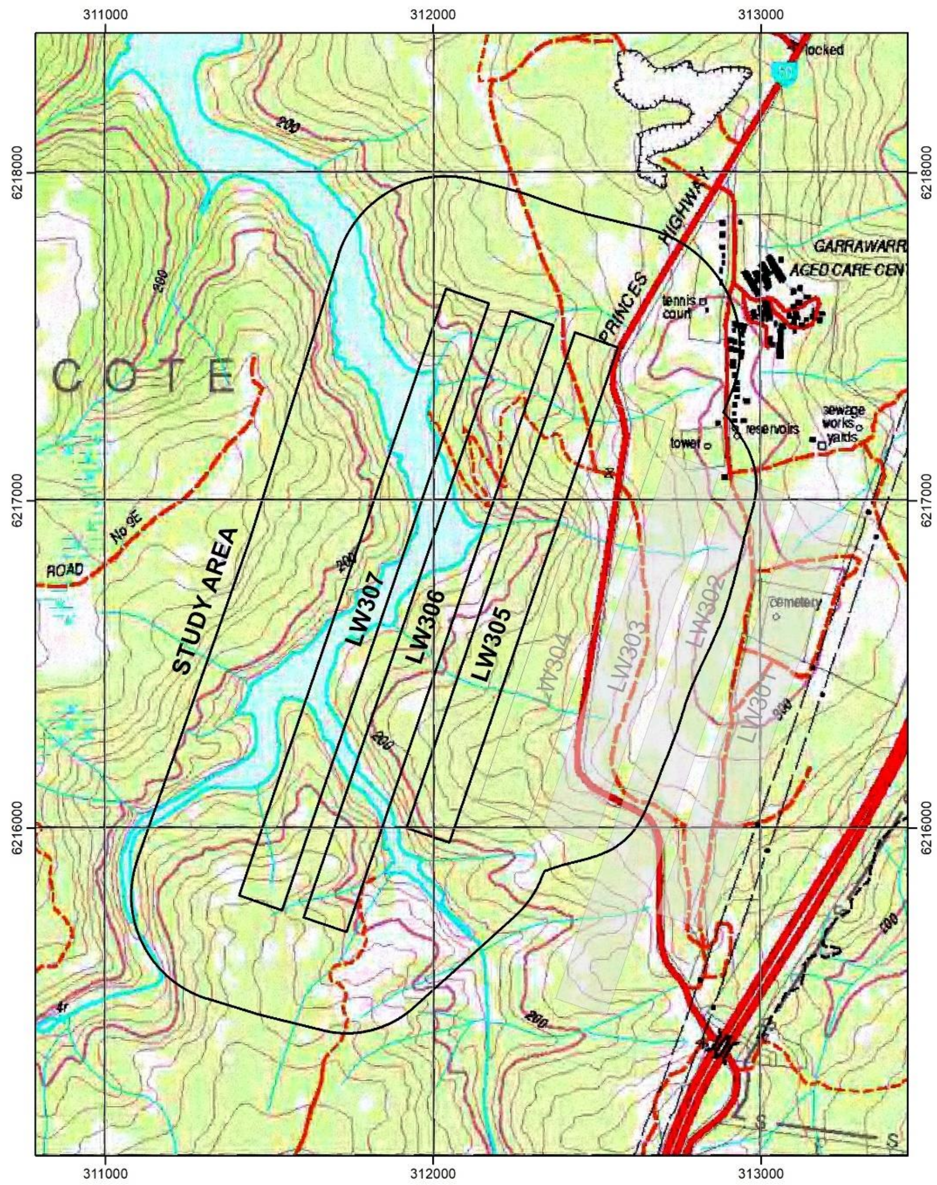

Fig. 2.1 The Proposed Longwalls 305 to 307 Overlaid on CMA Map No. Appin 9029-1S

A summary of the natural and built features within the Study Area is provided in Table 2.1. The locations of these features are shown in Drawings Nos. MSEC1057-07 to MSEC1057-10, in Appendix E.

The descriptions, predictions and impact assessments for the natural and built features are provided in Chapters 5 through to 11. The section number references are provided in Table 2.1.

Table 2.1 Natural and Built Features

Item	Within Study Area	Section Number Reference
NATURAL FEATURES		
Catchment Areas or Declared Special Areas	✓	5.2
Rivers or Creeks	✓	5.3 to 5.6
Aquifers or Known Groundwater Resources	✓	5.7
Springs	×	
Sea or Lake	×	
Shorelines	×	
Natural Dams	×	
Cliffs or Pagodas	✓	5.9 & 5.10
Steep Slopes	✓	5.11
Escarpments	×	
Land Prone to Flooding or Inundation	×	
Swamps, Wetlands or Water Related Ecosystems	✓	5.13
Threatened or Protected Species	✓	5.14
National Parks	×	
State Forests	×	
State Conservation Areas	×	
Natural Vegetation	✓	5.15
Areas of Significant Geological Interest	×	
Any Other Natural Features Considered Significant	×	
PUBLIC UTILITIES		
Railways	×	6.1
Roads (All Types)	✓	6.2 to 6.4
Bridges	✓	6.5
Tunnels	×	
Culverts	✓	6.6
Water, Gas or Sewerage Infrastructure	✓	6.7
Liquid Fuel Pipelines	×	
Electricity Transmission Lines or Associated Plants	✓	6.8
Telecommunication Lines or Associated Plants	✓	6.9
Water Tanks, Water or Sewage Treatment Works	✓	6.7
Dams, Reservoirs or Associated Works	✓	6.11
Air Strips	×	
Any Other Public Utilities	×	
PUBLIC AMENITIES		
Hospitals	×	
Places of Worship	×	
Schools	×	
Shopping Centres	×	
Community Centres	×	
Office Buildings	✓	11.1
Swimming Pools	×	
Bowling Greens	×	
Ovals or Cricket Grounds	×	
Race Courses	×	
Golf Courses	×	
Tennis Courts	×	
Any Other Public Amenities	×	

Item	Within Study Area	Section Number Reference
FARM LAND AND FACILITIES		
Agricultural Utilisation or Agricultural Suitability of Farm Land	✓	8.1
Farm Buildings or Sheds	×	
Tanks	×	
Gas or Fuel Storages	×	
Poultry Sheds	×	
Glass Houses	×	
Hydroponic Systems	×	
Irrigation Systems	×	
Fences	✓	8.2
Farm Dams	×	
Wells or Bores	×	
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	✓	10.1 & 10.2
ITEMS OF ARCHITECTURAL SIGNIFICANCE	×	
PERMANENT SURVEY CONTROL MARKS	✓	10.4
RESIDENTIAL ESTABLISHMENTS		
Houses	✓	11.1
Flats or Units	×	
Caravan Parks	×	
Retirement or Aged Care Villages	✓	11.1
Associated Structures such as Workshops, Garages, On-Site Waste Water Systems, Water or Gas Tanks, Swimming Pools or Tennis Courts	✓	11.1
Any Other Residential Features	×	
ANY OTHER ITEM OF SIGNIFICANCE	×	
ANY KNOWN FUTURE DEVELOPMENTS	×	

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

3.1. Introduction

This chapter provides overviews of mine subsidence parameters and the methods that have been used to predict the mine subsidence movements resulting from the extraction of the proposed Longwalls 305 to 307. Further details on longwall mining, the development of subsidence and the methods used to predict mine subsidence movements are provided in the background reports entitled *Introduction to Longwall Mining and Subsidence* and *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*.

3.2. Overview of Conventional Subsidence Parameters

The normal ground movements resulting from the extraction of 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/km (km^{-1})*, but the values of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *km (km)*.
- **Strain** is the relative differential horizontal movements of the ground. **Normal strain** is calculated as the change in horizontal distance between two points on the ground, divided by the original horizontal distance between them. Strain is typically expressed in units of *millimetres per metre (mm/m)*. **Tensile Strains** occur where the distance between two points increases and **Compressive Strains** occur when the distance between two points decreases. So that ground strains can be compared between different locations, they are typically measured over bay lengths that are equal to the depth of cover between the surface and seam divided by 20.

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

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

The **incremental** subsidence, tilts, curvatures and strains are the additional parameters which result from the extraction of each longwall. The **total** subsidence, tilts, curvatures and strains are the accumulative parameters after the completion of each longwall within 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 or built features, 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 4.6.

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 say 400 m, such as the case within the Study Area, the observed subsidence profiles along monitoring survey lines are generally smooth. Where the depth of cover is less than say 100 m, the observed subsidence profiles along monitoring lines are generally irregular. Very irregular subsidence movements are observed with much higher tilts and strains at very shallow depths of cover where the collapsed zone above the extracted longwalls extends up to or near 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:

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

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

3.4.1. Non-conventional Subsidence Movements due to Changes in Geological Conditions

It is possible that surface features located above the longwalls could experience localised and elevated strains due to unknown geological structures (i.e. anomalies). Non-conventional or anomalous movements have not been identified during the extraction of Longwalls 301 to 303. It is believed that most non-conventional ground movements are the 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 and strains.

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

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

In this report, non-conventional ground movements are being included statistically in the predictions and impact assessments, by basing these on the frequency of past occurrence of both the conventional and non-conventional ground movements and impacts. The analysis of strains provided in Section 4.4 includes those resulting from both conventional and non-conventional anomalous movements. The impact assessments for the natural and built features, which are provided in Chapters 5 through to 11, include historical impacts resulting from previous longwall mining which have occurred as the result of both conventional and non-conventional subsidence movements.

3.4.2. Non-conventional Subsidence Movements due to Steep Topography

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

Further discussions on the potential for down slope movements for the steep slopes within the Study Area are provided in Section 5.11.

3.4.3. Valley Related Movements

Watercourses may be subjected to valley related movements, which are commonly observed along river and creek alignments 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.

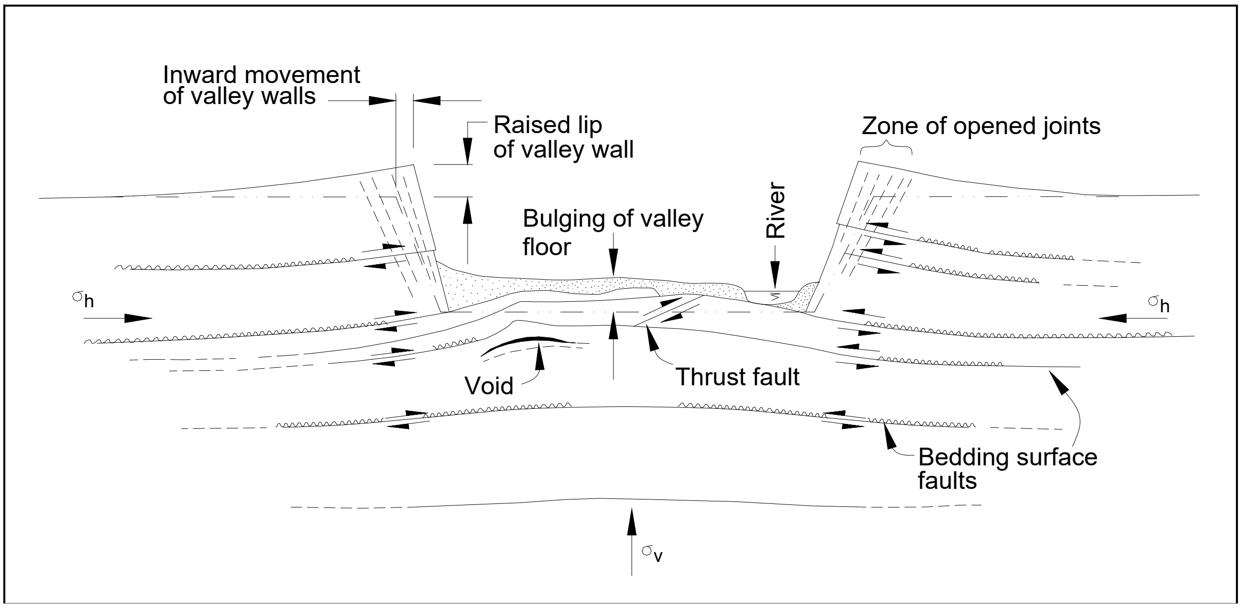

Fig. 3.1 Valley Formation in Flat-Lying Sedimentary Rocks (after Patton and Hendren 1972)

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 down slope movements. Valley related movements are normally described by the following parameters:

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

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

The predicted valley related movements resulting from the extraction of the proposed longwalls were made using the empirical method outlined in ACARP Research Project No. C9067 (Waddington and Kay, 2002). Further details can be obtained from the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

The reliability of the predicted valley related upsidence and closure movements is discussed in Section 3.7.

3.5. The Incremental Profile Method

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

The database consists of detailed subsidence monitoring data from many mines and collieries in NSW including: Angus Place, Appin, Baal Bone, Bellambi, Beltana, Blakefield South, Bulli, Carborough Downs, Chain Valley, Clarence, Coalcliff, Cook, Cooranbong, Cordeaux, Corrimal, Cumnock, Dartbrook, Delta, Dendrobium, Eastern Main, Ellalong, Fernbrook, Glennies Creek, Grasstree, Gretley, Invincible, John Darling, Kemira, Kestrel, Lambton, Liddell, Mandalong, Metropolitan, Mt. Kembla, Moranbah, 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 Incremental Profile Method use the database of observed incremental subsidence profiles, the longwall geometries, local surface and seam information and geology. The method has a tendency 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 Incremental Profile Method can be obtained from *www.minesubsidence.com*.

3.6. Calibration of the Incremental Profile Method

The standard Incremental Profile Method as used for the Southern Coalfield was calibrated to local conditions using observed monitoring data above the previously extracted longwalls at the Colliery. The calibration of the Incremental Profile Method is outlined in detail in the MSEC285 report. The calibrated model predicts subsidence greater than the standard model so as to account for the local geology at Metropolitan Colliery.

An adjustment was made to the model for the prediction of the magnitude of subsidence for the first panel in a longwall series. Following the completion of Longwall 301 it was found from several monitoring lines, that the predicted magnitude of vertical subsidence was less than the observed subsidence. The magnitude of the predicted vertical subsidence has been increased for the prediction of subsidence parameters for Longwalls 305 to 307 and subsequent longwalls. A plot of the predicted and observed vertical subsidence for the 300XL line at Metropolitan Colliery is shown in Fig. 3.2 for the extraction of Longwall 301 and in Fig. 3.3 for the extraction of Longwalls 301 and 302. The predicted profiles of vertical subsidence prior to the adjustment are shown as red lines and the predicted profiles of vertical subsidence after the adjustment are shown as blue lines.

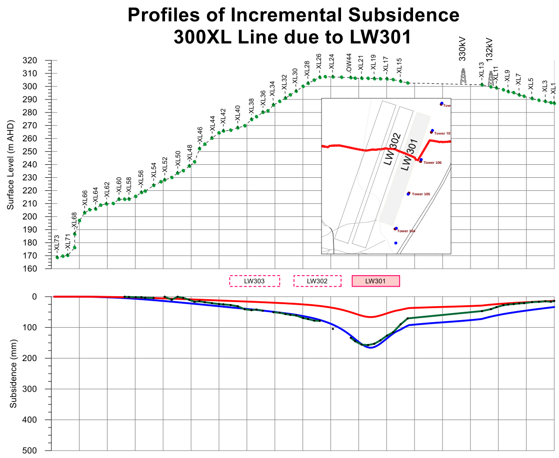

Fig. 3.2 Predicted Vertical Subsidence due to the Extraction of Longwall 301

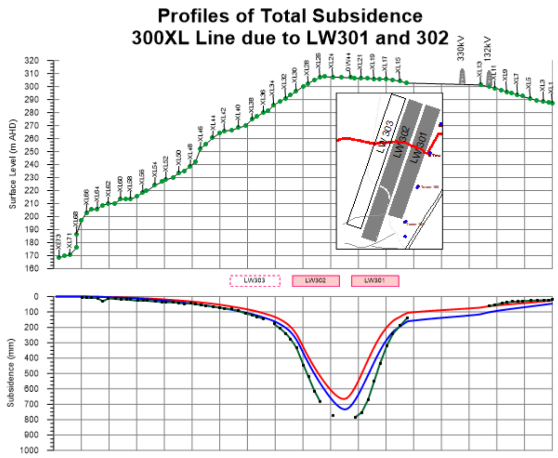

Fig. 3.3 Predicted Vertical Subsidence due to the Extraction of Longwall 301 and 302

The maximum predicted vertical subsidence after Longwall 301, based on the adjusted model is similar to the maximum observed value, as shown in Fig. 3.2. Whilst the maximum predicted vertical subsidence after Longwall 302 is less than the maximum observed value, as shown in Fig. 3.3, it is within ±15 % which is generally considered acceptable for subsidence prediction methodologies.

3.7. Reliability of the Predicted Conventional Subsidence Parameters

The Incremental Profile Method is based upon a large database of observed subsidence movements in the Southern Coalfield and has been found, in most cases, to give reasonable, if not, conservative predictions of maximum subsidence, tilt and curvature. The predicted profiles obtained using this method also reflect the way in which each parameter varies over the mined area and indicate the movements that are likely to occur at any point on the surface.

The following findings have been previously documented in relation to the Incremental Profile Method:

- The observed subsidence profiles reasonably match those predicted using the standard or calibrated prediction curves. While there is reasonable correlation, it is highlighted that in some locations away from the points of maxima and, in particular beyond the longwall goaf edges, that the observed subsidence can exceed that predicted. In these locations, however, the magnitude of subsidence is low and there were no associated significant tilts, curvatures and strains.
- In some cases, however, the observed subsidence has exceeded those predicted. It is highlighted, that in one rare case in the Southern Coalfield, the maximum observed subsidence substantially exceeded that predicted above Longwall 24A and parts of Longwall 25 to 27 at Tahmoor Colliery. In the Tahmoor cases, the maximum observed subsidence of 1169 mm and 1216 mm, or 54 % and 55 % of the extracted seam thicknesses, were more than double the predicted amounts of 500 mm and 600 mm, or 23 % and 27 % of the extracted seam thickness. This was a very unusual and rare event for the Southern Coalfield and geotechnical advice indicates the cause was unusual geology (Gale W, *Investigation into Abnormal Increased Subsidence above Longwall Panels at Tahmoor*

Colliery NSW, MSTS Conference, 2011). The abnormal subsidence was found to be associated with the localised weathering of joint and bedding planes above a depressed water table adjacent to the incised Bargo River Gorge. Similar increased subsidence has not been observed beside other incised gorges. To put this in perspective, the surface area that was affected by increased subsidence at Tahmoor represents less than 1 % of the total surface area affected by longwall mining in the Southern Coalfield.

- The observed tilt and curvature profiles also reasonably matched the predicted profiles using the standard or calibrated prediction curves. The observed curvatures were derived from the smoothed subsidence profiles, so as to obtain overall levels of curvature, rather than the localised curvatures at each survey mark.
- The maximum observed tilts and curvatures were, in most cases, similar to the maximums predicted using the standard or calibrated prediction curves. The observed tilts and curvatures exceeded those predicted at the tributary crossings, at the locations of the upsidence movements, as the predicted profiles did not include non-conventional valley related movements. There was also some scatter in the observed tilt and curvature profiles.

The prediction of the conventional subsidence parameters at a specific point is more difficult. Variations between predicted and observed parameters at a point can occur where there is a lateral shift between the predicted and observed subsidence profiles, which can result from seam dip or variations in topography. In these situations, the lateral shift can result in the observed parameters being greater than those predicted in some locations, whilst the observed parameters being less than those predicted in other locations.

The prediction of strain at a point is even more difficult as there tends to be a large scatter in observed strain profiles. It has been found that measured strains can vary considerably from those predicted at a point, not only in magnitude, but also in sign, that is, the tensile strains have been observed where compressive strains were predicted, and vice versa. For this reason, the prediction of strain in this report has been based on a statistical approach, which is discussed in Section 4.4.

The tilts, curvatures and strains observed at the streams are likely to be greater than the predicted conventional movements, as a result of valley related movements, which is discussed in Section 3.4.3. Specific predictions of upsidence, closure and compressive strain due to the valley related movements are provided for the streams in Sections 5.3 to 5.6. The impact assessments for the streams are based on both the conventional and valley related movements.

It is also likely that some localised irregularities will occur in the subsidence profiles due to near surface geological features. The irregular movements are accompanied by elevated tilts, curvatures and strains, which often exceed the conventional predictions. In most cases, it is not possible to predict the locations or magnitudes of these irregular movements. For this reason, the strain predictions provided in this report are based on a statistical analysis of measured strains in the Southern Coalfield, including both conventional and non-conventional anomalous strains, which is discussed in Section 4.4. Further discussions on irregular movements are provided in Section 4.7.

The Incremental Profile Method approach allows site specific predictions for each natural and built feature and hence provides a more realistic assessment of the subsidence impacts than by applying the maximum predicted parameters at every point, which would be overly conservative and would yield an excessively overstated assessment of the potential subsidence impacts.

It is expected, therefore, that the calibrated Incremental Profile Method should generally provide reasonable, if not, slightly conservative predictions for conventional subsidence, tilt and curvature resulting from the extraction of the proposed longwalls. Allowance should, however, be made for the possibility of observed movements exceeding those predicted as the result of anomalous or non-conventional movements, or for greater subsidence, to occur in some places.

The reliability of the predictions obtained using the standard Incremental Profile Method is illustrated by comparing the magnitudes of observed movements with those predicted for previously extracted longwalls in the Southern Coalfield. The comparisons have been made for monitoring lines at Metropolitan Colliery and the nearby Appin Colliery (Areas 3, 4 and 7), Tower Colliery and West Cliff Colliery (Area 5).

The comparison between the maximum observed total subsidence and the maximum predicted total subsidence for the monitoring lines is illustrated in Fig. 3.4. The results shown in this figure are the maximum observed and predicted subsidence for each monitoring line at the completion of each longwall. The results for Metropolitan Colliery have been presented as red data points.

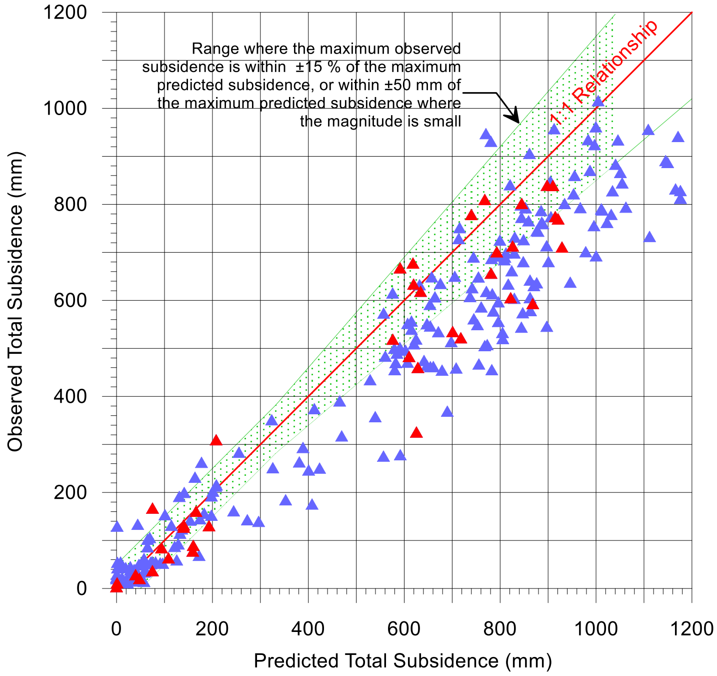

Fig. 3.4 Comparisons between Maximum Observed Incremental Subsidence and Maximum Predicted Incremental Subsidence for the Previously Extracted Longwalls in the Southern Coalfield

It can be seen from the above figure, that in most cases the observed subsidence was typically less than that predicted. The observed subsidence exceeded that predicted in some cases, but was typically less than +15 % or +50 mm of the prediction. In the locations where the magnitude of subsidence was small (i.e. beyond the limits of the active longwall), the observed subsidence was typically within ±100 mm of the prediction.

The distribution of the ratio of the maximum observed to maximum predicted incremental subsidence for the monitoring lines is illustrated in Fig. 3.5 (left). A gamma distribution has been fitted to the results and is also shown in this figure.

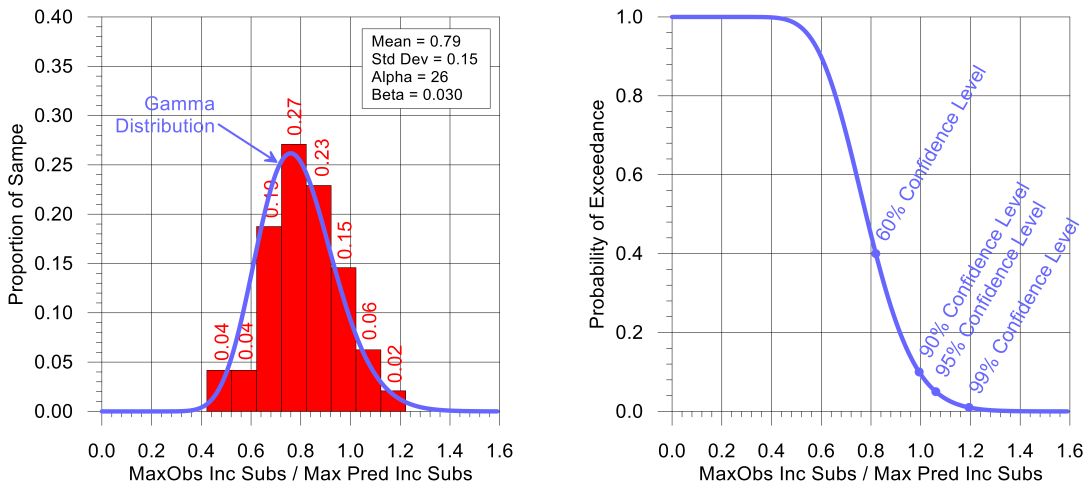

Fig. 3.5 Distribution of the Ratio of the Maximum Observed to Maximum Predicted Incremental Subsidence for Previously Extracted Longwalls in the Southern Coalfield

The probabilities of exceedance have been determined, based on the gamma distribution, which is shown in Fig. 3.5 (right). It can be seen from this figure that, based on the monitoring data from the Southern Coalfield, there is an approximate 90 % confidence level that the maximum observed incremental subsidence will be less than the maximum predicted incremental subsidence using the standard model.

4.1. Introduction

The following sections provide the maximum predicted conventional subsidence parameters resulting from the extraction of Longwalls 305 to 307. The predicted subsidence parameters and the impact assessments for the natural and built features are provided in Chapters 5 to 11.

It should be noted that the predicted conventional subsidence parameters were obtained using the Incremental Profile Model for the Southern Coalfield, which was calibrated to local conditions based on the available monitoring data from Metropolitan Colliery.

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. Such effects have been addressed separately in the impact assessments for each feature provided in Chapters 5 to 11.

4.2. Maximum Predicted Conventional Subsidence, Tilt and Curvature

The maximum predicted conventional subsidence parameters resulting from the extraction of Longwalls 305 to 307 were determined using the calibrated Incremental Profile Method, which was described in Chapter 3. A summary of the maximum predicted values of incremental conventional subsidence, tilt and curvature, due to the extraction of Longwall 305 to 307 based on the Extraction Plan Layout, is provided in Table 4.1.

Table 4.1 Maximum Predicted Incremental Conventional Subsidence, Tilt and Curvature Resulting from the Extraction of Longwall 305 to 307

Longwall	Maximum Predicted Incremental Conventional Subsidence (mm)	Maximum Predicted Incremental Conventional Tilt (mm/m)	Maximum Predicted Incremental Conventional Hogging Curvature (km^{-1})	Maximum Predicted Incremental Conventional Sagging Curvature (km^{-1})
Due to LW305	525	4	0.05	0.10
Due to LW306	300	2	0.04	0.07
Due to LW307	275	2	0.04	0.07

The predicted total conventional subsidence contours after the extraction of Longwalls 305 to 307 are shown in Drawing No. MSEC1057-11. The predicted total conventional subsidence contours include predictions for all longwalls extracted prior to Longwalls 305 to 307.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature, within the Study Area, after the extraction of Longwalls 304 to 307 based on the Extraction Plan Layout, is provided in Table 4.2. The predicted tilts provided in this table are the maxima after the completion of each longwall. The predicted curvatures are the maxima at any time during or after the extraction of each of the longwalls.

Table 4.2 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature after the Extraction of Longwalls 304 to 307

Longwalls	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})
After LW304	1050	4.5	0.05	0.06
After LW305	1100	4.5	0.05	0.09
After LW306	1100	4.5	0.06	0.09
After LW307	1100	4.5	0.06	0.09

The maximum predicted total subsidence resulting from the extraction of Longwalls 305 to 307 is 1100 mm, which represents around 39 % of the minimum extraction height of 2.8 m. The maximum predicted total conventional tilt is 4.5 mm/m (i.e. 0.45 %), which represents a change in grade of 1 in 220. The maximum predicted total conventional curvatures are 0.06 km^{-1} hogging and 0.09 km^{-1} sagging, which represent minimum radii of curvature of 17 km and 11 km, respectively.

The predicted conventional subsidence parameters vary across the Study Area as the result of, amongst other factors, variations in the depths of cover and extraction heights. To illustrate this variation, the predicted profiles of conventional subsidence, tilt and curvature have been determined along Prediction Line 1, the location of which is shown in Drawing No. MSEC1057-11.

The predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 1, resulting from the extraction of Longwalls 305 to 307, are shown in Fig. C.01 in Appendix C. The predicted incremental profiles along the prediction line, due to the extraction of Longwalls 305 to 307 for the Extraction Plan Layout, are shown as dashed black lines. The predicted total profiles along the prediction line, after the extraction of Longwalls 305 to 307 for the Extraction Plan Layout, are shown as solid blue lines. The range of predicted curvatures in any direction to the prediction lines, at any time during or after the extraction of the longwalls for the Extraction Plan Layout, are shown by the grey shading. The predicted total profiles based on the Preferred Project Layout are shown as the red lines for comparison.

The reliability of the predictions of subsidence, tilt and curvature, obtained using the Incremental Profile Method, is discussed in Section 3.7.

4.3. Comparison of Maximum Predicted Conventional Subsidence, Tilt and Curvature

The comparison of the maximum predicted subsidence parameters resulting from the extraction of Longwalls 305 to 307 with those based on the Preferred Project Layout for Longwalls 305 to 307 and the Preferred Project Layout for Longwalls 301 to 317 is provided in Table 4.3. The values are the maxima within the Study Area.

Table 4.3 Comparison of Maximum Predicted Conventional Subsidence Parameters based on the Preferred Project Layout and the Extraction Plan Layout

Layout	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})
Preferred Project Layout (LW301-317) (Report No. MSEC403)	1250	5.0	0.07	0.10
Preferred Project Layout (after LW307) (Report No. MSEC403)	1250	3.0	0.06	0.10
Extraction Plan Layout (Report No. MSEC1057)	1100	4.5	0.06	0.09

In previous MSEC subsidence reports (including MSEC285 report for the EA and MSEC403 for the Preferred Project Layout) predictions were provided for strain rather than curvature. The predicted conventional strains were based on the best estimate of the average relationship between curvature and strain. 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 and this factor was used for the Preferred Project Layout. In order to provide a suitable comparison of predicted subsidence parameters for the Preferred Project Layout and the currently proposed Longwalls 305 to 307, the predicted curvatures have been derived back from the predicted conventional strains presented in the MSEC403 report using the strain-curvature relationship factor of 15.

It can be seen from Table 4.3, that the maximum predicted total subsidence and curvature based on the Extraction Plan Layout for Longwalls 305 to 307 are similar to or less than the maxima predicted based on the Preferred Project Layout for Longwalls 305 to 307. The predicted total tilt based on the Extraction Plan Layout is higher than that based on the Preferred Project Layout after Longwall 307. The maximum predicted tilt based on the Extraction Plan Layout occurs in the eastern side of the Study area above Longwall 303, where the longwall widths are wider than those based on the Preferred Project Layout. The predicted tilt above Longwalls 305 to 307 based on the Extraction Plan Layout are similar to or less than those based on the Preferred Project Layout after Longwall 317.

The maximum predicted subsidence parameters based on the Preferred Project Layout occur in the north east of the Study Area where the longwall panels are wider and pillars are narrower. This area has been left unmined in the Extraction Plan Layout due to shortening of the northern ends of Longwalls 305 and 307, in addition to shortening of the northern ends of Longwalls 301 to 304. The maximum predicted subsidence parameters due to the Extraction Plan Layout occur in the east of the Study Area above previously extracted Longwall 303.

The location of Prediction Line 1 is at the southern half of Longwalls 305 to 307 of the Preferred Project Layout where pillar widths are greater and therefore, the predicted subsidence parameters in the eastern side of the study area are less than those based on the Extraction Plan Layout as shown in Fig C.01, in Appendix C. The predicted subsidence parameters at the western side of the Study Area based on the Preferred Project Layout are similar to those based on the Extraction Plan Layout as the panel width and pillar widths are the same.

4.4. Predicted Strains

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

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 maximum 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. Predicted strains using this relationship are rounded to the nearest 0.5 mm/m.

The maximum predicted conventional strains resulting from the extraction of Longwalls 305 to 307 for the Extraction Plan Layout, based on applying a factor of 15 to the maximum predicted total curvatures, are 1.0 mm/m tensile and 1.5 mm/m compressive.

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 305 to 307 has been determined using monitoring data from the previously extracted longwalls in the Southern Coalfield. The monitoring data was used from the nearby Appin, Tower, West Cliff and Tahmoor Collieries, where the overburden geology and depths of cover are reasonably similar to the proposed longwalls. The panel widths at these collieries are greater than those at Metropolitan Colliery and, therefore, the statistical analyses should provide a reasonable, if not, conservative 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 movements, which are addressed separately in this report. The strains resulting from damaged or disturbed survey marks have also been excluded.

4.4.1. Analysis of Strains Measured in Survey Bays

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

The 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 in the Southern Coalfield, for survey bays that were located directly above goaf or the chain pillars that are located between the extracted longwalls.

The histogram of the maximum observed tensile and compressive strains measured in survey bays above goaf, for monitoring lines from the Southern Coalfield, is provided in Fig. 4.1. The probability distribution functions, based on the fitted Generalised Pareto Distributions (GPDs), have also been shown in this figure.

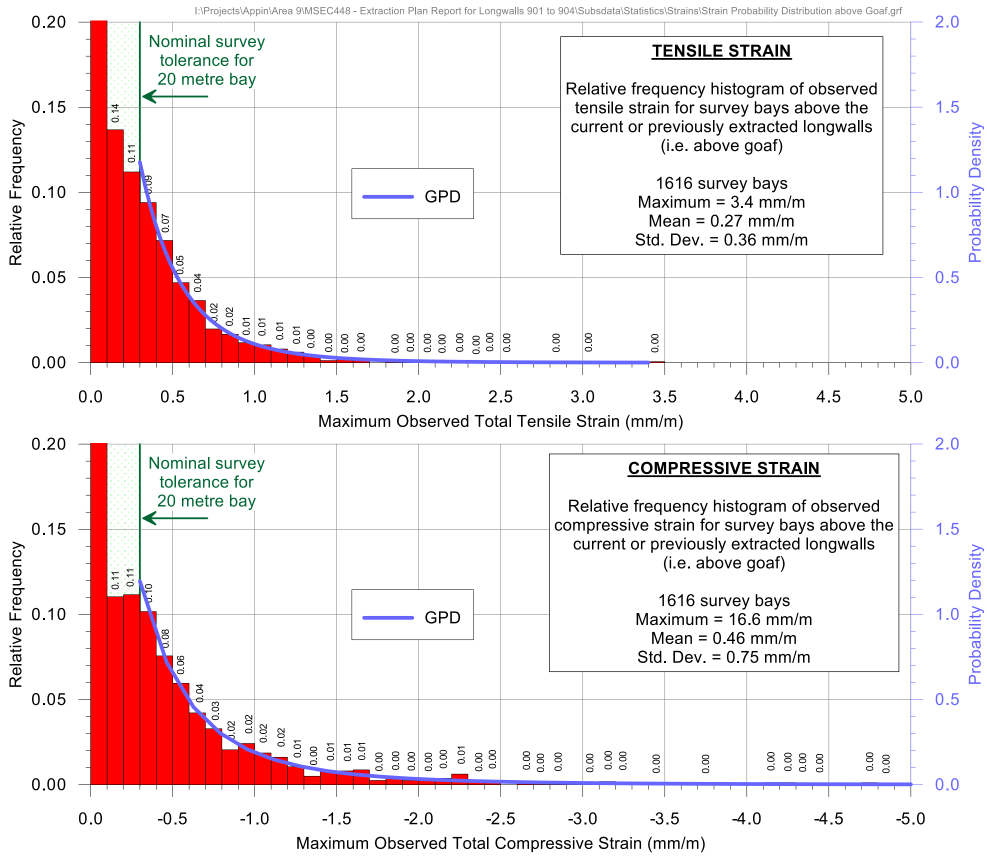

Fig. 4.1 Distributions of the Measured Maximum Tensile and Compressive Strains during the Extraction of Previous Longwalls in the Southern Coalfield for Bays Located Above Goaf

Confidence levels have been determined from the empirical strain data using the GPD. 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 per longwall).

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.

Table 4.4 Probabilities of Exceedance for Strain for Survey Bays above Goaf

Strain (mm/m)		Probability of Exceedance
Compression	-6.0	1 in 500
	-4.0	1 in 175
	-2.0	1 in 35
	-1.0	1 in 10
	-0.5	1 in 3
	-0.3	1 in 2
Tension	+0.3	1 in 3
	+0.5	1 in 6
	+1.0	1 in 25
	+2.0	1 in 200
	+3.0	1 in 1,100

The 95 % confidence levels for the maximum total strains that the individual survey bays above goaf experienced at any time during mining were 0.9 mm/m tensile and 1.6 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 3.2 mm/m compressive.

It is noted, that the maximum observed compressive strain of 16.6 mm/m, which occurred along the T-Line at the surface above Appin Longwall 408, was the result of movements along a low angle thrust fault which daylighted above the Cataract Tunnel. All remaining compressive strains were less than 7 mm/m. The inclusion of the strain at the fault above Appin Longwall 408 has a substantial influence on the probabilities of exceeding the strains provided in Table 4.4, particularly at the high magnitudes of strain.

The probabilities for survey bays located above goaf are based on the strains measured anywhere above the previously extracted longwalls in the Southern Coalfield. 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.

This is illustrated in Fig. 4.2, which shows the distribution of incremental strains measured above previously extracted longwalls in the Southern Coalfield. 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.

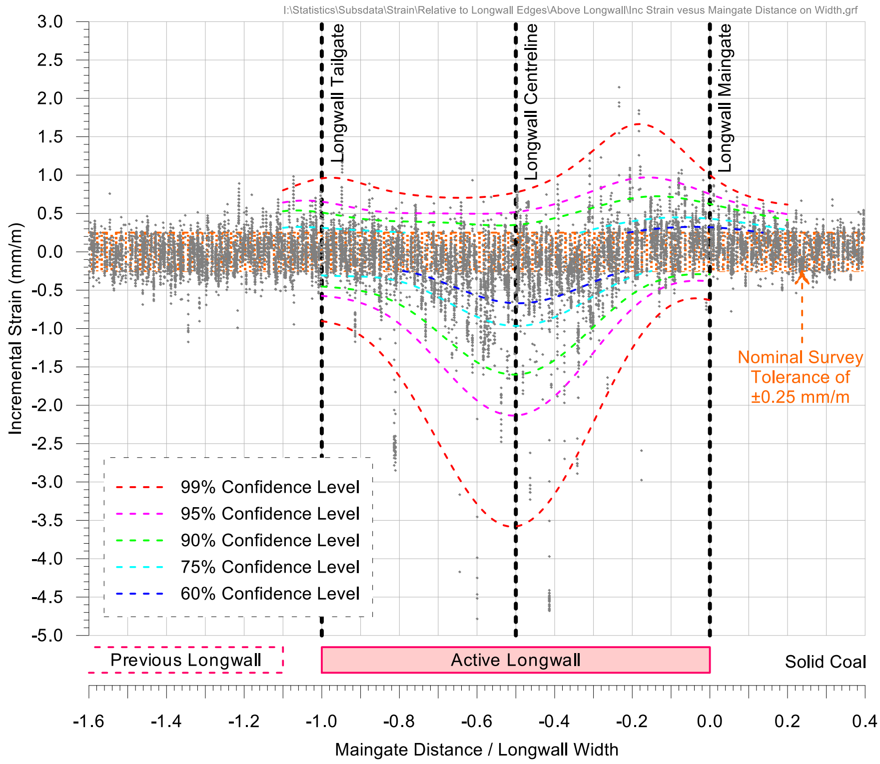

Fig. 4.2 Observed Incremental Strains versus Normalised Distance from the Longwall Maingate for Previously Extracted Longwalls in the Southern Coalfield

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 in the Southern Coalfield, 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*".

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

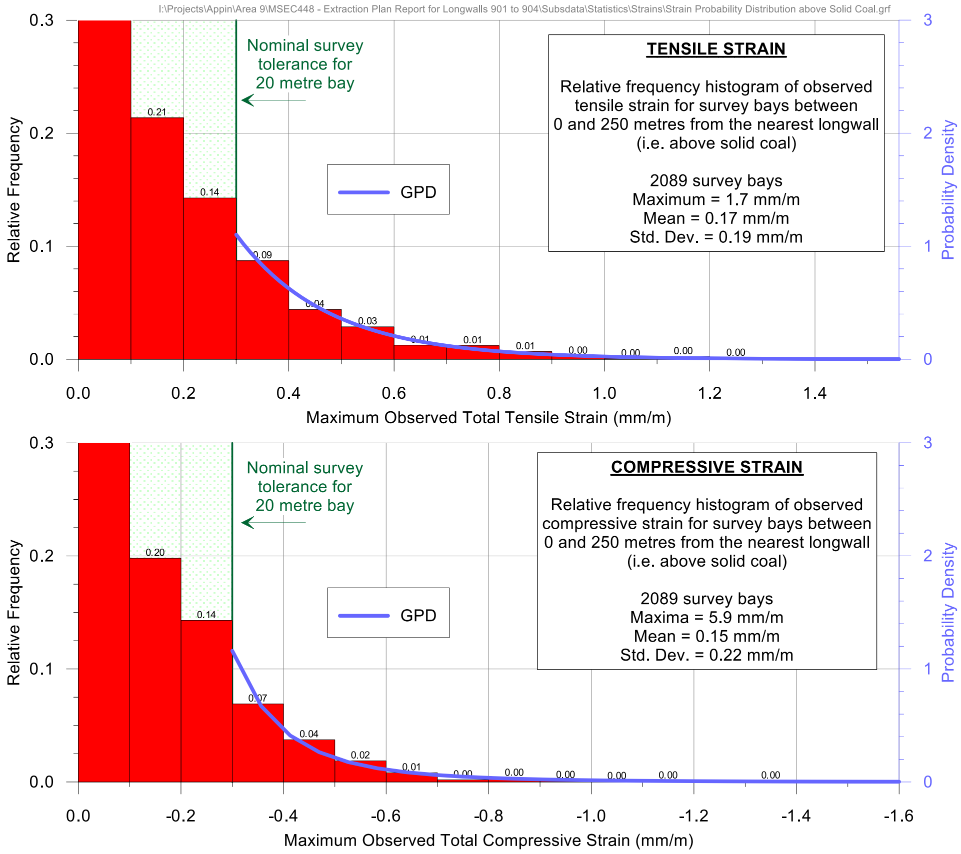

Fig. 4.3 Distributions of the Measured Maximum Tensile and Compressive Strains during the Extraction of Previous Longwalls in the Southern Coalfield for Bays Located Above Solid Coal

Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during 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.

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 2,000
	-1.5	1 in 800
	-1.0	1 in 200
	-0.5	1 in 25
	-0.3	1 in 7
Tension	+0.3	1 in 5
	+0.5	1 in 15
	+1.0	1 in 200
	+1.5	1 in 2,500

The 95 % confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining were 0.6 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 0.9 mm/m tensile and 0.8 mm/m compressive.

4.4.2. Analysis of Strains Measured Along Whole Monitoring Lines

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

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

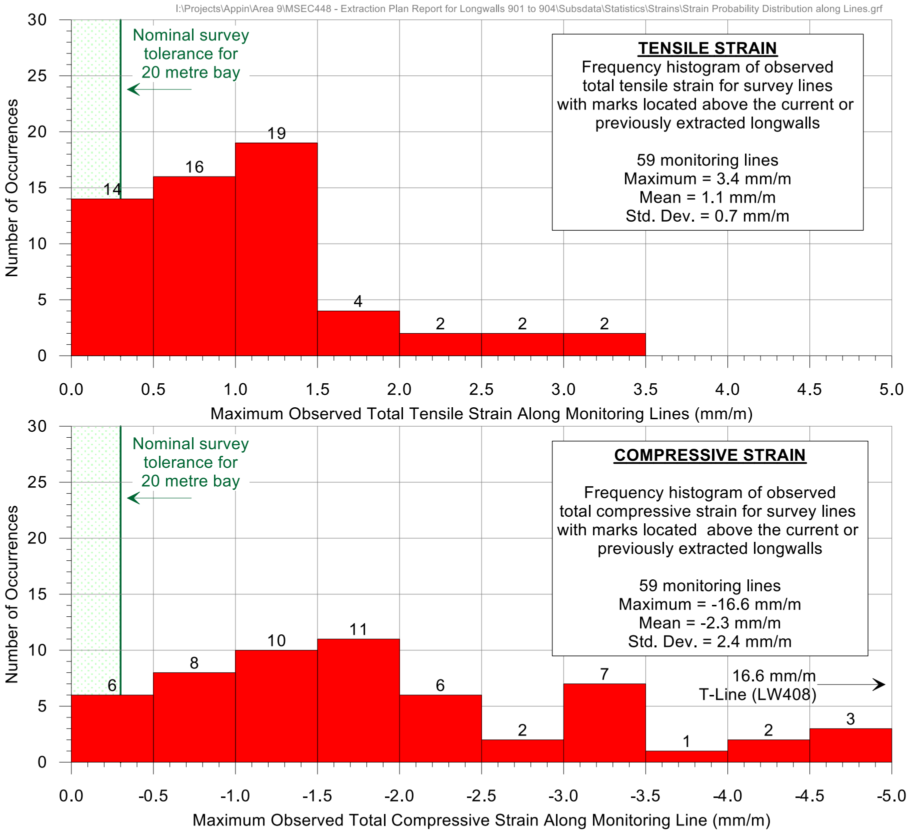

Fig. 4.4 Distributions of Measured Maximum Tensile and Compressive Strains along the Monitoring Lines during the Extraction of Previous Longwalls in the Southern Coalfield

It can be seen from Fig. 4.4, that 30 of the 59 monitoring lines (i.e. 51 %) have recorded maximum total tensile strains of 1.0 mm/m, or less, and that 53 monitoring lines (i.e. 89 %) have recorded maximum total tensile strains of 2.0 mm/m, or less. It can also be seen, that 35 of the 59 monitoring lines (i.e. 59 %) have recorded maximum compressive strains of 2.0 mm/m, or less, and that 51 of the monitoring lines (i.e. 86 %) have recorded maximum compressive strains of 4.0 mm/m, or less.

4.4.3. Analysis of Strains Resulting from Valley Closure Movements

The streams within the Study Area are expected to experience localised and elevated compressive strains resulting from valley related movements. The strains resulting from valley related movements are more difficult to predict than strains in flatter terrain, as they are dependent on many additional factors, including the valley shape and valley height, the valley geomorphology and the local geology in the valley base.

The predicted strains resulting from valley related movements, for the streams located directly above the proposed longwalls, have been determined using the monitoring data for longwalls which have previously mined directly beneath streams in the Southern Coalfield.

The relationship between total closure strain and total closure movement, based on monitoring data for longwalls which have previously mined directly beneath streams in the Southern Coalfield, is provided in Fig. 4.5. The confidence levels, based on the fitted GPDs, have also been shown in this figure.

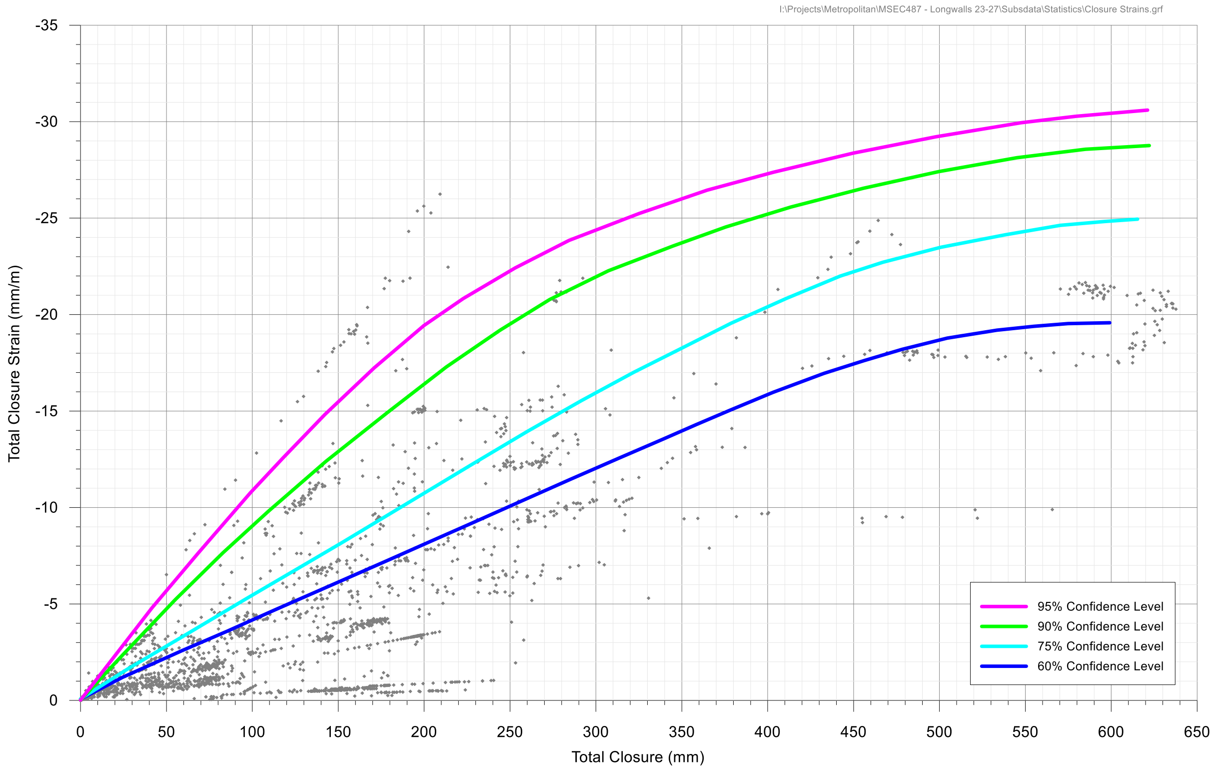

Fig. 4.5 Total Closure Strain versus Total Closure Movement Based on Monitoring Data for Streams Located Directly Above Longwalls in the Southern Coalfield

It can be seen from Fig. 4.5 that total compressive strains up to approximately 20 mm/m to 25 mm/m have been measured for total closures varying between approximately 150 mm to 650 mm. It should be noted, however, that the measured compressive strain is dependent on the length of the survey bay in which the strain was measured. Typical measurements and predictions of conventional strain are based on an approximate survey bay length of 20 m in the Southern Coalfield. Where survey lines are established across streams, for the purposes of measuring valley closure movements, they are often established with survey bay lengths shorter than 20 m in order to provide greater detail and these should not be compared to strain measurements and predictions based on 20 m bay lengths. The bay lengths for the data presented in Fig. 4.5 have been plotted below in a graph of bay length versus total closure and Fig. 4.6 has been reproduced to show the distribution of bay lengths.

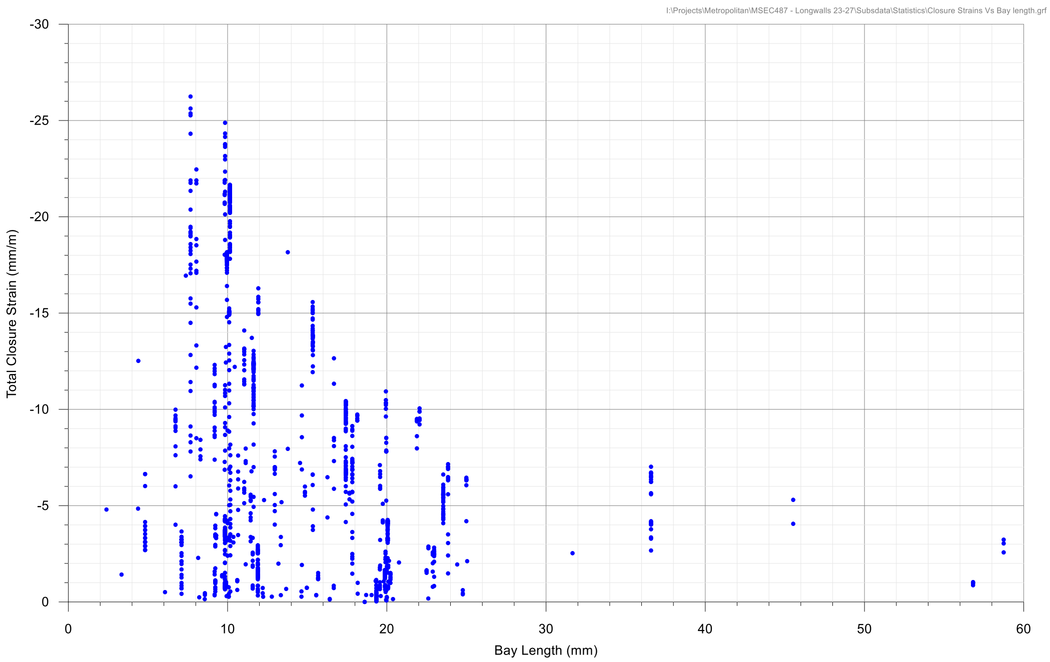

Fig. 4.6 Total Closure Strain versus Bay Length Based on Monitoring Data for Streams Located Directly Above Longwalls in the Southern Coalfield

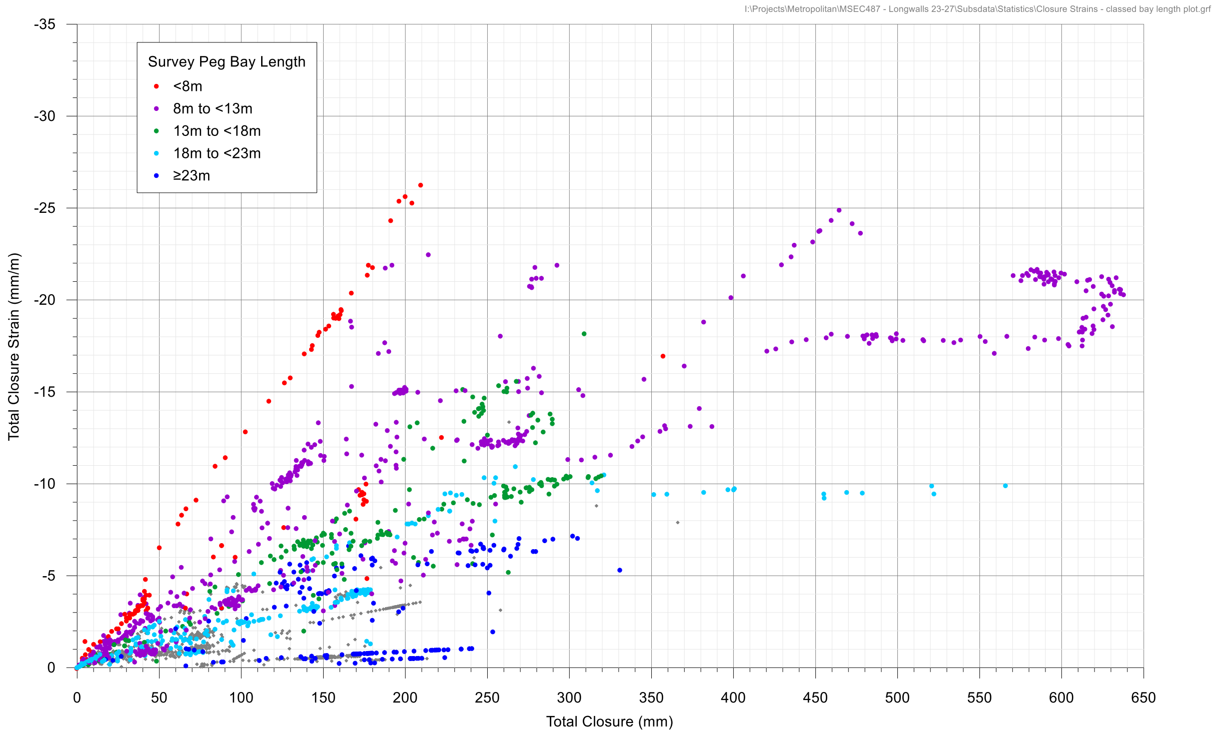

Fig. 4.7 Total Closure Strain versus Total Closure Movement Based on Monitoring Data for Streams Located Directly Above Longwalls in the Southern Coalfield

It can be seen from Fig. 4.6 and Fig. 4.7 that the majority of the data with high compressive strains has been measured over bay lengths much less than 20 m. The maximum measured compressive strain for an approximate 20 m bay length is 11 mm/m as indicated by the cyan coloured points in Fig. 4.7.

4.4.4. 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, dependant on the orientation in which they are measured. The maximum normal strains, referred to as the 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) normal 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 pegs 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, mid-ordinate deviation, angular distortion and shear index. In this report, 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 mid-ordinate deviation measured at survey marks above goaf, for previously extracted longwalls in the Southern Coalfield, is provided in Fig. 4.8. As the typical bay length was 20 m, the calculated mid-ordinate deviations were over a chord length of 40 m. The probability distribution function, based on the fitted GPD, has also been shown in this figure.

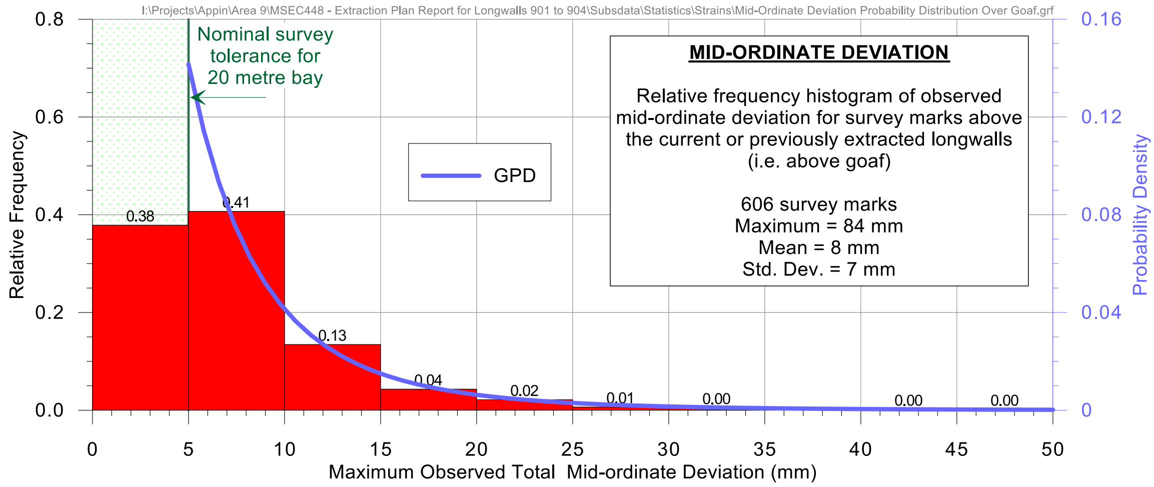

Fig. 4.8 Distribution of Measured Maximum Mid-ordinate Deviation during the Extraction of Previous Longwalls in the Southern Coalfield for Marks Located Above Goaf

A summary of the probabilities of exceedance for horizontal mid-ordinate deviation for survey bays located above goaf, based the fitted GPD, is provided in Table 4.6.

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 40 m Chord Length	10	1 in 4
	20	1 in 20
	30	1 in 70
	40	1 in 175
	50	1 in 400
	60	1 in 800
	70	1 in 1,400
	80	1 in 2,300

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 20 mm and 35 mm, respectively.

4.5. Predicted Conventional Horizontal Movements

The predicted conventional horizontal movements over the proposed Longwalls 305 to 307 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 conventional strains from curvatures, and this has been found to give a reasonable correlation with measured data. This factor will in fact 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 total conventional tilt within the Study Area, at any time during or after the extraction of the proposed Longwalls 305 to 307, is 4.5 mm/m. The maximum predicted conventional horizontal movement is, therefore, approximately 70 mm, i.e. 4.5 mm/m multiplied by a factor of 15.

Conventional horizontal movements do not directly impact on natural or built features, rather impacts occur as a result of differential horizontal movements. Strain is the rate of change of horizontal movement. The impacts of strain on the natural and built features are addressed in the impact assessments for each feature, which have been provided in Chapters 5 to 11.

4.6. 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.

An empirical database of observed incremental far-field horizontal movements has been compiled using monitoring data from the NSW Coalfields, but predominantly from the Southern Coalfield. The far-field horizontal movements resulting from longwall mining were generally observed to be orientated towards the extracted longwall. At very low levels of far-field horizontal movements, however, there was a high scatter in the orientation of the observed movements, particularly in areas of sloping terrain.

The observed incremental far-field horizontal movements, resulting from the extraction of longwalls in the Southern Coalfield, are provided in Fig. 4.9. The data is based on survey marks located outside of the mining area (i.e. above solid coal). The confidence levels, based on fitted GPDs, have also been shown in this figure to illustrate the spread of the data.

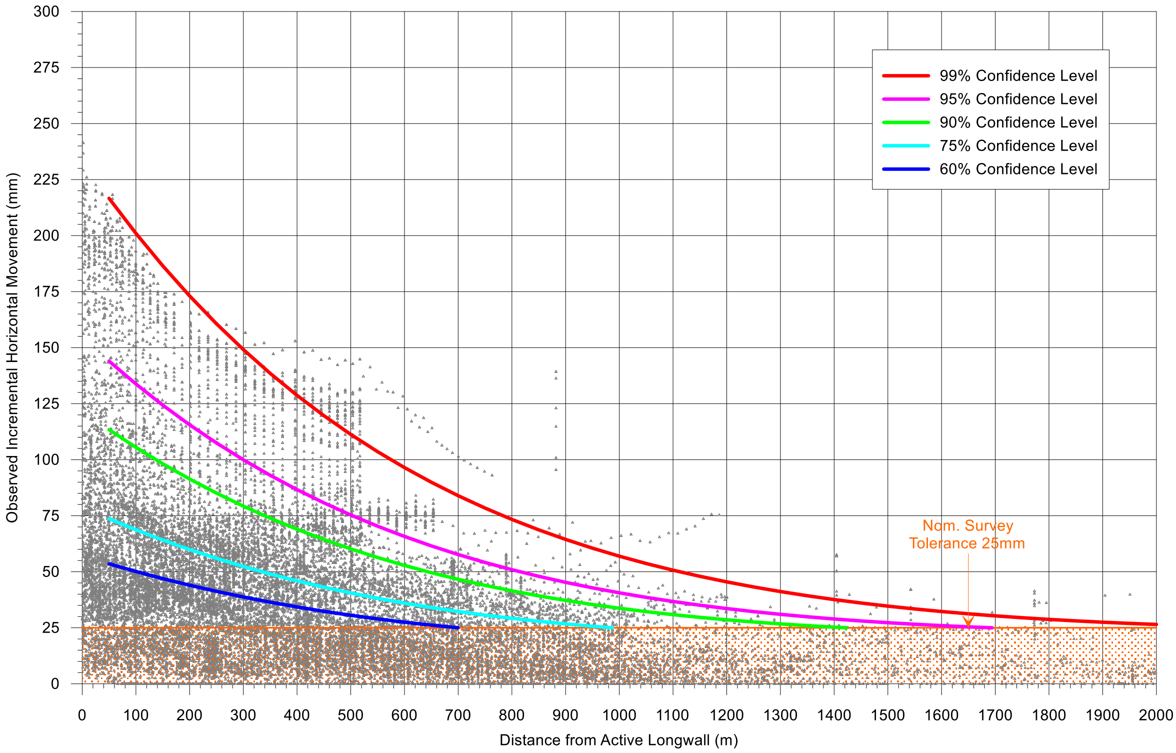

Fig. 4.9 Observed Incremental Far-Field Horizontal Movements from the Southern Coalfield (Solid Coal)

As successive longwalls within a series of longwalls are mined, the magnitudes of the incremental far-field horizontal movements decrease. This is possibly due to the fact that once the in-situ stresses within the strata have been redistributed around the collapsed zones above the first few extracted longwalls, the potential for further movement is reduced. The total far-field horizontal movement is not, therefore, the sum of the incremental far-field horizontal movements for the individual longwalls.

The predicted far-field horizontal movements resulting from the extraction of the proposed longwalls are 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 the order of survey tolerance. While the impacts of far-field horizontal movements on the natural and built features within the vicinity of the Study Area are not expected to be significant, there are structures which are sensitive to small differential movements, including the transmission towers and road bridges to the east of the proposed longwalls. These features are discussed further in Section 6.5 and Section 6.8.

4.7. Non-Conventional Ground Movements

It is likely non-conventional ground movements will occur within the Study Area, due to near surface geological conditions, steep topography and valley related movements, which were discussed in Section 3.4. These non-conventional movements are often accompanied by elevated tilts and curvatures which 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 to 5.6. 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 5.11.

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 Southern Coalfield, including both conventional and non-conventional anomalous strains, which is discussed in Section 4.4. In addition to this, the impact assessments for the natural and built features, which are provided in Chapters 5 to 11, include historical impacts resulting from previous longwall mining which have occurred as a result of both conventional and non-conventional subsidence movements.

The largest known case of 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 period of time. Regular ground monitoring across the fault indicated that the rate of differential movement was less than 0.5 mm per 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 per week.

The development of strain at the low angle thrust fault, as measured along the T-Line during the extraction of Longwall 408, is illustrated in Fig. 4.10. Photographs of the anomalous ground movements associated with this fault are provided in the photographs in Fig. 4.11 and Fig. 4.12.

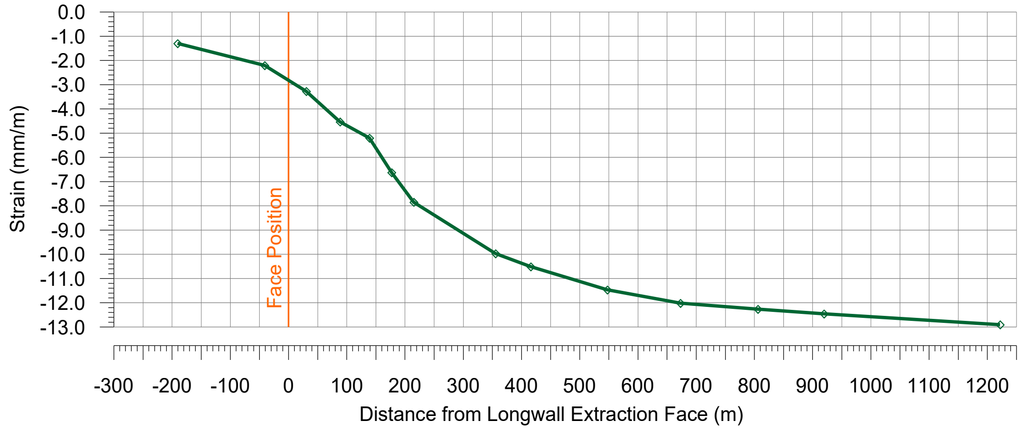

Fig. 4.10 Development of Strain at the Low Angle Thrust Fault Measured along the T-Line during the Extraction of Appin Longwall 408

Fig. 4.11 Surface Compression Humping due to Low Angle Thrust Fault

Fig. 4.12 Surface Compression Humping due to Low Angle Thrust Fault

The developments of strain at anomalies identified in the Southern Coalfield and elsewhere, excluding the low angle thrust fault discussed previously, are illustrated in Fig. 4.13. It can be seen from this figure, that the non-conventional movements develop gradually. For these cases, the maximum rate of development of anomalous strain was 2 mm/m per week. Based on the previous experience of longwall mining in the Southern Coalfield and elsewhere, it has been found that non-conventional anomalous movements can be detected early by regular ground monitoring and visual inspections.

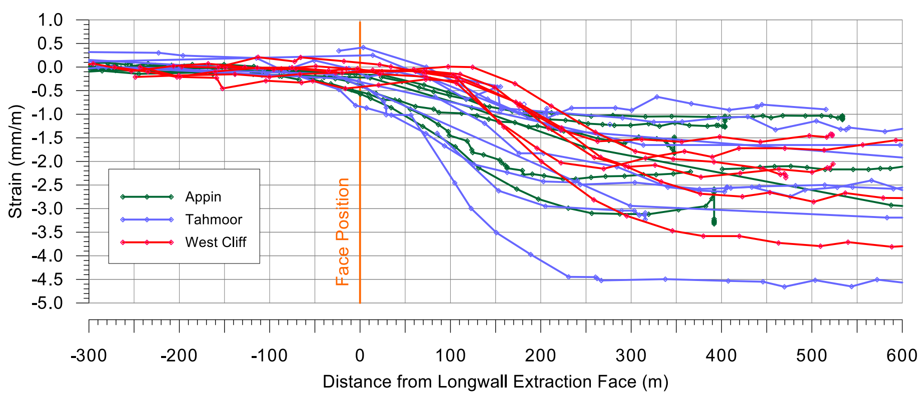

Fig. 4.13 Development of Non-Conventional Anomalous Strains in the Southern Coalfield

A study of anomalies for the majority of ground survey data within the Southern Coalfield was undertaken in 2006 by MSEC. Forty-one (41) monitoring lines were examined for anomalies, which represent a total of 58.2 km of monitoring lines, and approximately 2,980 survey pegs. The monitoring lines crossed over 75 longwalls. The selected lines represented all the major lines over the subsided areas, and contained comprehensive information on subsidence, tilt and strain measurements. A total of 20 anomalies were detected, of which 4 were considered to be significant. The observed anomalies affected 41 of the approximately 2,980 survey pegs monitored. This represented a frequency of 1.4 %.

The above estimates are based on ground survey data that crossed only a small proportion of the total surface area affected by mine subsidence. Recent mining beneath urban and semi-rural areas at Tahmoor and Thirlmere by Tahmoor Colliery Longwalls 22 to 25 provides valuable “whole of panel” information. A total of approximately 35 locations (not including valleys) have been identified over the four extracted longwalls. The surface area directly above the longwalls is approximately 2.56 km^2. This equates to a frequency of 14 sites per square kilometre or one site for every 7 hectares.

4.8. General Discussion on Mining Induced Ground 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 a number of 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 de-stressing 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.

Surface cracking in soils as a result of conventional subsidence movements is not commonly observed where the depths of cover are greater than say 400 m, and any cracking that has been observed has generally been isolated and of a minor nature.

Cracking is found more often in the bases of stream valleys due to the compressive strains associated with upsidence and closure movements. The likelihood and extent of cracking along the streams within the Study Area are discussed in Sections 5.3 to 5.6. Cracking can also occur at the tops and on the sides of steep slopes as a result of downslope movements.

Surface cracks are more readily observed in built features such as road pavements. In the majority of these cases no visible ground deformations can be seen in the natural ground adjacent to the cracks in the road pavements. In rare instances more noticeable ground deformations, such as humping or stepping of the ground can be observed at thrust faults. Examples of ground deformations previously observed in the Southern Coalfield, where the depths of cover exceed 400 m, are provided in the photographs in Fig. 4.14 to Fig. 4.17 below.

Fig. 4.14 Surface Compression Buckling Observed in a Pavement

Fig. 4.15 Surface Tension Cracking along the Top of a Steep Slope

Fig. 4.16 Surface Tension Cracking along the Top of a Steep Slope

Fig. 4.17 Fracturing and Bedding Plane Slippage in Sandstone Bedrock in the Base of a Stream

Localised ground buckling and shearing can occur wherever faults, dykes and abrupt changes in geology occur near the ground surface. The identified geological structures at seam level within the Study Area are discussed in Section 1.5. Discussions on irregular ground movements are provided in Section 4.7.

5.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE NATURAL FEATURES

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the natural features located within the Study Area for Longwalls 305 to 307 and selected features located outside the Study Area. The predicted parameters for each of the natural features have been compared to the predicted parameters based on the Preferred Project Layout. Supporting impact assessments for the natural features have also been undertaken by other specialist consultants for the Extraction Plan Layout.

Impact assessments for some natural features have also been provided by the other specialist consultants on the projects. The assessments provided in this chapter should be read in conjunction with the assessments provided in all other relevant reports accompanying this application.

5.1. Natural Features

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

- springs;
- seas or lakes;
- shorelines;
- natural dams;
- escarpments;
- national parks;
- state forests;
- state recreation or conservation areas;
- areas of significant geological interest; and
- other significant natural features.

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

5.2. Catchment Areas and Declared Special Areas

The Study Area lies within the Woronora Special Area, which is controlled by WaterNSW. The Study Area also lies within the Dams Safety Committee (DSC) Notification Area for the Woronora Reservoir, which is also known as Lake Woronora.

The boundary of the DSC Notification Area is shown in Drawing No. MSEC1057-07. The proposed Longwalls 305 to 307 are located within the DSC Notification Area. The Woronora Special Area provides the main water supply for the Sutherland region, via the Woronora Reservoir.

The Woronora Reservoir full supply level occurs within the Study Area and Longwalls 306 and 307 will be extracted beneath the main body of the Woronora Reservoir. Longwall 305 does not extend beneath the Woronora Reservoir. Subsidence predictions and impact assessments for the Woronora Reservoir full supply level are provided in Section 5.5.

5.3. Waratah Rivulet

5.3.1. Description of the Waratah Rivulet

The Waratah Rivulet flows to the north east and into the Woronora Reservoir approximately 330 m (at the Fully Supply Level) to the south west of Longwalls 305 to 307. The location of the rivulet is shown in Drawing No. MSEC1057-07.

5.3.2. Predictions for the Waratah Rivulet

The predicted profiles of vertical subsidence, upsidence and closure along the Waratah Rivulet (to the Woronora Reservoir Full Supply Level), resulting from the extraction of Longwalls 305 to 307 (based on the Extraction Plan Layout), are shown in Fig. C.02, in Appendix C. The predicted incremental profiles along the Waratah Rivulet / Woronora Reservoir Full Supply Level, due to the extraction of Longwalls 305 to 307, are shown as dashed black lines. The predicted total profiles for the Extraction Plan Layout are shown as solid blue lines. The predicted total profiles based on the Preferred Project Layout are shown as the solid red lines for comparison.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the Waratah Rivulet, resulting from the Extraction Plan Layout, is provided in Table 5.1. The values are the predicted maxima within the Study Area.

Table 5.1 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Waratah Rivulet from the Extraction of Longwalls 304 to 307

Longwall	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})
After LW304	< 20	< 0.5	< 0.01	< 0.01
After LW305	< 20	< 0.5	< 0.01	< 0.01
After LW306	< 20	< 0.5	< 0.01	< 0.01
After LW307	< 20	< 0.5	< 0.01	< 0.01

The maximum predicted conventional tilt for the Waratah Rivulet based on the Extraction Plan Layout is less than 0.5 mm/m (i.e. 0.05 %, or 1 in 2,000). The maximum predicted conventional curvatures are less than 0.01 km^{-1} hogging and sagging, which equate to minimum radii of curvature of greater than 100 km. The predicted conventional strains for the Waratah Rivulet based on the Extraction Plan Layout (based on 15 times the curvature) are less than 0.5 mm/m tensile and compressive.

A summary of the maximum predicted values of total upsidence and closure for the Waratah Rivulet within the Study Area, resulting from the Extraction Plan Layout, is provided in Table 5.2. The compressive strains due to valley closure effects have also been provided (based on the method outlined in Section 4.4.3).

Table 5.2 Maximum Predicted Total Upsidence, Closure and Compressive Strain for the Waratah Rivulet within the Study Area after the Extraction of Longwalls 304 to 307

Longwall	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)	Maximum Predicted Closure Strain based on the 90 % Confidence Level (mm/m)	Maximum Predicted Closure Strain based on the 95 % Confidence Level (mm/m)
After LW304	20	40	4	5
After LW305	20	40	4	5
After LW306	20	50	5	6
After LW307	30	70	7	8

The method used to predict the valley related compressive strains is based on the measured strains for streams that were located directly above previous longwall mining. The Waratah Rivulet is located above solid coal therefore the actual valley related compressive strains are expected to be less than those provided in Table 5.2.

A summary of the predicted valley closure for the rock bars downstream of Pool P, resulting from the Extraction Plan Layout, is provided in Table 5.3. The rock bar downstream of Pool P is 1.1 km from Longwall 307. The rock bars downstream of Pool T are within 600 m of Longwalls 305 to 307. Rock bars V and W are located near the Study Area boundary.

Table 5.3 Maximum Predicted Total Closure at Rock bars along the Waratah Rivulet

Longwall	RB-P	RB-Q	RB-R	RB-S	RB-T	Boulderfield-U	RB-V	RB-W
After LW304	125	100	125	100	80	70	50	30
After LW305	125	100	125	100	80	70	50	30
After LW306	125	100	125	100	80	70	50	30
After LW307	125	100	125	100	80	80	70	50

It can be seen from Table 5.3 that there is negligible additional predicted closure at the rock bars from the extraction of Longwalls 305 and 306. The maximum additional predicted total closure due to the extraction of Longwalls 305 to 307 based on the Extraction Plan layout is 10 mm at Boulderfield U and 20 mm at Rock bars V and W.

5.3.3. Comparison of the Predictions for the Waratah Rivulet

The comparison of the maximum predicted subsidence parameters for the Waratah Rivulet, resulting from the Extraction Plan Layout, with those based on the Preferred Project Layout is provided in Table 5.4. The values are the predicted maxima within the Study Area.

Table 5.4 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Waratah Rivulet based on the Preferred Project Layout and the Extraction Plan Layout

Layout	Maximum Predicted Total Vertical Subsidence (mm)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
Preferred Project Layout (After LW307) (Report No. MSEC403)	< 20	100	150
Extraction Plan Layout (Report No. MSEC1057)	< 20	30	70

The maximum predicted vertical subsidence, upsidence and closure for the Waratah Rivulet, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout.

The comparison of the maximum predicted closure for the rock bars, resulting from the Extraction Plan Layout, with those based on the Preferred Project Layout is provided in Table 5.5.

Table 5.5 Comparison of Maximum Predicted Closure for the Waratah Rivulet **Rock bars based on the Preferred Project Layout and the Extraction Plan Layout**

Layout	Maximum Predicted Total Closure (mm)							
	RB-P	RB-Q	RB-R	RB-S	RB-T	Boulderfield-U	RB-V	RB-W
Preferred Project Layout (After LW307) (Report No. MSEC403)	125	100	125	125	100	150	150	125
Extraction Plan Layout (Report No. MSEC1057)	125	100	125	100	80	80	70	50

The maximum predicted closure for the rock bars downstream of Pool P, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout at Boulderfield U and Rock bars S, T, V and W, and they are the same at Rock bars P, Q and R.

5.3.4. Impact Assessments and Recommendations for the Waratah Rivulet

The maximum predicted subsidence parameters for the Waratah Rivulet, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout.

The Waratah Rivulet is located at the Study Area boundary to the south west of Longwall 307 and it is 330 m from the corner of this longwall. At this distance, the conventional subsidence parameters due to the extraction of Longwalls 305 to 307 are negligible and less than expected levels of survey accuracy. Impacts due conventional subsidence movements, including changes in gradient, flooding, ponding and scouring are not expected to occur.

The performance measure for watercourses as described in the project approval requires negligible environmental consequences along the portion of the '*Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P)'*. This section of the Waratah Rivulet includes Pool P to Rock bar W, located to the south of Longwalls 305-307.

The predictions of total closure for the rock bars/boulderfield downstream of the pools along the Waratah Rivulet, from Pool P to Pool W are summarised in Table 5.3. It can be seen from this table that the predicted total closure resulting from the extraction of Longwalls 305 to 307 does not change at Rock bar P to T inclusive. The predicted total closure for the Boulderfield U and Rock bar V and W also does not change for the extraction of Longwalls 305 and 306. The incremental increase in predicted closure at Boulderfield U is 10 mm resulting from the extraction of Longwall 307. The incremental increase in predicted closure at Rock bar V and W is 20 mm resulting from the extraction of Longwall 307.

Previous assessments of stream impacts for the Waratah Rivulet, Eastern Tributary and other tributaries at Metropolitan Colliery have used a relationship between predicted total closure at rock bars and proportion of impacted pools for streams in the Southern Coalfield. The relationship identified approximately 10 % of pools that were impacted at a predicted total valley closure of up to 200 mm, where the streams are located outside the mining area.

Impacts to some pools along the Eastern Tributary have occurred at predicted values of total valley closure of less than 200 mm resulting in a higher proportion of impacted pools at lower magnitudes of predicted total valley closure. As a result of the impacts to pools along the Eastern Tributary, located above solid coal, the predicted valley closure impact relationship is not adopted and an adaptive management approach is instead used for the lower reaches of the Eastern Tributary as described in Section 5.4.4.

A predicted total valley closure of 200 mm has been successfully used as a design tool for mining in the vicinity of the Waratah Rivulet from Pool P to Rock bar W. Impacts to pools along the Waratah Rivulet have not occurred at predicted total valley closure of less than 200 mm. Impacts that have occurred along the Waratah Rivulet have been the result of mining directly beneath the Waratah Rivulet or in close proximity (< 100 m) to the rock bars with predicted total valley closure greater than 200 mm. Some pools along the Waratah Rivulet have also been mined directly beneath without impact with predicted total closure up to 800 mm.

A geological assessment was carried out by Strata Control (2019) for the Eastern Tributary and Waratah Rivulet, with a particular focus on Pool P to Rock bar W along the Waratah Rivulet and comparisons with Pool ETAM along the Eastern Tributary. The assessment identified a thick unit (approximately 25 m) of thinly bedded sandstone along the Eastern Tributary at the location of Pool ETAM. The thinly bedded sandstone is considered to be of lower strength, and more weathered than adjoining thickly bedded sandstone units and therefore more prone to impact from valley closure movements. In addition, a higher frequency of seam level faults and surface lineaments have been identified in the vicinity of the Eastern Tributary. The thinly bedded units identified along the along Waratah Rivulet were limited to less than 5 m thickness and the frequency of seam level faults and surface lineaments was considerably less. Based on the results of the assessment, the geological features identified along the Eastern Tributary are considered to be unique, compared to the Waratah Rivulet.

The extracted longwalls in the vicinity of Rock bars P to W have been set back from the Waratah Rivulet by distances of 150 m or more. The predicted maximum total closure for these rock bars after the extraction of Longwall 307 is 125 mm and no impacts have occurred along this section of the Waratah Rivulet to date. Longwall 307 is located 330 m to Rock bar W, 320 m to Rock bar V and 400 m to Boulderfield U. The additional predicted closure due to the extraction of Longwalls 305 to 307 is very small and there is considered to be a low likelihood of impacts to the Rock bars as a result of valley closure movements.

Subsidence predictions for the Waratah Rivulet, resulting from future extraction of Longwalls 308 to 314 have been undertaken and are presented in Attachment 1.

5.4. The Eastern Tributary

5.4.1. Description of the Eastern Tributary

The Eastern Tributary flows in an approximate south to north direction and flows into the Woronora Reservoir approximately 300 m (at the Full Supply Level) to the south east of Longwalls 305 and 306. The Eastern Tributary is over 500 m from Longwall 307 at its nearest point.

5.4.2. Predictions for the Eastern Tributary

The predicted profiles of vertical subsidence, upsidence and closure along the Eastern Tributary (to the Woronora Reservoir Full Supply Level), resulting from the extraction of Longwalls 305 to 307 (based on the Extraction Plan Layout), are shown in Fig. C.03, in Appendix C. The predicted incremental profiles along the Eastern Tributary/Woronora Reservoir Full Supply Level, due to the extraction of Longwalls 305 to 307 for the Extraction Plan Layout, are shown as dashed black lines. The predicted total profiles for the Extraction Plan Layout are shown as solid blue lines. The predicted total profiles based on the Preferred Project Layout are shown as the solid red lines for comparison.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the Eastern Tributary, resulting from the Extraction Plan Layout, is provided in Table 5.6. The values are the predicted maxima within the Study Area.

Table 5.6 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Eastern Tributary after the Extraction of Longwalls 304 to 307

Longwall	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})
After LW304	40	< 0.5	< 0.01	< 0.01
After LW305	40	< 0.5	< 0.01	< 0.01
After LW306	60	< 0.5	< 0.01	< 0.01
After LW307	60	< 0.5	< 0.01	< 0.01

The maximum predicted conventional tilt for the Eastern Tributary based on the Extraction Plan Layout is less than 0.5 mm/m (i.e. < 0.05 %, or 1 in 2,000), which is orientated across its alignment (i.e. towards Longwalls 305 to 307). The maximum predicted conventional curvatures are less than 0.01 km^{-1} hogging and sagging, which equate to minimum radii of curvature of greater than 100 km. The predicted conventional strains for the Eastern Tributary based on the Extraction Plan Layout (based on 15 times the curvature) are less than 0.5 mm/m tensile and compressive.

A summary of the maximum predicted values of total upsidence and closure for the Eastern Tributary within the Study Area, resulting from the Extraction Plan Layout, is provided in Table 5.7. The compressive strains due to valley closure effects have also been provided (based on the method outlined in Section 4.4.3).

Table 5.7 Maximum Predicted Total Upsidence, Closure and Compressive Strain for the Eastern Tributary after the Extraction of Longwalls 304 to 307

Longwall	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)	Maximum Predicted Closure Strain based on the 90 % Confidence Level (mm/m)	Maximum Predicted Closure Strain based on the 95 % Confidence Level (mm/m)
After LW304	40	60	6	7
After LW305	50	70	7	8
After LW306	60	80	8	9
After LW307	60	80	8	9

The method used to predict the valley related compressive strains is based on the measured strains for streams that were located directly above the longwalls. The Eastern Tributary is located above solid coal therefore actual valley related compressive strains are expected to be less than those provided in Table 5.7.

A summary of the predicted valley closure for Pools ETAS/ETAT and ETAU resulting from the Extraction Plan Layout is provided in Table 5.3.

Table 5.8 Maximum Predicted Total Closure at Rock bars Downstream of Pools ETAS/ETAT and ETAU

Longwall	ETAS/ETAT	ETAU
After LW304	60	60
After LW305	70	70
After LW306	80	80
After LW307	80	80

The additional predicted total closure due to the extraction of Longwalls 305 and 306 based on the Extraction Plan layout at Pools ETAS/ETAT and ETAU is 20 mm. There is no incremental increase in total closure at Pools ETAS/ETAT and ETAU due to the extraction of Longwall 307.

5.4.3. Comparison of the Predictions for the Eastern Tributary

The comparison of the maximum predicted subsidence parameters for the Eastern Tributary, resulting from the Extraction Plan Layout, with those based on the Preferred Project Layout is provided in Table 5.9. The values are the predicted maxima within the Study Area.

Table 5.9 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Eastern Tributary based on the Preferred Project Layout and the Extraction Plan Layout

Layout	Maximum Predicted Total Vertical Subsidence (mm)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
Preferred Project Layout (After LW307) (Report No. MSEC403)	375	375	225
Extraction Plan Layout (Report No. MSEC1057)	60	60	80

The maximum predicted vertical subsidence, upsidence and closure for the Eastern Tributary, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout.

The comparison of the maximum predicted closure for Pools ETAS/ETAT and ETAU, resulting from the Extraction Plan Layout, with those based on the Preferred Project Layout is provided in Table 5.5.

Table 5.10 Comparison of Maximum Predicted Closure for the Eastern Tributary Pools based on the Preferred Project Layout and the Extraction Plan Layout

Layout	Maximum Predicted Total Closure (mm)	
	Pools ETAS/ETAU	Pool ETAU
Preferred Project Layout (After LW307) (Report No. MSEC403)	225	225
Extraction Plan Layout (Report No. MSEC1057)	80	80

The maximum predicted closure for Pools ETAS/ETAT and ETAU, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout.

5.4.4. Impact Assessments and Recommendations for the Eastern Tributary

The maximum predicted subsidence parameters for the Eastern Tributary, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout.

Previous assessments of stream impacts for the Waratah Rivulet, Eastern Tributary and other tributaries at Metropolitan Colliery have used a relationship between predicted total closure at rock bars and proportion of impacted pools for streams in the Southern Coalfield. The relationship identified approximately 10 % of pools were impacted at a predicted total valley closure of up to 200 mm, where the streams ire located outside the mining area

Impacts to some pools along the Eastern Tributary have occurred at predicted values of total valley closure of less than 200 mm resulting in a higher proportion of impacted pools at lower magnitudes of predicted total valley closure. As a result, the predicted valley closure impact relationship is not used for the Eastern Tributary, and an adaptive management approach will instead be adopted for Longwalls 305 and 306 specifically as described below.

Longwall 307 is located approximately 570 m from Pool ETAU. At this distance, there is no increase in predicted valley related movements and conventional subsidence parameters and it is considered that the adaptive management approach will not be required. A review of the monitoring data would be conducted at the completion of Longwalls 305 and 306 to confirm discontinuation of the adaptive management approach for the Eastern Tributary.

As a result of the observed impacts to the Eastern Tributary, the finishing ends of Longwalls 303 to 305 have been set back to minimise predicted valley closure at the Eastern Tributary. Metropolitan Colliery have established a comprehensive monitoring and adaptive management program to identify subsidence related movements at the Eastern Tributary during the extraction of Longwall 303 and the same monitoring and adaptive management program will be used for the extraction of Longwall 304 and Longwalls 305 and 306. Similar monitoring of subsidence movements using high resolution survey methods has been successfully implemented for the Sandy Creek Waterfall at the Dendrobium Coal Mine by South32.

Subsidence survey monitoring for the Eastern Tributary TARP includes the following:

- Cross lines across rock bars downstream of Pools ETAQ, ETAR, ETAT and ETAU, with expected accuracy of closure measurement of ±2 mm.

- Three high resolution fixed lines, A Line, B Line and C Line, using prisms attached to sandstone across the base of the Eastern Tributary Valley near Pool ETAU. The lines are surveyed using a high precision total station. Expected accuracy for these lines is ±1 mm.
- Three real time Global Navigation Satellite System, GNSS, monitoring stations providing real time closure monitoring around Pool ETAU, with telemetry and trend monitoring. The expected accuracy of measurement between GNSS stations is ±10 mm.

In addition, a high accuracy Leica total station is used to improve the accuracy and repeatability of surveyed data.

A Technical Committee will review the results of the monitoring program and report to the Metropolitan Colliery in accordance with a Trigger Action Response Plan for decisions by the Colliery on adaptive management for Longwalls 305 and 306.

5.5. Woronora Reservoir

5.5.1. Description of the Woronora Reservoir

The Woronora Reservoir Full Supply Level is located above Longwalls 306 and 307 and within the Study Area. The area of the Full Supply Level immediately downstream of the Waratah Rivulet and Eastern Tributary is referred to as an inundation area. When the Woronora Reservoir is at full capacity, this area is flooded. When the water level is below the Full Supply Level, portions of the inundation area form temporary pools above exposed rock bars that would normally be covered at the Full Supply Level.

5.5.2. Predictions for the Woronora Reservoir

The predicted profiles of vertical subsidence, upsidence and closure for the Woronora Reservoir Full Supply Level, resulting from the extraction of Longwalls 305 to 307 (based on the Extraction Plan Layout), are shown in Fig. C.02 (for the alignment of the Waratah Rivulet) and in Fig. C.03 (for the alignment of the Eastern Tributary), in Appendix C. The predicted incremental profiles due to the extraction of Longwalls 305 to 307 for the Extraction Plan Layout, are shown as dashed black lines. The predicted total profiles for the Extraction Plan Layout are shown as solid blue lines. The predicted total profiles based on the Preferred Project Layout are shown as the solid red lines for comparison.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the Woronora Reservoir Full Supply Level, resulting from the Extraction Plan Layout is provided in Table 5.11. The values are the predicted maxima within the Study Area.

Table 5.11 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Woronora Reservoir Full Supply Level after the Extraction of Longwalls 304 to 307

Longwall	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})
After LW304	40	< 0.5	< 0.01	< 0.01
After LW305	50	< 0.5	< 0.01	< 0.01
After LW306	300	1	0.02	0.03
After LW307	400	1	0.02	0.04

The maximum predicted conventional tilt for the Woronora Reservoir Full Supply Level based on the Extraction Plan Layout is 1.0 mm/m (i.e. 0.1 %, or 1 in 1000). The maximum predicted conventional curvatures are 0.02 km^{-1} hogging and 0.04 km^{-1} sagging, which equate to minimum radii of curvature of 50 km and 25 km respectively. The predicted conventional strains for the Woronora Reservoir Full Supply Level based on the Extraction Plan Layout (based on 15 times the curvature) are less than 0.5 mm/m tensile and 1 mm/m compressive.

A summary of the maximum predicted values of total upsidence and closure for the Woronora Reservoir Full Supply Level, resulting from the Extraction Plan Layout, is provided in Table 5.12. The compressive strains due to valley closure effects have also been provided (based on Section 4.4.3).

Table 5.12 Maximum Predicted Total Upsidence, Closure and Compressive Strain for the Woronora Reservoir Full Supply Level after the Extraction of Longwalls 304 to 307

Longwall	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)	Maximum Predicted Closure Strain based on the 90 % Confidence Level (mm/m)	Maximum Predicted Closure Strain based on the 95 % Confidence Level (mm/m)
After LW304	40	80	8	9
After LW305	200	175	15	18
After LW306	350	450	> 25	> 25
After LW307	600	575	> 25	> 25

5.5.3. Comparison of the Predictions for the Woronora Reservoir

The comparison of the maximum predicted subsidence parameters for the Woronora Reservoir Full Supply Level, resulting from the Extraction Plan Layout, with those based on the Preferred Project Layout is provided in Table 5.13. The values are the predicted maxima within the Study Area.

Table 5.13 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Woronora Reservoir Full Supply Level based on the Preferred Project Layout and the Extraction Plan Layout

Layout	Maximum Predicted Total Vertical Subsidence (mm)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
Preferred Project Layout (After LW307) (Report No. MSEC403)	475	775	800
Extraction Plan Layout (Report No. MSEC1057)	400	600	575

The maximum predicted vertical subsidence, upsidence and closure for the Woronora Reservoir Full Supply Level, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout.

5.5.4. Impact Assessments and Recommendations for the Woronora Reservoir

The maximum predicted subsidence parameters for the Woronora Reservoir, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout.

The potential impacts on the Woronora Reservoir, based on the Extraction Plan Layout, therefore, are the same or less than those assessed based on the Preferred Project Layout. The assessments of the potential impacts for the Woronora Reservoir were provided in Section 5.4.2 of Report No. MSEC285, which supported the Project EA and Preferred Project Layout. Where the reservoir level is low, the temporary pools and rock bars that may be exposed within the inundation area would be subject to potential subsidence impacts described for other tributaries in Section 5.6 below.

5.6. Other Tributaries

There are a number of streams located above Longwalls 305 to 307, as shown in Drawing No. MSEC1057-07. These streams consist of shallow drainage lines from the topographical high points, forming tributaries where valley heights increase and drain into the Woronora Reservoir.

The streams are located directly above Longwalls 305 to 307 and could, therefore, experience the full range of predicted subsidence movements, as summarised in Table 4.2, with a maximum predicted closure up to 700 mm. The maximum predicted subsidence parameters, based on the Extraction Plan Layout, are similar to the maxima based on the Preferred Project Layout, as summarised in Table 4.3.

The overall potential impacts on the tributaries above Longwalls 305 to 307, based on the Extraction Plan Layout, are the same as those assessed for the Preferred Project Layout. A summary of potential impacts to the tributaries is provided below:

- Cracking in the bedrock along base of the tributaries and fracturing and dilation of the underlying strata above and immediately adjacent to the proposed longwalls;
- Leakage from pools where cracking in the bedrock occurs; and
- Potential loss of surface water flow by diversion through subsurface fractures.

5.7. Aquifers and Known Groundwater Resources

The aquifers and groundwater resources within the vicinity of the proposed longwalls have been described in the Groundwater Assessment report by Dr Noel Merrick (Heritage Computing) (2008) in Appendix B of the Metropolitan Coal Project EA.

Descriptions of the aquifers and known groundwater resources within the Study Area are provided in the Metropolitan Coal Longwalls 305 to 307 Water Management Plan.

5.8. Natural Dams

There are no natural dams within the Study Area. There are natural pools in streams and in the upper reaches of the Woronora Reservoir full supply level when reservoir water levels are low, as described in Sections 5.3 to 5.6.

5.9. Cliffs and Overhangs

Consistent with the Project Approval, cliffs have been defined as a continuous rock face, including overhangs, having a minimum height of 10 metres and a slope of greater than 66° (2 to 1). The locations of the cliffs were determined from site inspections and from an aerial laser scan of the area.

Most of the cliffs and overhangs identified within the Project underground mining area are located along the alignment of the Waratah Rivulet or Waratah Rivulet arm of the Woronora Reservoir. The cliffs and overhangs have formed within the Hawkesbury Sandstone.

The locations of the cliffs and overhangs within the Study Area and surrounds are shown in Drawing No. MSEC1057-07. Five cliffs have been identified within the Study Area (sites COH11, COH12, COH13, COH16 and COH17) and four cliffs (COH7, COH8, COH9 and COH10) are located outside the Study Area and within 600 metres of Longwalls 305 to 307.

The descriptions, predictions and impact assessments for cliffs are provided in the following sections.

5.9.1. Descriptions of the Cliffs and Overhangs

Details of the cliffs and overhangs within 600 metres of Longwalls 305-307 are provided in Table 5.14. Several of the cliffs and overhangs listed in Table 5.14 are less than 10 metres in height but have been included in the assessment due to the sensitivity of some overhangs to potential movements resulting from mine subsidence.

There are also a number of rock ledges, which are located across the Study Area, generally within the valleys of the drainage lines. Rock ledges are discussed in Section 5.10.

Table 5.14 Details of Cliffs and Overhangs within 600 metres of Longwalls 305 to 307

Cliff and Overhang ID	Approx. Overall Length (m)	Approx. Maximum Height (m)	Approx. Maximum Overhang Depth (m)
COH7	30	6.5	10
	25	6.5	6
	15	5	7
	15	5	5.5
COH8	30	6	6.5
COH9	30	5.5	6
	5	1	2.5
COH10	40	7	5

Cliff and Overhang ID	Approx. Overall Length (m)	Approx. Maximum Height (m)	Approx. Maximum Overhang Depth (m)
	35	6.5	2
	25	7	3
COH11	20	16	3
COH12	30	9	4
COH13	40	12	2
COH16	35	7.5	5.5
COH17	80	11	7

5.9.2. Predictions for the Cliffs

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the cliffs within the Study Area, resulting from the Extraction Plan Layout, is provided in Table 5.15. The predicted tilts provided in this table are the maxima after the completion of Longwalls 305 to 307. The predicted curvatures are the maxima at any time during or after the extraction of Longwalls 305 to 307.

The cliffs located outside of the Study Area and within 600 metres of Longwalls 305-307 are not expected to experience any measurable vertical subsidence resulting from the extraction of Longwalls 305-307.

The cliffs are located along the alignments of the streams and will not experience the predicted valley closures which act across the alignments of the streams. The predicted strains for the cliffs include those resulting from non-conventional movements.

Table 5.15 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the cliffs after the Extraction of Longwall 307

ID	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})
COH11	40	< 0.5	< 0.01	< 0.01
COH12	40	< 0.5	< 0.01	< 0.01
COH13	90	1.0	0.02	< 0.01
COH16	< 20	< 0.5	< 0.01	< 0.01
COH17	125	< 0.5	< 0.01	< 0.01

The predicted strains for cliffs within the Study Area are provided in Table 5.16. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1).

Table 5.16 Predicted Strains for cliffs based on Conventional and Non-Conventional Anomalous Movements

ID	Type	Conventional based on 15 times Curvature	Non-conventional based on the 95 % Confidence Level	Non-conventional based on the 99 % Confidence Level
COH 13	Tension	< 0.5	0.9	1.6
	Compression	< 0.5	1.6	3.2
COH 11, 12, 16, 17	Tension	< 0.5	0.6	0.9
	Compression	< 0.5	0.5	0.8

5.9.3. Comparison of the Predictions for the Cliffs

The comparison of the maximum predicted subsidence parameters for the cliffs within the Study Area based on the Extraction Plan Layout, with those based on the Preferred Project Layout is provided in Table 5.17.

Table 5.17 Comparison of Maximum Predicted Conventional Subsidence Parameters for cliffs based on the Extraction Plan Layout and the Preferred Project Layout

ID	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})	
	Preferred Project Layout	Extraction Plan Layout	Preferred Project Layout	Extraction Plan Layout	Preferred Project Layout	Extraction Plan Layout	Preferred Project Layout	Extraction Plan Layout
COH11	70	40	1.0	< 0.5	0.01	< 0.01	< 0.01	< 0.01
COH12	125	40	1.5	< 0.5	0.02	< 0.01	< 0.01	< 0.01
COH13	300	90	2.0	1.0	0.01	0.02	0.02	< 0.01
COH16	< 20	< 20	< 0.5	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
COH17	475	125	0.5	< 0.5	0.01	< 0.01	0.03	< 0.01

Predicted subsidence values based on the Extraction Plan Layout are less than or the same as those based on the Preferred Project Layout. The predicted tilts for these cliffs based on the Extraction Plan Layout are unchanged or less than those based on the Preferred Project Layout. Hogging curvatures based on the Extraction Plan Layout are less than those based on the Preferred Project Layout at four cliff sites and higher than that based on the Preferred Project Layout at one site (Cliff COH13). Sagging curvatures based on the Extraction Plan Layout are less than or unchanged from those based on the Preferred Project Layout.

A summary of the maximum predicted vertical subsidence, tilt and curvature for the cliffs is provided in Table 5.18.

Table 5.18 Comparison of Maximum Predicted Conventional Subsidence Parameters for the cliffs based on the Extraction Plan Layout and the Preferred Project Layout

Layout	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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	475	2.0	0.04	0.05
Preferred Project Layout (After LW307) (Report No. MSEC403)	475	2.0	0.02	0.03
Extraction Plan Layout (Report No. MSEC1057)	125	1.0	0.02	<0.01

Whilst hogging curvature increases at COH13 as a result of the Extraction Plan Layout, it can be seen from Table 5.18, that the maximum predicted conventional hogging curvature for the cliffs, based on the Extraction Plan Layout, is the same as the maxima predicted based on the Preferred Project Layout after Longwall 307.

5.9.4. Impact Assessments for the Cliffs

A discussion of the impact assessments for the cliffs and overhangs is provided in Section 5.6.2 of the MSEC285 Report for the EA Layout. The potential for impacts on the cliffs and overhangs, based on the Extraction Plan Layout, are similar to those based on the Preferred Project Layout. Based on comparisons with other mines in the Southern Coalfield where cliff lines have been undermined, the lengths of potential cliff instabilities are expected to be less than 3 % of the lengths of these cliffs.

Although isolated rock falls have been observed over solid coal outside the extracted goaf areas of longwall mining in the Southern Coalfield, there have been no recorded cliff instabilities outside the extracted goaf areas of longwall mining in the Southern Coalfield. It is possible that isolated rock falls could occur as a result of the extraction of the proposed longwalls. It is not expected, however, that any large cliff instabilities would occur outside the longwall footprints as a result of the extraction of the longwalls.

5.10. Rock Ledges

There are rock ledges, also called rock outcrops and minor cliffs, located across the Study Area.

The rock ledges will experience the full range of predicted subsidence movements, as summarised in Table 4.1 and Table 4.2. The maximum predicted subsidence parameters for the rock ledges, based on the Extraction Plan Layout, therefore, are similar to the maxima predicted based on the Preferred Project Layout, as summarised in Table 4.3.

The potential impacts on the rock ledges, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Preferred Project Layout, specifically, the potential for fracturing of sandstone and subsequent rockfalls, particularly where the rocks ledges are marginally stable.

5.11. Steep Slopes

The locations of steep slopes are shown on Drawing No. MSEC1057-07. Steep slopes are presented based on the definition used in the subsidence assessment for the EA and MSEC285 Report (a natural gradient between 18° and 63°) and also based on the definition in the Project Approval 08_0149 (a natural gradient between 33° and 66°).

There are steep slopes located above Longwalls 305 to 307. The natural gradients for the steep slopes within the Study Area are typically up to 1 in 2, with some isolated areas with natural gradients up to 1 in 1.5.

The steep slopes could experience the full range of predicted subsidence movements, as summarised in Table 4.2. The maximum predicted subsidence parameters for the steep slopes, based on the Extraction Plan Layout, therefore, are similar to the maxima based on the Preferred Project Layout, as summarised in Table 4.3.

The potential impacts on the steep slopes, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Preferred Project Layout. The potential for ground surface cracking, is discussed in Section 4.8. The size and extent of surface cracking at the steep slopes is expected to be similar to that observed during the extraction of earlier longwalls at Metropolitan Coal.

5.12. Land Prone to Flooding and Inundation

No major natural flood prone areas have been identified within the Study Area.

An area between the Woronora Reservoir surface water level and the full supply level was defined as land prone to inundation, as described in Sections 2.3.12 and 5.4 in the MSEC285 report. Photographs of the inundation area are shown in Fig. 5.1. When the Woronora Reservoir is at full capacity the inundation area is flooded. When the water level is below the full supply level, portions of the inundation area form temporary pools above exposed rock bars that would normally be covered when the reservoir is at full supply.

Fig. 5.1 Woronora Reservoir Inundation Area

The Woronora Reservoir full supply level is shown in Drawing No. MSEC1057-07, which shows the Woronora Reservoir within the Study Area Boundary.

Predictions of subsidence, upsidence and closure for this section of the full supply level for the Extraction Plan Layout are shown Fig. C.02 and C.03, in Appendix C, and are discussed in Section 5.5.

5.13. Swamps, Wetlands and Water Related Ecosystems

5.13.1. Descriptions of the Swamps

The locations of the swamps are shown in Drawing No. MSEC1057-07. The mapped extents of these swamps is based on field inspections and validation by Eco Logical Australia. There are 18 swamps located within the Study Area. There are a further 10 swamps that are located outside the Study Area and within 600 metres of Longwalls 305 to 307.

Detailed descriptions of the swamps within the study area are provided in the Metropolitan Coal Longwalls 305 to 307 Biodiversity Management Plan.

5.13.2. Predictions for the Swamps

The maximum predicted subsidence parameters for each of the swamps located within the Study Area are provided in Table. D.01, in Appendix D. The predictions have been provided based on the Extraction Plan Layout, as well as for the Preferred Project Layout (After LW307) and the Preferred Project Layout (After LW317), for comparison.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the swamps, resulting from the Extraction Plan Layout, is provided in Table 5.19. The predicted tilts provided in this table are the maxima after the completion of Longwall 307. The predicted curvatures are the maxima at any time during or after the extraction of Longwalls 305 to 307.

Table 5.19 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Swamps within the Study Area after the Extraction of Longwall 307

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})
S40	850	4.0	0.05	0.06
S41	1050	5.0	0.04	0.12
S46	1100	0.5	0.05	0.06
S47	1050	1.5	0.03	0.03
S48	800	3.0	0.06	0.05
S49	900	2.0	0.05	0.08
S50	950	2.0	0.04	0.09
S51/S52	1100	2.0	0.04	0.04
S53	1100	3.0	0.05	0.05
S58	225	2.0	0.03	0.01
S69	20	< 0.5	< 0.01	< 0.01
S70	< 20	< 0.5	< 0.01	< 0.01
S71a	40	< 0.5	< 0.01	< 0.01
S71b	20	< 0.5	< 0.01	< 0.01
S72	< 20	< 0.5	< 0.01	< 0.01
S73	< 20	< 0.5	< 0.01	< 0.01
S84	100	1.5	0.02	< 0.01
S86	< 20	< 0.5	< 0.01	< 0.01

The maximum predicted strains for the swamps located directly above Longwalls 305 to 307 are provided in Table 5.20. The values have been derived for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1). The compressive strains due to valley closure effects are provided separately.

Table 5.20 Maximum Predicted Strains for the Swamps Located directly above Longwalls 305 to 307 based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 times Curvature	Non-conventional based on the 95 % Confidence Level	Non-conventional based on the 99 % Confidence Level
Tension	1.0	0.9	1.6
Compression	2.0	1.6	3.2

A number of the swamps within the Study Area are located along the alignments of tributaries (shallow drainage lines, based on Department of Lands mapping) and, therefore, could experience valley related effects. A summary of the maximum predicted upsidence and closure for these swamps, after the extraction of Longwalls 305 to 307 for the Extraction Plan Layout, is provided in Table 5.21. The compressive strains due to valley closure effects have also been provided (based on the method outline in Section 4.4.3).

Table 5.21 Maximum Predicted Total Upsidence, Closure and Valley Related Strain for the Swamps within the Study Area after the Extraction of Longwall 307

Location	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)	Maximum Predicted Closure Strain based on the 90 % Confidence Level (mm/m)	Maximum Predicted Closure Strain based on the 95 % Confidence Level (mm/m)
S51/S52	90	40	6	7
S53	100	40	6	7
S58	< 20	< 20	< 2	< 2

The predicted total closures for the swamps in Table 5.21 do not increase after the extraction of Longwall 304.

5.13.3. Comparison of the Predictions for the Swamps

The comparison of the maximum predicted subsidence parameters for the swamps within the Study Area, with those based on the Preferred Project Layout is provided in Table D.01, in Appendix D.

It can be seen from Table D.01 that the maximum predicted subsidence values based on the Extraction Plan Layout are significantly less than or the same as the values for the Preferred Project Layout at nine of the swamps, and higher at the other nine swamps. The increases in maximum predicted subsidence occur at the swamps located in the areas where pillar widths have been narrowed for Longwalls 301 to 304. The predicted hogging and sagging curvatures are reduced or unchanged for the majority of the swamps based on the Extraction Plan Layout, where the hogging and sagging curvatures increase slightly at three and four of the 18 swamps, respectively.

A summary of the maximum predicted vertical subsidence, tilt and curvature for the swamps within the Study Area is provided in Table 5.22. A summary of the maximum predicted upsidence and closure for the swamps within the Study Area is provided in Table 5.23.

Table 5.22 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Swamps based on the Extraction Plan Layout and the Preferred Project Layout

Layout	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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1150	5.0	0.07	0.10
Preferred Project Layout (After LW307) (Report No. MSEC403)	1150	5.0	0.06	0.10
Extraction Plan Layout (Report No. MSEC1057)	1100	5.0	0.06	0.12

Table 5.23 Comparison of Maximum Predicted Upsidence and Closure for the Swamps based on the Extraction Plan Layout and the Preferred Project Layout

Layout	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
Preferred Project Layout (After LW317) (Report No. MSEC403)	100	40
Preferred Project Layout (After LW307) (Report No. MSEC403)	100	40
Extraction Plan Layout (Report No. MSEC1057)	100	40

It can be seen from Table 5.22, that the maximum predicted conventional subsidence, tilt and curvatures for the swamps, based on the Extraction Plan Layout, are similar to, or less than the maxima based on the Preferred Project Layout after Longwalls 305 to 307. The predicted parameters for the individual swamps increase or decrease, depending on their locations relative to Longwalls 305 to 307.

It can be seen from Table 5.23, that the maximum predicted upsidence and closure for the swamps, based on the Extraction Plan Layout, are the same as the maxima predicted based on the Preferred Project Layout after Longwalls 305 to 307.

5.13.4. Impact Assessments and Recommendations for the Swamps

Whilst the predicted subsidence parameters increase at a small number of swamps, the maximum values are similar to the maxima predicted for other swamps located above the previously extracted longwalls at the Colliery. The potential impacts for the swamps, based on the Extraction Plan Layout, therefore, are similar to those assessed based on the Preferred Project Layout.

Cracking of the bedrock within upland swamps is expected to be isolated and of a minor nature, due to the relatively low magnitudes of the predicted curvatures and strains and the relatively high depths of cover. The minor cracking within the swamps would generally not be expected to propagate through swamp soil profiles.

Whilst swamp grades vary naturally, the predicted maximum mining-induced tilts are generally an order of magnitude lower than the existing natural grades within the swamps. The predicted tilts would not be expected to have a significant effect on the localised or overall gradient of the swamps or the flow of surface water.

The three swamps listed in the performance measures in the Project Approval 08_0149 (Swamps S76, S77 and S92) are located outside the Study Area boundary. At the distances outside the Study Area boundary, these swamps are not predicted to experience measurable subsidence or valley related movements due to the extraction of Longwalls 305 to 307.

5.14. Threatened, Protected Species or Critical Habitats

There are no lands within the Study Area that have been declared as critical habitat under the *Biodiversity Conservation Act 2016*. However, threatened and protected species and their habitats occur within the Study Area as described in the Longwalls 305 to 307 Biodiversity Management Plan.

5.15. Natural Vegetation

The vegetation within the Study Area generally consists of native bushland. A detailed survey of the natural vegetation has been undertaken and is described in the Baseline Flora Survey report (Bangalay Botanical Surveys, April 2008) in Appendix E of the Metropolitan Coal Project EA.

Natural vegetation covers the majority of the Study Area. The natural vegetation could, therefore, experience the full range of predicted subsidence movements, as summarised in Table 4.2. The maximum predicted subsidence parameters for the natural vegetation, based on the Extraction Plan Layout, therefore, are similar to the maxima based on the Preferred Project Layout, as summarised in Table 4.3.

The potential impacts on the natural vegetation, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Preferred Project Layout.

5.16. Areas of Significant Geological Interest

There are no areas of significant geological interest within the Study Area. A brief description of the geology within the Study Area is provided in Section 1.5.

6.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE PUBLIC UTILITIES

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the public utilities located within the Study Area for Longwalls 305 to 307. The predicted parameters for each of the built features have been compared to the predicted parameters based on the Preferred Project Layout.

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

- Tunnels;
- Gas pipelines;
- Liquid fuel pipelines;
- Water and sewage treatment works; and
- Air strips.

6.1. Railways

There are no railways located within the Study Area. The Illawarra Railway is located at a minimum distance of 2.0 km to the north east of Longwall 305.

At this distance, the railway is not expected to experience measurable conventional vertical subsidence, tilts or curvatures and only low level horizontal movements. It is unlikely that the railway and associated infrastructure would experience adverse impacts as a result of extracting Longwalls 305 to 307.

Old workings are present beneath, and in the vicinity of, the Illawarra Railway. At approximately 2 km from the proposed Longwall 305, it is unlikely that the railway and associated infrastructure would experience adverse impacts from old workings as a result of the extraction of the proposed Longwalls 305 to 307. An assessment of long term subsidence above old workings was undertaken and presented at the 8th Triennial Conference on Mine Subsidence in 2011 in a paper titled "*An Analysis of Long Term Subsidence at Metropolitan Colliery*". A copy of the paper is attached. The assessment covered data over a 14 year period of monitoring and found that the goaf/chain pillar system was in a longer term stable condition and ongoing subsidence movements appeared to be reducing to zero.

Total station survey within the culverts has been conducted since the commencement of Longwall 301 and real time 3D monitoring of the valley sides of both culverts, including closure, has been conducted since the commencement of Longwall 303. Observed movements to date have been within the limits of accuracy of the survey methods with no indications of developing subsidence related movements. The total station survey within the culverts and real time 3D monitoring will be continued during the extraction of Longwall 304.

Given the increasing distance of the longwall extraction from the Illawarra Railway, it is considered that monitoring developed for the extraction of Longwalls 301 to 304 could be relaxed for the extraction of future longwalls from LW305 onwards. Consideration could be given to cessation of monitoring following a review of the monitoring conducted during the extraction of Longwall 304.

6.2. M1 Princes Motorway

The M1 Princes Motorway is located outside the Study Area to the east of Longwalls 305 to 307 as shown on Drawing No. MSEC1057-08. The distance of the M1 Princes Motorway from Longwalls 305 to 307 varies from 1040 m near the finishing (southern) end to 1,100 m near the commencing (northern) end of Longwall 305. Longwalls 301 to 304 are located closer to the M1 Princes Motorway with 210 metres distance to the finishing (southern) end of Longwall 301 and 335 metres distance to the commencing (northern) end of Longwall 301.

At a distance of over 1,020 m from Longwall 305, the RMS assets are located outside the Study Area and are not expected to experience measurable conventional vertical subsidence, tilts, curvatures or strains (i.e. no greater than survey accuracy). The RMS assets could however experience low level far-field horizontal movements. The far-field horizontal movements are expected to be similar to those observed for previous longwall mining in the Southern Coalfield.

The observed incremental far-field horizontal movements, resulting from the extraction of longwalls in the Southern Coalfield, are provided in Fig. 4.9. The absolute horizontal movements measured at distances greater than 1 km from mining are in the order of 40 mm based on the 95 % confidence level. Far-field horizontal movements tend to be bodily movements orientated towards the mining area. The strains associated with these low level horizontal movements are not expected to be measurable.

Whilst the M1 Princes Motorway could experience low level far-field horizontal movements, the associated tilts, curvatures or strains are not expected to be measurable. The potential for impacts on the M1 Princes Motorway and associated infrastructure, based on the Extraction Plan Layout, are the same as those based on the Preferred Project Layout. It is unlikely that the M1 Princes Motorway and associated infrastructure would experience adverse impacts as a result of Longwalls 305 to 307.

It is recommended that monitoring and management strategies developed for the extraction of Longwalls 301-304 are updated and continued, in consultation with RMS, to manage the potential impacts on the RMS infrastructure. It is expected that the RMS infrastructure can be maintained in safe and serviceable conditions with the implementation of the appropriate monitoring and management strategies.

6.3. Old Princes Highway

6.3.1. Description of the Old Princes Highway

The Old Princes Highway is a regional road that crosses through the Study Area. The Old Princes Highway crosses directly above previous Longwalls 301 to 304. The highway passes close to the commencing end of Longwall 305, but does not cross directly above the proposed Longwalls 305 to 307. The location of the highway is shown in Drawing No. MSEC1057-08.

The Old Princes Highway is often referred to as Princes Highway and is referred to as such in other reports including previous reports prepared by MSEC. The section of Princes Highway located within the Study Area was renamed as Old Princes Highway in October 2002 (NSW Government Gazette No. 189, 25th October 2002).

The section of the Old Princes Highway located within the Study Area comprises a single carriageway with a flexible asphalt pavement and grass verges. A photograph of the highway is provided in Fig. 6.1.

Fig. 6.1 Old Princes Highway

The total length of the Old Princes Highway that is located within the Study Area is approximately 1.9 km.

6.3.2. Predictions for the Old Princes Highway

The predicted profiles of vertical subsidence, tilt and curvature along the alignment of the Old Princes Highway, resulting from the extraction of Longwalls 305 to 307, are shown in Fig. C.04, in Appendix C. The predicted incremental profiles for the highway, due to the extraction of Longwalls 305 to 307 for the Extraction Plan Layout, are shown as dashed black lines. The predicted total profiles for the highway, after the extraction of each of the longwalls for the Extraction Plan Layout, are shown as solid blue lines. The predicted total profiles based on the Preferred Project Layout are shown as red lines for comparison.

A summary of the maximum predicted values of total subsidence, tilt and curvature for the Old Princes Highway, after the extraction of Longwalls 305 to 307, is provided in Table 6.1. The values are the maxima anywhere along the section of the highway located within the Study Area.

Table 6.1 Predicted Total Subsidence, Tilt and Curvature for the Old Princes Highway after the Extraction of Longwalls 305 to 307

Longwall	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})
After LW304	925	2.5	0.05	0.03
After LW305	1050	2.5	0.05	0.07
After LW306	1050	3.0	0.05	0.07
After LW307	1050	3.0	0.05	0.07

The maximum predicted total subsidence for the Old Princes Highway, following the extraction of Longwall 304 and after the extraction of Longwalls 305 to 307, is 1,050 mm. The maximum predicted conventional tilt for the highway after the extraction of Longwall 307 is 3.0 mm/m (i.e. 0.3 %, or 1 in 330). The maximum predicted conventional curvatures are 0.05 km^{-1} hogging and 0.07 km^{-1} sagging, which equate to minimum radii of curvature of 20 km and 14 km respectively.

The predicted strains for the section of the Old Princes Highway located directly above the Longwalls 301 to 304 are provided in Table 6.2. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1).

Table 6.2 Predicted Strains for the Section of the Old Princes Highway Located directly above longwalls based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 times Curvature (mm/m)	Non-conventional based on the 95 % Confidence Level (mm/m)	Non-conventional based on the 99 % Confidence Level (mm/m)
Tension	1.0	0.9	1.6
Compression	1.0	1.6	3.2

The Old Princes Highway does not cross any major streams within the Study Area. The highway, therefore, is not expected to experience valley closure effects.

6.3.3. Comparison of the Predictions for the Old Princes Highway

The comparison of the maximum predicted subsidence parameters for the Old Princes Highway with those based on the Preferred Project Layout is provided in Table 6.3. The values are the maxima anywhere along the section of the highway located within the Study Area.

Table 6.3 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Old Princes Highway based on the Extraction Plan Layout and the Preferred Project Layout

Layout	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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1150	5.0	0.05	0.07
Preferred Project Layout (After LW307) (Report No. MSEC403)	1100	1.5	0.05	0.07
Extraction Plan Layout (Report No. MSEC1057)	1050	3.0	0.05	0.07

The maximum predicted vertical subsidence based on the Extraction Plan Layout is less than the maxima based on the Preferred Project Layout (After LW307).

The maximum predicted tilt based on the Extraction Plan Layout is higher than that based on the Preferred Project Layout (After LW307). Maximum predicted total curvatures based on the Extraction Plan Layout are the same as those based on the Preferred Project Layout. The potential impacts on the Old Princes Highway based on the Extraction Plan Layout are similar to those based on the Preferred Project Layout. The impact assessments for the highway are provided in the following section.

6.3.4. Impact Assessments and Recommendations for the Old Princes Highway

The maximum predicted conventional tilt for the Old Princes Highway after the extraction of Longwall 307 is 3.0 mm/m (i.e. 0.3 %, or 1 in 330). The predicted changes in grade are small, less than 1 %, and therefore are unlikely to result in adverse impacts on the serviceability or surface water drainage for the highway. If additional localised ponding or adverse changes in surface water drainage were to occur as the result of mining, the highway could be repaired using normal road maintenance techniques.

The maximum predicted conventional curvatures for the highway are 0.05 km^{-1} hogging and 0.07 km^{-1}sagging, which equate to minimum radii of curvature of 20 km and 14 km respectively. The predicted strains are 0.9 mm/m tensile and 1.6 mm/m compressive based on the 95 % confidence level and 1.5 mm/m tensile and 3.2 mm/m compressive based on the 99 % confidence level.

The maximum predicted curvatures and the range of potential strains for the Old Princes Highway are similar to those typically experienced elsewhere in the Southern Coalfield. Longwalls in the Southern Coalfield have been successfully mined directly beneath roads with bitumen and asphaltic pavements.

For example, at Tahmoor Colliery, Longwalls 22 to 31 have mined beneath approximately 28 kilometres of local roads. A total of 52 impact sites have been observed and, therefore, this equates to an average of one impact for every 540 metres of pavement. The majority of the impacts were minor and did not present a public safety risk. The potential impacts due to conventional subsidence movements include minor cracking, rippling, bumps and stepping in the road surface. The nature of potential impacts to the pavement is also affected by the type of construction of the road pavement.

Approximately 770 metres of the Old Princes Highway have been mined beneath by Longwalls 301 to 303. Potential impacts on the Old Princes Highway are being managed using monitoring (visual and/or ground survey lines) and impacts can be remediated during active subsidence using normal road maintenance techniques. Final repair of the highway would be undertaken at the completion of the longwalls. No adverse impacts or anomalous movements have been identified along the Old Princes Highway during the extraction of Longwalls 301 to 303. Only low level additional movements are predicted for the highway due to the extraction of Longwalls 305 to 307.

It is recommended that monitoring and management strategies developed for the extraction of Longwalls 304 are updated and continued, in consultation with Wollongong City Council, to manage potential impacts on the Old Princes Highway. It is expected that the highway can be maintained in safe and serviceable conditions with the implementation of the appropriate monitoring and management strategies.

6.4. Fire Trails and Four Wheel Drive Tracks

The locations of the unsealed four wheel drive tracks and fire roads within and adjacent to the Study Area are shown in Drawings Nos. MSEC1057-08 and MSEC1057-09. Tracks are located directly above Longwalls 305 to 307 and previously extracted longwalls. The tracks would therefore experience the full range of subsidence movements during the extraction of Longwalls 305 to 307, which are provided in Chapter 4.

The maximum predicted subsidence parameters for the unsealed four wheel drive tracks and fire roads, based on the Extraction Plan Layout, are similar to the maxima predicted based on the Preferred Project Layout. The predicted maximum tilt based on the Extraction Plan Layout is slightly higher than that based on the Preferred Project Layout to the east of Longwalls 305 to 307 but maximum predicted tilts are similar above the longwalls. The potential impacts for the unsealed four wheel drive tracks and fire roads, based on the Extraction Plan Layout, are similar to those assessed based on the Preferred Project Layout. Impact assessments for the fire trails and four wheel drive tracks are provided in Section 5.13 of the MSEC285 Report.

It is possible that the four wheel drive tracks and fire roads could experience surface cracking during the mining period, particularly where the tracks and roads are located near the tops of existing slopes. The size and extent of surface tension cracking on slopes is expected to be minor and similar to that observed during the extraction of previous longwalls at the Metropolitan Colliery. Further discussion on mining induced ground deformations is provided in Section 4.8.

It is recommended that monitoring and management strategies developed for the extraction of Longwalls 301 to 304 are updated and continued to manage the potential impacts on the fire trails and four wheel drive tracks. It is expected that the fire trails and four wheel drive tracks can be maintained in safe and serviceable conditions with the implementation of the appropriate monitoring and management strategies.

6.5. Bridges

Bridge 2 (RMS reference BN616-southbound and BN617-northbound) is located approximately 1,020 m to the south east of Longwall 305 as shown in Drawing No. MSEC1057-08. A photograph of Bridge 2 is shown in Fig. 6.2 below.

Fig. 6.2 Bridge 2

The next nearest bridge is Cawleys Rd overpass (RMS reference BN615), located approximately 1.67 km from Longwall 305.

At these distances, Bridge 2 and Cawleys Rd overpass are not expected to experience measurable conventional vertical subsidence, tilts or curvatures. The bridges could experience low level far-field horizontal movements. The far-field horizontal movements are expected to be similar to those observed for previous longwall mining in the Southern Coalfield.

The observed incremental far-field horizontal movements, resulting from the extraction of longwalls in the Southern Coalfield, are provided in Fig. 4.9. The absolute horizontal movements measured at distances greater than 1 km from mining are in the order of 40 mm based on the 95 % confidence level. Observed horizontal movements have been recorded at several real time GNSS monitoring units located to the east of Longwalls 301 to 303. The observations to date show a maximum observed incremental horizontal movement of 15 mm at 1 km from an active longwall. Far-field horizontal movements tend to be bodily movements orientated towards the mining area. The strains associated with these low level horizontal movements are not expected to be measurable.

The potential for differential horizontal movement was assessed by analysing the far-field horizontal movement data discussed in Section 4.6. The data set was analysed to determine incremental relative opening and closing and incremental mid ordinate deviation.

Relative opening and closing movement is calculated as the change in the distance between two survey marks (either positive opening, or negative closing) over two survey epochs.

A plot of the calculated incremental relative opening and closing movement for the current database of observed far-field horizontal movements that were used for this assessment is provided in Fig. 6.3. The incremental relative opening and closing movement was calculated for pegs with a spacing of 20 m ±10 m.

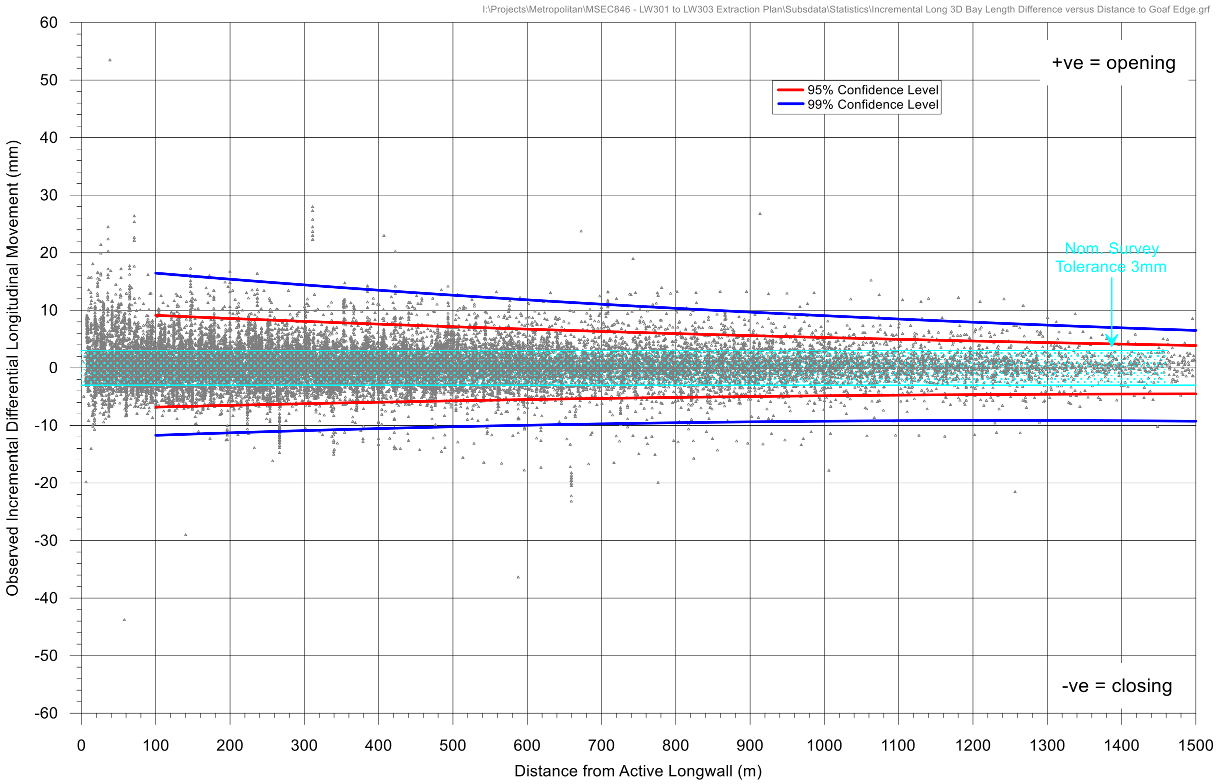

Fig. 6.3 Incremental Differential Horizontal Movements versus Distance from Active Longwall for Marks Spaced at 20 m ±10 m

Mid ordinate deviation provides a measure of out of plane movement or horizontal bending by calculating the mid ordinate deviation between three survey pegs. The mid ordinate deviation is the change in perpendicular horizontal distance from a point to a chord formed by points on either side. A schematic sketch of the mid ordinate deviation is provided in, Fig. 6.4.

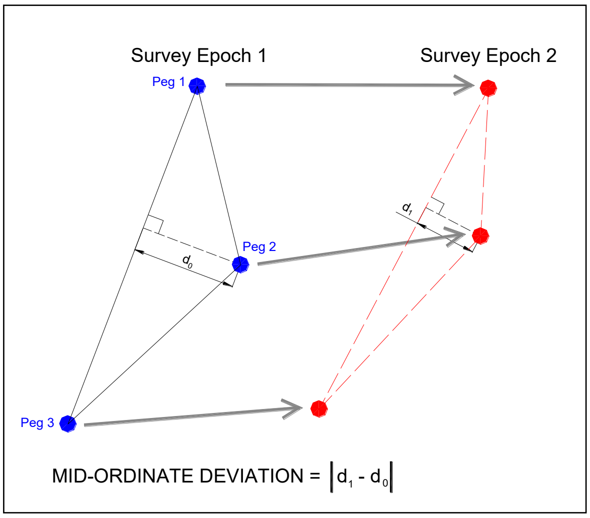

Fig. 6.4 Schematic Representation of Mid Ordinate Deviation

A plot of the calculated incremental mid-ordinate deviation for the current database of observed far-field horizontal movements that were used for this assessment is provided in Fig. 6.5. The mid ordinate deviation was calculated for pegs with a spacing of 20 m ±10 m, or an approximate spacing of 40 m over the three pegs.

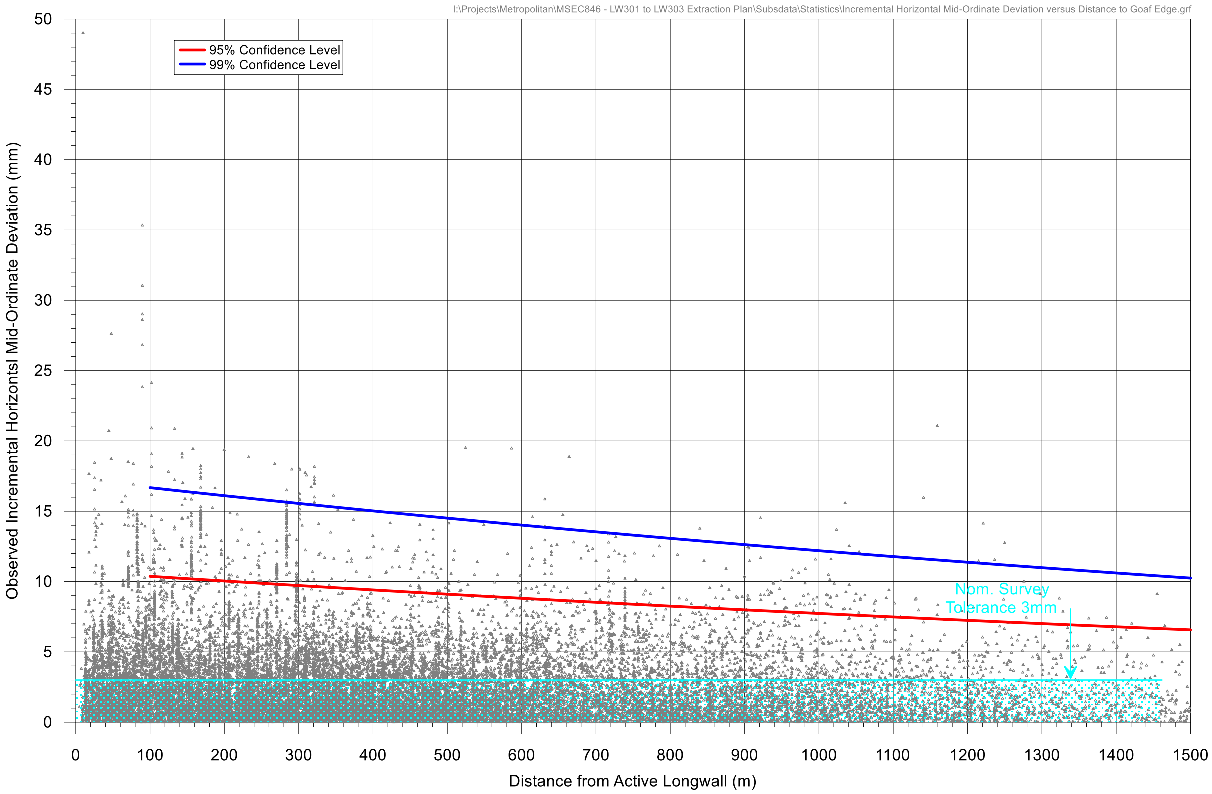

Fig. 6.5 Observed Incremental Mid-Ordinate Deviation versus Distance from Active Longwall for Marks Spaced at 20 m ±10 m

An assessment of Bridge 2 and Cawleys Road overpass by Cardno was undertaken for the extraction of Longwalls 301 to 303 and indicated that the bridges were sensitive to small differential movements. Given closer proximity of Bridge 2 to the extracted longwalls, a high accuracy monitoring system, using fibre optic monitoring, was implemented by the RMS technical committee to monitor movements at Bridge 2. A monitoring system for Cawleys Road overpass using fixed survey prisms was established. Details of the monitoring systems are outlined in the Built Features Management Plan for RMS infrastructure.

It is recommended that monitoring and management strategies developed for the extraction of Longwalls 301-304 are updated and continued, in consultation with RMS, to manage the potential impacts on the RMS infrastructure. It is expected that the RMS infrastructure can be maintained in safe and serviceable conditions with the implementation of the appropriate monitoring and management strategies.

6.6. Road Drainage Culverts

A series of culverts cross the M1 Princes Motorway. The culverts comprise pipes of varying diameters from 375 mm to 1800 mm. The pipe materials comprise asbestos cement (pipes up to 600 mm diameter) and steel reinforced concrete (pipes up to 1800 mm diameter). In addition to the culverts, there are also a number of other drainage structures, such as kerbs, gutters, pits and drainage pipes. The largest culvert comprises two 1800 mm pipes located to the north east of the longwalls at Cawleys Creek.

Since the drainage culverts are located along the M1 Princes Motorway, the predicted movements at the culverts resulting from the extraction of the proposed Longwalls 305 to 307 are the same as those discussed in Section 6.2 for the M1 Princes Motorway and the potential impacts on the culverts based on the Extraction Plan Layout, therefore, are the same as those based on the Preferred Project Layout.

It is considered unlikely that impacts to the culverts would occur as a result of the extraction of Longwalls 305 to 307. Should impacts occur, they are expected to be isolated and of a minor nature and easily repairable.

6.7. Water Infrastructure

6.7.1. Descriptions of the Water Infrastructure

The locations of the water infrastructure within the Study Area are shown in Drawings Nos. MSEC1057-08 to MSEC1057-10.

There are two potable water supply pipelines located within the Study Area. *Water Main 1* crosses the northern end of Longwall 305 and Longwalls 301 to 304, and comprises a 300 mm diameter Cast Iron Cement Lined (CICL) pipeline. *Water Main 2* crosses Longwalls 301 to 303 and comprises a 300 mm diameter CICL pipeline. Water Main 2 is located 150 m to the north east of Longwall 305 at its nearest point.

A sewer main is located outside the Study Area, 650 m to the north east of Longwall 305. This pipeline is a 150 mm PVC pressure main. There are also networks of potable water and sewer pipelines located outside of the Study Area, within the nearby township of Helensburgh to the south-east of the longwalls. These networks are located at a minimum distance of 1.6 km from Longwall 305.

6.7.2. Predictions for the Water Infrastructure

The predicted profiles of vertical subsidence, tilt and curvature along the alignments of Water Main 1 and Water Main 2, resulting from the extraction of Longwalls 305 to 307, are shown in Figs. C.05 and C.06, respectively, in Appendix C. The predicted incremental profiles for the pipelines, due to the extraction of Longwalls 305 to 307 for the Extraction Plan Layout, are shown as dashed black lines. The predicted total profiles for the pipelines, after the extraction of Longwalls 303 and 304 for the Extraction Plan Layout, are shown as solid blue lines. The predicted total profiles based on the Preferred Project Layout are shown as red lines for comparison.

Summaries of the maximum predicted values of total subsidence, tilt and curvature for the Water Mains 1 and 2, after the extraction of Longwalls 305 to 307, are provided in Table 6.4. The values are the maxima anywhere along the sections of the pipelines located within the Study Area.

Table 6.4 Predicted Total Subsidence, Tilt and Curvature for Water Main 1 and 2 after the Extraction of Longwalls 305 to 307

Pipeline	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})
Water Main 1	1100	2.5	0.05	0.04
Water Main 2	950	3.0	0.03	0.03

The maximum predicted total subsidence for the water mains within the Study Area, following the extraction of Longwall 305 to 307, are 1100 mm for Water Main 1 and 950 mm for Water Main 2. The maximum predicted conventional tilt for these pipelines is 3.0 mm/m (i.e. 0.3 %, or 1 in 330). The maximum predicted conventional curvatures are 0.05 km^{-1} hogging and 0.04 km^{-1} sagging, which equate to minimum radii of curvature of 20 kilometres and 25 kilometres, respectively.

The predicted strains for the sections of the water mains located directly above Longwalls 305 to 307 are provided in Table 6.5. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1).

Table 6.5 Predicted Strains for the Sections of the Water Mains Located directly above Longwalls 305 to 307 based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 times Curvature (mm/m)	Non-conventional based on the 95 % Confidence Level (mm/m)	Non-conventional based on the 99 % Confidence Level (mm/m)
Tension	1.0	0.9	1.6
Compression	0.5	1.6	3.2

The water mains do not cross any major streams within the Study Area. The pipelines, therefore, are not expected to experience valley closure effects.

The sewer main to the north east of the Study Area is not expected to experience measurable tilts, curvatures or strains. Similarly, the networks of water and sewerage pipelines located within the township of Helensburgh are not expected to experience any measurable vertical subsidence, tilts, curvatures or strains. The pipelines could experience low level far-field horizontal movements. However, these absolute horizontal movements tend to be bodily movements that are not associated with measurable strains.

6.7.3. Comparison of the Predictions for the Water Infrastructure

The comparison of the maximum predicted subsidence parameters for Water Main 1 and 2 based on the Extraction Plan Layout with those based on the Preferred Project Layout is provided in Table 6.6. The values are the maxima anywhere along the sections of the pipelines located within the Study Area.

Table 6.6 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Water Mains based on the Extraction Plan Layout and the Preferred Project Layout

Layout	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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	975	4.0	0.07	0.07
Preferred Project Layout (After LW307) (Report No. MSEC403)	950	2.5	0.06	0.07
Extraction Plan Layout (Report No. MSEC1057)	1100	2.5	0.05	0.04

The maximum predicted vertical subsidence for the water mains based on the Extraction Plan Layout is slightly greater than the maximum based on the Preferred Project Layout. However, the potential for impact does not result from absolute vertical subsidence, but rather from the differential movements (i.e. tilt, curvature and strain).

The maximum predicted tilt, curvatures and strains for the water mains based on the Extraction Plan Layout are similar to or less than the maxima predicted based on the Preferred Project Layout. The potential impacts based on the Extraction Plan Layout, therefore, are similar to those based on the Preferred Project Layout. The impact assessments for the water mains are provided in the following section.

6.7.4. Impact Assessment and Recommendations for Water Infrastructure

Water Mains 1 and 2 are pressure mains and, therefore, are unlikely to be adversely impacted by the mining induced vertical subsidence or tilt. These pipelines are direct buried and are likely to experience the curvatures and ground strains resulting from the extraction of Longwalls 305 to 307.

The maximum predicted conventional curvatures within the Study Area for the water mains are 0.05 km^{-1} hogging and 0.04 km^{-1} sagging, which equate to minimum radii of curvature of 20 kilometres and 8 kilometres, respectively. Higher curvatures were predicted for the previous Longwalls 301 to 304. Localised and elevated curvatures could develop along the pipelines due to non-conventional movements resulting from unknown near surface geological structures (i.e. anomalies).

The predicted curvatures and strains for the water mains are similar to those where longwalls in the Southern Coalfield have previously mined directly beneath similar pipelines. It has been found from this previous experience that the impacts on CICL pipelines in the Southern Coalfield are rare and generally of a minor nature. Some examples of mining beneath water mains in the Southern Coalfield are provided in Table 6.7.

Table 6.7 Examples of Mining Beneath Water Mains in the Southern Coalfield

Colliery and Longwalls	Pipelines	Observed 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 DICL and 300 mm CICL pipelines at a creek crossing, elsewhere no other reported impacts
Tahmoor LW22 to LW25	2.7 km DICL pipes 7.3 km CICL pipes	1200 mm Subsidence 6 mm/m Tilt 1.5 mm Tensile Strain 2 mm (typ.) and up to 5 mm/m Comp. Strain (Extensive street monitoring)	One reported impact to the distribution network 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

Based on this experience, it is possible that some minor leakages of the water mains could occur following the extraction of Longwalls 305 to 307. However, the incidence of impacts is likely to be very low and of a minor nature. Impacts to Water Main to resulting from the extraction of Longwalls 305 to 307 are less likely due to the greater distance from the pipeline to these longwalls. It is expected that any impacts could be remediated by locally exposing the pipeline and repairing or replacing the affected section.

Watermains 1 and 2 have been mined beneath by Longwalls 301 to 303. Monitoring adjacent to Watermain 2 indicates the pipeline has experienced 1086 mm maximum total subsidence, 5 mm/m total tilt, 1.6 mm/m tensile strain and 1.8 mm/m compressive strain. No impacts have been recorded to date for Watermains 1 and 2.

It is recommended that monitoring and management strategies developed for the extraction of Longwalls 301 to 304 are updated and continued, in consultation with Sydney Water, to manage potential impacts on the water mains that are located directly above the longwalls. It is expected that these pipelines can be maintained in serviceable conditions with the implementation of the appropriate monitoring and management strategies.

The sewer main adjacent to the north-eastern part of the Study Area and the networks of water and sewer pipelines located within the township of Helensburgh are all located outside of the predicted 20 mm subsidence contour. It is unlikely that these pipelines would experience adverse impacts as a result of the proposed Longwalls 305 to 307.

6.8. Electrical Infrastructure

6.8.1. Descriptions of the Electrical Infrastructure

The locations of the electrical infrastructure are shown in Drawing No. MSEC1057-08. The infrastructure comprises a 132 kV transmission line owned by Endeavour Energy, a 330 kV transmission line owned by TransGrid and 11 kV (low voltage) distribution lines owned by Endeavour Energy.

The 132 kV and 330 kV transmission lines are located to the east of Longwall 301 and are located outside the Study Area. The 132 kV transmission line towers are located over 930 m from Longwalls 305 to 307. The 330 kV transmission line towers are located over 870 m from Longwalls 305 to 307.

The main low voltage distribution line runs between the township of Helensburgh and the Garrawarra Complex to the north east of the Study Area and is labelled Powerline 1 in Drawing No. MSEC1059-08. The low voltage powerlines within the Study Area service the Garrawarra Complex in the north-eastern part of the Study Area. The powerlines comprise aerial conductors supported on timber poles. The nearest pole is approximately 340 m from Longwall 305. Underground powerlines are also present within the Garrawarra Complex and are understood to be private lines. There are no powerlines above Longwalls 305 to 307.

6.8.2. Predictions for the Electrical Infrastructure

The transmission lines are located over 870 m from Longwalls 305 to 307. Powerline 1 is located over 550 m from Longwalls 305 to 307. At these distances, the transmission lines and Powerline 1 are not expected to experience measurable conventional vertical subsidence, tilts or curvatures due to the extraction of Longwalls 305 to 307. The transmission towers and power poles could experience low level far-field horizontal movement. The far-field horizontal movements are expected to be similar to those observed for previous longwall mining in the Southern Coalfield.

The observed incremental far-field horizontal movements, resulting from the extraction of longwalls in the Southern Coalfield, are provided in Fig. 4.9. The absolute horizontal movements measured at distances greater than 870 m from mining are in the order of 45 mm based on the 95 % confidence level. The absolute horizontal movements measured at distances greater than 550 m from mining are in the order of 70 mm based on the 95 % confidence level.

Far-field horizontal movements tend to be bodily movements orientated towards the mining area. The strains associated with these low level horizontal movement are not expected to be measurable.

The range of potential ground strains at the transmission towers was assessed statistically using the monitoring data from Metropolitan Colliery and other nearby collieries. 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 movements. The strains resulting from damaged or disturbed survey marks have also been excluded.

The transmission towers are located at distances of 100 m or greater from Longwall 301. The database has therefore been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of the previous longwalls in the Southern Coalfield, for survey bays that were located outside and within 100 m to 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 located above solid coal, for monitoring lines in the Southern Coalfield, is provided in Fig. 6.6. The probability distribution functions, based on a fitted *Generalised Pareto Distribution (GPD)*, have also been shown in this figure.

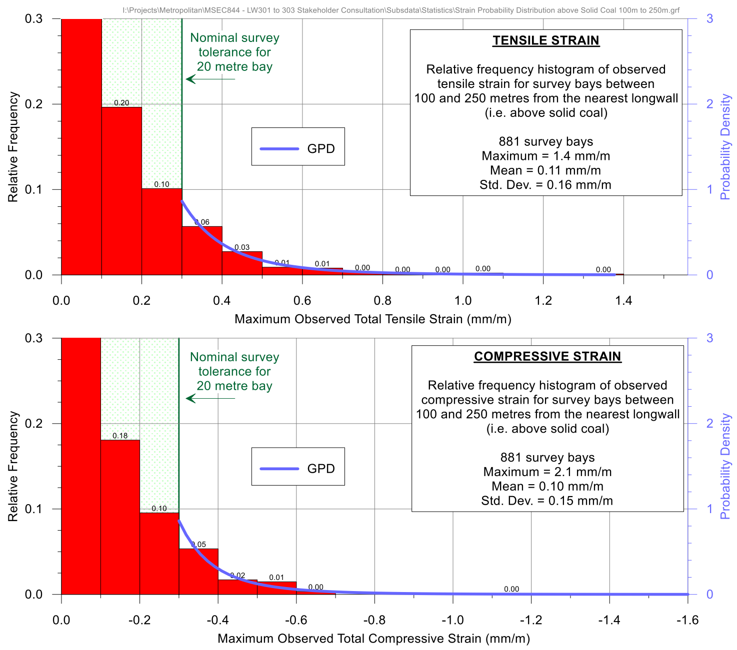

Fig. 6.6 Distributions of the Measured Maximum Tensile and Compressive Strains during the Extraction of Previous Longwalls in the Southern Coalfield Above Solid Coal (100 to 250 m)

The 95 % confidence levels for the maximum total strains that the individual survey bays above solid coal (100 to 250 m) experienced at any time during mining are 0.4 mm/m tensile and compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining are 0.7 mm/m tensile and 0.6 mm/m compressive.

The aerial powerlines and power poles within the Study Area that service the Garrawarra Complex are located to the north east of Longwalls 305 to 307. A summary of the maximum predicted values of total subsidence, tilt and curvature for the low voltage powerlines in the Garrawarra Complex, resulting from the extraction of Longwall 304 and Longwalls 305 to 307 for the Extraction Plan Layout, is provided in Table 6.8. The values are the maxima anywhere within this network.

Table 6.8 Predicted Total Subsidence, Tilt and Curvature for the Low Voltage Powerlines in the Garrawarra Complex after the Extraction of Longwalls 304 to 307

Longwall	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})
After LW304	300	3.0	0.03	< 0.01
After LW305	325	3.0	0.03	< 0.01
After LW306	325	3.0	0.03	< 0.01
After LW307	325	3.0	0.03	< 0.01

The maximum predicted total subsidence is 325 mm. The maximum predicted conventional tilt is 3.0 mm/m (i.e. 0.3 %, or 1 in 330). The maximum predicted conventional curvatures are 0.03 km^{-1} hogging and less than 0.01 sagging, which equate to minimum radii of curvature of 33 km and greater than 100 km, respectively. It can be seen from in Table 6.8 that the predicted total tilt and curvature do not increase after the extraction of Longwall 304.

The predicted strains for the low voltage powerlines located to the north east of Longwalls 305 to 307 are provided in Table 6.9. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1).

Table 6.9 Predicted Strains for the low voltage powerlines due to Longwalls 305 to 307 based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 times Curvature (mm/m)	Non-conventional based on the 95 % Confidence Level (mm/m)	Non-conventional based on the 99 % Confidence Level (mm/m)
Tension	< 0.5	0.5	0.8
Compression	< 0.5	0.6	0.9

There are no streams in the locations of the power poles within the Study Area. The 11 kV powerlines, therefore, are not expected to experience valley closure effects.

6.8.3. Comparisons of the Predictions for the Electrical Infrastructure

The comparisons of the maximum predicted subsidence parameters for the low voltage powerlines in the Garrawarra Centre based on the Extraction Plan Layout, with those based on the Preferred Project Layout, are provided in Table 6.10. The values for the powerlines are the maxima anywhere along their alignments within the Study Area.

Table 6.10 Comparison of maximum predicted conventional subsidence parameters for the low voltage powerlines based on the Extraction Plan Layout and the Preferred Project Layout

Layout	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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1200	5.5	0.05	0.14
Preferred Project Layout (After LW307) (Report No. MSEC403)	1200	5.5	0.05	0.14
Extraction Plan Layout (Report No. MSEC1057)	325	3.0	0.03	< 0.01

The maximum predicted subsidence parameters for the low voltage powerlines, based on the Extraction Plan Layout, are less than the maxima based on the Preferred Project Layout. The predicted subsidence parameters reduce due to the shortened commencing (i.e. northern) ends of Longwalls 302, 303 and 304.

6.8.4. Impact Assessments and Recommendations for the Electrical Infrastructure

Whilst the 132 kV and 330 kV transmission lines and Powerline 1 could experience low level far-field horizontal movements, the associated tilts, curvatures or strains are not expected to be measurable. It is unlikely that the transmission lines and Powerline 1 would experience adverse impacts as a result of Longwalls 305 to 307.

The potential for impacts on the transmission lines, based on the Extraction Plan Layout, are the same as those based on the Preferred Project Layout. It is expected that the transmission lines would be maintained in a safe and serviceable condition during and after mining.

The low voltage powerlines comprise aerial conductors supported on timber and concrete poles and buried cables. Experience from the Southern Coalfield indicates that the potential impacts on these types of powerlines are rare and generally of a minor nature. Some remedial measures have been required, which include adjustments to cable catenaries, pole tilts and consumer cables which connect between the poles and building structures. The incidence of these impacts, however, was very low.

It is expected that the low voltage powerlines can be maintained in safe and serviceable conditions with the development of the appropriate monitoring and management plans.

6.9. Telecommunications Infrastructure

6.9.1. Descriptions of the Telecommunications Infrastructure

The locations of the telecommunications infrastructure are shown in Drawing No. MSEC1057-08.

Optical fibre cables are located within the Study Area to the north east of Longwall 305. There are no optical fibre cables above Longwalls 305 to 307.

Three optical fibre cables are located to the east of the Study Area over 750 m from Longwall 305. These cables are major Sydney service lines owned by Telstra, Optus and Vocus. The Telstra and Optus cables are labelled Cable 1 in Drawing No. MSEC1057-08.

There are two optical fibre cables to the north east of Longwall 305, owned by Telstra and Optus. The Optus cable extends from a tower north of Longwall 303, towards the south, above Longwalls 302 and 301 and is labelled Cable 2 in Drawing No. MSEC1057-08. The Telstra cable extends towards the north from a point above the commencing end of Longwall 303 and is labelled Cable 2 in Drawing No. MSEC1057-08.

Copper telecommunications cables owned by Telstra are also located above Longwalls 304 within the Study Area and to the north of Longwall 303 and these cables service the Garrawarra Complex.

There are a number of telecommunications towers and compounds that are located to the north of Longwall 303. These installations are owned by Telstra, Axicom and Sydney Trains. Photographs of the towers and compounds for three of these installations are provided in Fig. 6.7 to Fig. 6.9.

Fig. 6.7 Telecommunications Tower and Compound owned by Telstra

Fig. 6.8 Telecommunications Tower and Compound owned by Sydney Trains

Fig. 6.9 Telecommunications Tower and Compound owned by Axicom

6.9.2. Predictions for the Telecommunications Infrastructure

The predicted profiles of vertical subsidence, tilt and curvature along the alignments of the optical fibre cables resulting from the extraction of Longwalls 305 to 307, are shown in Fig. C.07 for Telstra Cable 2, and Fig. C.08 for Optus Cable 2 in Appendix C. The predicted incremental profiles for the cables, due to the extraction of Longwalls 305 to 307 for the Extraction Plan Layout, are shown as dashed black lines. The predicted total profiles for the cables, after the extraction of Longwall 304 and Longwalls 305 to 307 for the Extraction Plan Layout, are shown as solid blue lines. The predicted total profiles based on the Preferred Project Layout are shown as the red lines for comparison.

Summaries of the maximum predicted values of total subsidence, tilt and curvature for the optical fibre cables, after the extraction of Longwalls 304 to 307, are provided in Table 6.11 and Table 6.12. The values are the maxima anywhere along the sections of the cables located within the Study Area.

Table 6.11 Predicted Total Subsidence, Tilt and Curvature for the Telstra Optical Fibre Cable 2 after the Extraction of Longwalls 304 to 307

Longwall	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})
After LW304	300	2.5	0.02	< 0.01
After LW305	350	2.5	0.02	< 0.01
After LW306	350	2.5	0.02	< 0.01
After LW307	350	2.5	0.02	< 0.01

Table 6.12 Predicted Total Subsidence, Tilt and Curvature for the Optus Optical Fibre Cable 2 after the Extraction of Longwalls 304 to 307

Longwall	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})
After LW304	700	3.0	0.03	0.03
After LW305	725	3.0	0.03	0.03
After LW306	725	3.0	0.03	0.03
After LW307	725	3.0	0.03	0.03

The maximum predicted conventional tilt for the optical fibre cables within the Study Area is 3.0 mm/m (i.e. 0.3 %, or 1 in 330). The maximum predicted conventional curvatures are 0.03 km^{-1} hogging and sagging, which equate to minimum radii of curvature of 33 km.

A summary of the maximum predicted values of total subsidence, tilt and curvature for the copper telecommunications cables, resulting from the extraction of Longwalls 305 to 307, are provided in Table 6.13. The values are the maxima anywhere within the network located within the Study Area.

Table 6.13 Predicted Total Subsidence, Tilt and Curvature for the Copper Telecommunications Cables after the Extraction of Longwalls 304 to 307

Longwall	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})
After LW304	400	3.5	0.03	0.03
After LW305	525	4.0	0.03	0.03
After LW306	525	4.0	0.03	0.03
After LW307	550	4.0	0.03	0.03

The maximum predicted conventional tilt for the copper telecommunications cables is 4.0 mm/m (i.e. 0.4 %, or 1 in 250). The maximum predicted conventional curvatures are 0.03 km^{-1} hogging and sagging, which equate to minimum radii of curvature of 33 km.

The maximum predicted strains for the optical fibre cables and copper telecommunications cables located above the longwall panels, within the Study Area, is provided in Table 6.14. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1).

Table 6.14 Predicted Strains for the Sections of the Optical Fibre Cables and Copper Telecommunications Cables above the Longwall panels based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 times Curvature (mm/m)	Non-conventional based on the 95 % Confidence Level (mm/m)	Non-conventional based on the 99 % Confidence Level (mm/m)
Tension	0.5	0.9	1.6
Compression	0.5	1.6	3.2

The maximum predicted strains for the optical fibre cables and copper telecommunications cables located above solid coal, is provided in Table 6.15. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1).Table 6.15 Predicted Strains for the Sections of the Optical Fibre Cables and Copper Telecommunications Cables above solid coal based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 times Curvature (mm/m)	Non-conventional based on the 95 % Confidence Level (mm/m)	Non-conventional based on the 99 % Confidence Level (mm/m)
Tension	0.5	0.6	0.9
Compression	0.5	0.5	0.8

The optical fibre cables and the copper telecommunications cables do not cross any major streams within the Study Area. The cables, therefore, are not expected to experience valley closure effects.

The telecommunications towers and compounds are located to the east of Longwalls 305 to 307. A summary of the maximum predicted values of total subsidence, tilt and curvature for these installations, afer the extraction of Longwalls 305 to 307, is provided in Table 6.16.

Table 6.16 Maximum Predicted Total Subsidence, Tilt and Curvature for the Telecommunications Towers and Compounds after the Extraction of Longwalls 304 to 307

Location	Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km^{-1})	Maximum Predicted Total Sagging Curvature (km^{-1})
Site 1 Axicom Optus	LW304	125	1.0	0.01	< 0.01
	LW305	150	1.5	0.01	< 0.01
	LW306	175	1.5	0.01	< 0.01
	LW307	175	1.5	0.01	< 0.01
Site 2 Axicom Vodafone	LW304	150	1.5	0.02	< 0.01
	LW305	175	1.5	0.02	< 0.01
	LW306	200	1.5	0.02	< 0.01
	LW307	200	1.5	0.02	< 0.01
Site 3 Telstra	LW304	175	2.0	0.02	< 0.01
	LW305	225	2.0	0.02	< 0.01
	LW306	225	2.0	0.02	< 0.01
	LW307	225	2.0	0.02	< 0.01
Site 4 Sydney Trains	LW304	400	3.5	0.03	< 0.01
	LW305	425	3.5	0.03	< 0.01
	LW306	450	3.5	0.03	< 0.01
	LW307	450	3.5	0.03	< 0.01

The maximum predicted conventional tilt for the telecommunications towers and compounds is 3.5 mm/m (i.e. 0.35 %, or 1 in 286). The maximum predicted conventional curvatures are 0.03 km^{-1} hogging and less than 0.01 km^{-1} sagging, which equate to minimum radii of curvature of 33 km and greater than 100 km, respectively.

The predicted strains for telecommunications towers and compounds are provided in Table 6.17. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4.1).

Table 6.17 Predicted Strains for the Telecommunications Towers and Compounds based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 times Curvature (mm/m)	Non-conventional based on the 95 % Confidence Level (mm/m)	Non-conventional based on the 99 % Confidence Level (mm/m)
Tension	0.5	0.9	1.6
Compression	0.5	1.6	3.2

The telecommunications towers and compounds are not located near any major streams. These installations, therefore, are not expected to experience valley closure effects.

6.9.3. Comparison of the Predictions for the Telecommunications Infrastructure

The comparisons of the maximum predicted subsidence parameters for optical fibre cables and the copper telecommunications cables with those based on the Preferred Project Layout are provided in Table 6.18 and Table 6.19. The values are the maxima anywhere along the sections of the cables located within the Study Area.

Table 6.18 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Optical Fibre Cables based on the Extraction Plan Layout and the Preferred Project Layout

Layout	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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1150	1.0	0.05	0.10
Preferred Project Layout (After LW307) (Report No. MSEC403)	1150	1.0	0.05	0.10
Extraction Plan Layout (Report No. MSEC1057)	725	3.0	0.03	0.03

Table 6.19 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Copper Cables based on the Extraction Plan Layout and the Preferred Project Layout

Layout	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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1200	5.5	0.05	0.14
Preferred Project Layout (After LW307) (Report No. MSEC403)	1150	5.0	0.05	0.14
Extraction Plan Layout (Report No. MSEC1057)	550	4.0	0.03	0.03

The maximum predicted tilt for the optical fibre telecommunications cables, based on the Extraction Plan Layout, are slightly greater than the maxima based on the Preferred Project Layout. However, as discussed in the following section, the potential for impacts on these cables are due to curvature and strain, rather than due to vertical subsidence and tilt. The maximum predicted subsidence, hogging and sagging curvature based on the Extraction Plan Layout, are similar to or less than the maxima based on the Preferred Project Layout.

The maximum predicted subsidence parameters for the copper telecommunications cables, based on the Extraction Plan Layout, are less than the maxima based on the Preferred Project Layout.

The comparison of the maximum predicted subsidence parameters for the telecommunications towers and compounds with those based on the Preferred Project Layout is provided in Table 6.20. The values are the maxima at any time during or after the extraction of the longwalls.

Table 6.20 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Telecommunications Towers based on the Extraction Plan Layout and the Preferred Project Layout

Layout	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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1150	1.0	0.04	0.07
Preferred Project Layout (After LW307) (Report No. MSEC403)	1100	1.5	0.04	0.07
Extraction Plan Layout (Report No. MSEC1057)	450	3.5	0.03	< 0.01

The maximum predicted tilt for the telecommunications towers and compounds, based on the Extraction Plan Layout, are greater than the maxima based on the Preferred Project Layout. The maximum predicted vertical subsidence, hogging curvature and tensile strain for the telecommunications towers and compounds, based on the Extraction Plan Layout, are similar to or less than the maxima predicted based on the Preferred Project Layout. The impact assessments for the telecommunications towers and compounds are provided in the following section.

6.9.4. Impact Assessment and Recommendations for Optical Fibre Cables

The optical fibre cables within the Study Area are direct buried or buried in conduits of various diameters and will not be impacted by the subsidence and tilt resulting from the extraction of Longwalls 305 to 307. The cables, however, are likely to experience the curvatures and ground strains resulting from the extraction of Longwalls 305 to 307. There is also the potential for localised curvatures and strains due to non-conventional ground movements. The conduit surrounding the cables reduces the potential for direct transfer of ground strain to the cables.

The tensile strains in the optical fibre cables can 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 within 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 cable 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, they could be of sufficient magnitude to result in the reduction in capacities of the cables or transmission loss.

Localised and elevated curvatures could develop along the optical fibre cables due to non-conventional movements resulting from near surface geological structures (i.e. anomalies). It is possible that these non-conventional movements could be sufficient to result in the attenuation of signal.

The predicted curvatures and strains for the optical fibre cables are similar to those where longwalls in the Southern Coalfield have previously mined directly beneath similar cables. It has been found from this previous experience that the potential impacts on optical fibre cables in the Southern Coalfield can be managed with the implementation of suitable monitoring and management strategies.

Some examples of mining beneath optical fibre cables in the Southern Coalfield are provided in Table 6.21.

Table 6.21 Examples of Mining Beneath Optical Fibre Cables in the Southern Coalfield

Colliery and Longwalls	Length of Optical Fibre Cables Directly Mined Beneath (km)	Observed Maximum Movements at 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 LW706	12.7 total for eight cables	1,200 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 LW29	1.9	775 mm Subsidence 0.8 mm/m Tensile Strain 3.9 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 LW38	3.4	1,300 mm Subsidence 1.3 mm/m Tensile Strain 5.5 mm/m Comp. Strain (Measured B-Line)	Survey, visual, OTDR, SBS. No reported impacts.
Metropolitan LW301 to 303	2.3	1,100 mm Subsidence 1.6 mm/m Tensile Strain 1.1 mm/m Comp. Strain (Measured Optic Water Line)	Ground survey, visual, OTDR. No reported impacts.

The strains transferred into the optical fibre cables can be monitored using Optical Time Domain Reflectometry (OTDR). The ground movements can also be monitored using traditional survey lines and visual inspections. These monitoring methods can be used to identify the development of irregular ground movements. If non-conventional movements or signal attenuation are detected during active subsidence, then the cable can be relieved by locally exposing and then reburying the affected section of cable.

The optical fibre cables have been directly mined beneath by Longwalls 301 and 302. There were no adverse impacts on these cables due to the extraction of Longwalls 301 to 303.

It is recommended that monitoring and management strategies developed for the extraction of Longwall 304 are updated and continued, in consultation with Telstra, Optus, and Vocus to manage the optical fibre cables for potential irregular ground movements for the extraction of Longwalls 305-307. It is expected that these cables can be maintained in serviceable condition with the implementation of the appropriate monitoring and management strategies.

6.9.5. Impact Assessment and Recommendations for Copper Telecommunications Cables

The copper telecommunications cables within the Study Area include both buried and aerial cables. The buried cables can be affected by curvatures and ground strains and the aerial cables can be affected by the changes in cable catenaries. Copper telecommunications cables are flexible and it has been found that these types of cables can typically tolerate strains up to 20 mm/m without adverse impacts.

Extensive experience of mining beneath copper telecommunications cables in the NSW Coalfields, where the observed strains were similar or greater than those predicted for the longwalls, indicates that incidences of impacts is very low and generally of a minor nature. Some remedial measures have been required, which include adjustments to cable catenaries, pole tilts and consumer cables which connect between the poles and building structures. The incidence of these impacts, however, was very low.

The copper telecommunications cables are predominantly located to the east of Longwalls 305 to 307. It is unlikely that the copper telecommunications cables would experience adverse impacts as a result of the extraction of Longwalls 305 to 307.

6.9.6. Impact Assessment and Recommendations for Telecommunications Towers and Compounds

The maximum predicted tilts for the telecommunications towers and compounds vary up to 3.5 mm/m (i.e. 0.35 %, or 0.2 degrees). The magnitudes of tilt are small (i.e. less than 1 %) and therefore are unlikely to adversely impact on the towers or compounds. Tilt can potentially effect directional antennas (i.e. microwave dishes) and therefore it is recommended that the infrastructure owners (e.g. radio engineers) review the predicted changes in alignment.

The maximum predicted conventional curvatures for these installations are 0.03 km^{-1} hogging and less than 0.01 km^{-1} sagging, which equate to minimum radii of curvature of 33 km and greater than 100 km, respectively. The predicted strains are 0.9 mm/m tensile and 1.6 mm/m compressive based on the 95 % confidence level and 1.6 mm/m tensile and 3.2 mm/m compressive based on the 99 % confidence level.

The steel framed building enclosures are supported on piers above concrete ground slabs. It is unlikely that these structures would experience adverse impacts due to their lightweight constructions and their elevation above natural ground. The brick building enclosures could potentially experience adverse impacts such as cracking of the brickwork or sticky entry doors. It is expected that these enclosures would remain in safe and serviceable conditions during and after mining. Adverse impacts could be remediated using normal building maintenance techniques.

It is recommended that monitoring and management strategies developed for the extraction of Longwalls 301 to 303 are updated and continued, in consultation with Optus, Axicom and Sydney Trains, to manage the towers for potential irregular ground movements.

6.10. Water Tanks, Water and Sewage Treatment Works

The discussions on the water storage tanks in the Garrawarra Complex are provided in Section 11.1.

6.11. Dams, Reservoirs or Associated Works

The full supply level of the Woronora Reservoir is located inside the Study Area and is discussed in Section 5.5.

The Woronora Dam wall is located approximately 6.5 km from the commencing end of Longwall 307 and the distance from the labyrinth spillway, which is to the south of the dam wall, is approximately 6.0 km.

The dam wall and spillway are located at large distances from Longwalls 305 to 307. It is not expected, therefore, that measurable conventional subsidence movements would occur at the dam wall and spillway.

Far-field horizontal movements have been measured up to distances of approximately 3.9 km from active longwalls, however, almost all of the measured data beyond approximately 2.5 km is within the order of survey tolerance or accuracy. A discussion of far-field horizontal movements in provided in Section 4.6.

It is unlikely that far-field movements would be observed at the distances of the dam wall and spillway from Longwalls 305 to 307.

7.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE PUBLIC AMENITIES

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

- Hospitals;
- Places of worship;
- Schools;
- Shopping centres;
- Community centres;
- Swimming pools;
- Bowling greens;
- Ovals or cricket grounds;
- Racecourses;
- Clubs
- Golf courses; and
- Tennis courts.

7.1. Office Buildings

Office buildings are located within the Garrawarra Complex, which is discussed in Section 11.1.

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the farm land and facilities located within the Study Area for Longwalls 305 to 307.

As listed in Table 2.1, the following farm land facilities were not identified within the Study Area nor in the immediate surrounds:

- Farm buildings or sheds;
- Tanks;
- Gas or fuel storages;
- Poultry sheds;
- Glass houses;
- Hydroponic systems;
- Irrigation systems;
- Farm Dams; and
- Wells or Bores.

8.1. Agricultural Utilisation

The agricultural land classification types in the vicinity of the proposed Longwalls 305 to 307 are illustrated in Fig. 8.1.

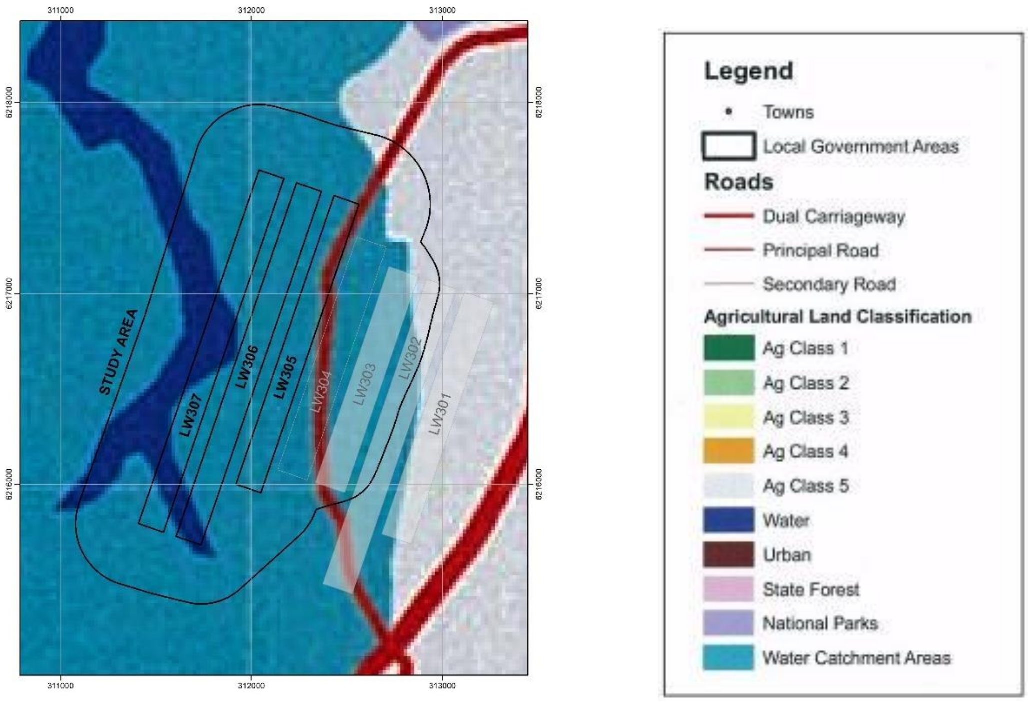

Fig. 8.1 Agricultural Land Classification within the Study Area (Source NSW DII November 2008)

It can be seen from the above figure, that the main land classification types in the vicinity of the proposed Longwalls 305 to 307 are Water Catchment on the south western side and Agricultural Class 5 and National Park on the north eastern side. There are no known agricultural activities within the Study Area.

8.2. Fences

Fences are located within the Study Area associated with the Garrawarra Complex and cadastral boundaries.

The fences could experience the full range of predicted subsidence movements, as summarised in Table 4.2. The maximum predicted subsidence parameters for the fences, based on the Extraction Plan

Layout, therefore, are similar to the maxima based on the Preferred Project Layout, as summarised in Table 4.3.

Fences can be affected by tilting of the fence posts and by changes of tension in the fence wires due to strain as mining occurs. Fences are generally flexible in construction and can usually tolerate significant tilts and strains.

Any impacts on the fences are likely to be of a minor nature and relatively easy to remediate by re-tensioning fencing wire, straightening fence posts, and if necessary, replacing some sections of fencing.

It is recommended that management plans be developed to manage potential impacts on fences during the mining of Longwalls 305 to 307.

9.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE INDUSTRIAL, COMMERICAL AND BUSINESS ESTABLISHMENTS

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the industrial, commercial and business establishments located within the Study Area for Longwalls 305 to 307. The predicted parameters for each of the built features have been compared to the predicted parameters based on the Preferred Project Layout.

As listed in Table 2.1, the following Industrial, Commercial and Business Establishments were not identified within the Study Area nor in the immediate surrounds:

- Factories;
- Workshops;
- Business or commercial establishments or improvements;
- Gas or fuel storages and associated plant;
- Waste storages and associated plant;
- Exploration bores;
- Buildings, equipment or operations that are sensitive to surface movements; and
- Surface mining (open cut) voids and rehabilitated areas.

9.1. Any Other Industrial, Commercial or Business Features

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

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the archaeological and heritage sites located within the Study Area for Longwalls 305 to 307. The predicted parameters for each of the features have been compared to the predicted parameters based on the Preferred Project Layout.

10.1. Aboriginal Heritage Sites

10.1.1. Descriptions of the Aboriginal Heritage Sites

The detailed descriptions of the Aboriginal heritage sites are provided in the baseline reports prepared by Niche Environment and Heritage. There are 36 Aboriginal heritage sites that have been identified within the Study Area. The locations of these sites are shown in Drawing No. MSEC1057-09.

The descriptions of the Aboriginal heritage sites within the Study Area are provided in Table D.02, in Appendix D. Of the 36 sites, 35 have sandstone overhangs of which 13 have art only, and 22 have art and/or artefacts and/or deposits. One site is an open site with grinding grooves.

10.1.2. Predictions for the Aboriginal Heritage Sites

The maximum predicted subsidence parameters for each of the Aboriginal heritage sites located within the Study Area is provided in Table D.02, in Appendix D. The predictions have been provided based on the Extraction Plan Layout, as well as for the Preferred Project Layout (After LW307) and the Preferred Project Layout (After LW317), for comparison.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the overhang sites and one open site, resulting from the Extraction Plan Layout, is provided in Table 10.1. The predicted tilts provided in this table are the maxima after the completion of Longwalls 305 to 307. The predicted curvatures are the maxima at any time during or after the extraction of Longwalls 305 to 307.

Table 10.1 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Aboriginal Heritage Sites within the Study Area after the Extraction of Longwalls 305 to 307

Site Type	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})
Overhangs	950	3.0	0.05	0.09
Open Site	< 20	< 0.5	< 0.01	< 0.01

The maximum predicted conventional tilt for the overhang sites is 3.0 mm/m (i.e. 0.3 %, or 1 in 330). The maximum predicted conventional curvatures for these sites are 0.05 km^{-1} hogging and 0.09 km^{-1} sagging, which equate to minimum radii of curvature of greater than 20 km and 11 km respectively. The maximum predicted tilt and curvatures for the open site are less than survey tolerance.

The predicted strains for the Aboriginal heritage sites located above solid coal is provided in Table 10.2. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis above solid coal provided in Section 4.4.1).

Table 10.2 Predicted Strains for the Aboriginal heritage sites above solid coal based on conventional and non-conventional anomalous movements

Type	Conventional based on 15 times Curvature (mm/m)	Non-conventional based on the 95 % Confidence Level (mm/m)	Non-conventional based on the 99 % Confidence Level (mm/m)
Tension	0.5	0.5	0.8
Compression	0.5	0.6	0.9

The predicted strains for the Aboriginal heritage sites located above longwall panels (including those above Longwalls 301 to 304) is provided in Table 10.3. The values have been provided for conventional movements (based on 15 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis above goaf provided in Section 4.4.1).

Table 10.3 Predicted Strains for the Aboriginal heritage Sites above goaf based on Conventional and Non-Conventional Anomalous Movements

Type	Conventional based on 15 times Curvature (mm/m)	Non-conventional based on the 95 % Confidence Level (mm/m)	Non-conventional based on the 99 % Confidence Level (mm/m)
Tension	1.0	0.9	1.6
Compression	1.5	1.6	3.2

10.1.3. Comparisons of the Predictions for the Aboriginal Heritage Sites

The comparisons of the maximum predicted conventional subsidence parameters for the Aboriginal heritage sites within the Study Area, resulting from the extraction of Longwalls 305 to 307, with those based on the Preferred Project Layout (After LW307) and the Preferred Project Layout (After LW317) are provided in Table 10.4. A comparison of the maximum predicted subsidence parameters for each of the Aboriginal heritage sites located within the Study Area is provided in Table D.02, in Appendix D.

Table 10.4 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Aboriginal heritage sites based on the Preferred Project Layout and the Extraction Plan Layout

Layout	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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	600	2.5	0.05	0.06
Preferred Project Layout (After LW307) (Report No. MSEC403)	600	3.0	0.05	0.04
Extraction Plan Layout (Report No. MSEC1057)	950	3.0	0.05	0.09

It can be seen from Table D.02 in Appendix D that there is an increase in the predicted vertical subsidence at six of the Aboriginal Heritage sites based on the Extraction Plan Layout when compared to the Preferred Project Layout after Longwall 307. The potential for impacts on these sites do not result from absolute vertical subsidence, but rather the differential movements (i.e. tilt, curvature and strain).

The predicted tilt increases at 13 of the 36 Aboriginal heritage sites based on the Extraction Plan Layout, however the maxima (3.0 mm/m) is the same as that predicted for the Preferred Project Layout after Longwall 307. The hogging curvatures based on the Extraction Plan Layout increase at six sites, and sagging curvatures at seven sites compared to the Preferred Project Layout after Longwall 307. Only two Aboriginal heritage sites are predicted to have sagging curvatures above 0.04 km^{-1} after Longwall 307.

Whilst the predicted subsidence parameters increase at a small number of Aboriginal heritage sites the maxima are similar to or less than the maxima predicted for other Aboriginal heritage sites located above the previously extracted longwalls at the Colliery. The potential impacts for these sites based on the Extraction Plan Layout, therefore, are similar to those assessed based on the Preferred Project Layout.

10.1.4. Impact Assessments and Recommendations for the Aboriginal Heritage Sites

The potential impacts for the Aboriginal heritage sites, based on the Extraction Plan Layout, are similar to or less than those assessed for this Extraction Plan or other Aboriginal heritage sites assessed for previous Metropolitan Coal Extraction Plans, based on the Preferred Project Layout. The assessments of the potential impacts for the Aboriginal heritage sites were provided in Section 5.24.2 of Report No. MSEC285, which supported the Project EA and Preferred Project Layout.

The magnitudes of predicted tilt and curvature for the majority of the Aboriginal heritage sites are small due to site locations above solid coal. Impacts to the sites located above solid coal are considered unlikely. Surface fracturing of the bedrock can occur outside the longwall layouts, as discussed in Section 4.8.

However such fracturing is minor and isolated and the likelihood of fracturing impacting the Aboriginal Heritage Sites outside the longwall layouts is considered to be low.

Sites located above Longwalls 304 and 305 where pillar width is narrower, and those located above Longwalls 306 and 307, have a higher risk of impacts, similar to those assessed based on the Preferred Project Layout, including the potential for fracturing and rock falls within overhangs.

The recommendations and management strategies for the Aboriginal heritage sites are the same as those based on the Preferred Project Layout.

10.2. European Heritage Sites

The Garrawarra Hospital is listed as local heritage significance in the *Wollongong Local Environmental Plan, 2009* with a number of items of heritage significance. Predictions and impact assessments for the Garrawarra Complex are provided in Section 11.1.

The Waterfall General (Garrawarra) Cemetery (the Cemetery) is located above Longwall 301 and at a distance of over 690 m from Longwall 305 (as shown in the attached Drawing No. MSEC1057-09) and it is outside the Study Area.

The Cemetery is unlikely to experience adverse impacts to the Cemetery features including headstones or fencing as a result of conventional subsidence movements.

Comprehensive monitoring of subsidence movements has been undertaken during the extraction of Longwalls 301 to 303 with magnitudes of observed differential movements consistent with predictions and no observed anomalous movements encountered. It is considered unlikely that non-conventional movements would be observed at the cemetery during the extraction of Longwalls 305 to 307.

Monitoring of non-conventional subsidence movements and the Cemetery is described in the Longwalls 305-307 Metropolitan Coal Subsidence Monitoring Program.

10.3. Items of Architectural Significance

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

10.4. Survey Control Marks

The locations of the survey control marks within and immediately adjacent to the Study Area are shown in Drawing No. MSEC1057-09. The locations and details of the survey control marks were obtained from the *Land and Property Management Authority* using the *SCIMS Online* website (SCIMS, 2016).

The survey control marks within the Study Area could experience the full range of predicted subsidence movements, as summarised in Table 4.2. The maximum predicted subsidence parameters for the survey control marks, based on the Extraction Plan Layout, therefore, are similar to the maxima based on the Preferred Project Layout, as summarised in Table 4.3.

There are survey control marks that are located outside the Study Area that are likely to experience either small amounts of subsidence or far-field horizontal movements as the longwalls are mined. Far-field horizontal movements have been measured up to distances of approximately 3.9 km from active longwalls, however, almost all of the measured data beyond approximately 2.5 km is within the order of survey tolerance or accuracy. A discussion of far-field horizontal movements in provided in Section 4.6.

The potential impacts on the survey control marks, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Preferred Project Layout. It would be necessary on the completion of Longwalls 305 to 307, when the ground has stabilised, to re-establish the coordinates for marks. The survey control network would be re-established following the completion of mining activities in consultation with Land and Property Information (LPI) NSW, as required by the *Surveyor General's Directions No.11 Preservation of Survey Infrastructure*."

11.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE RESIDENTIAL BUILDING STRUCTURES

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

- Flats or Units;
- Caravan Parks;
- Tennis courts;
- Swimming pools; and
- On-site water systems.

11.1. Garrawarra Complex

11.1.1. Descriptions of the Garrawarra Complex

The location of the Garrawarra Complex is shown in Drawing No. MSEC1057-09. The locations of the building structures and other built features and services on this complex are shown in Drawings Nos. MSEC1057-09 and MSEC1057-10.

The type and size of the building structures are shown in Table D.03, in Appendix D. There are a total of 86 building structures on the complex, comprising 57 residential or hospital buildings and 29 ancillary structures. There are also nine water storage tanks and a number of telecommunications towers located within the complex. All structures are located outside and to the north east of the longwalls.

The *hospital* building structures are Refs. A01a to A01k and B03a to B03l. These structures are located outside the Study Area at a minimum distance of 440 m from Longwalls 305 to 307. The buildings are not currently in use and have been fenced off. Photographs of the main hospital building structures are provided in Fig. 11.1 and Fig. 11.2.

Fig. 11.1 Hospital Building Structure (Ref. A01a)

Fig. 11.2 Hospital Building Structure (Ref. B03a)

The main *aged care* building structures are Refs. B01a to B01j and B02a to B02h. The other buildings associated with the aged care are Refs. B01k to B01q, B02i and B02j.

Structure Refs. B01a to B01d are located over 240 m to the north east of Longwalls 305 to 307. These buildings comprise single storey structures founded on a combination of ground slabs, strip footings and pad footings. The external walls are brick-veneer and the internal walls are of lightweight construction. The roofs are steel framed with metal sheeting. Photographs of these structures are provided in Fig. 11.3.

Fig. 11.3 Aged Care Building Structure Refs. B01a to B01d

Structure Ref. B01e is located 350 m to the east of Longwalls 305 to 307. This building is a double storey brick structure founded on a ground slab with a tiled roof. Photographs of this structure are provided in Fig. 11.4.

Fig. 11.4 Aged Care Building Structure Ref. B01e

Structure Refs. B02a to B02h are located outside the Study Area. These buildings comprise one and two storey structures founded on strip footings and ground slabs. The perimeter walls are double brick, but in some cases the upper levels have timber framed walls. The suspended floors are timber framed and in some cases are supported on steel frames. The tiled roofs are supported by timber frames. Photographs of two of these structures are provided in Fig. 11.5.

Fig. 11.5 Aged Care Building Structure Refs. B02a and B02b

The *houses* are Refs. A01m, A02a to A09a and B04a to B09a. The other buildings associated with the houses are Refs. A01l, A02b, A03b to A03d, A06b, and A08b to A08f. Structure Refs. A01m, A02a to A06a are located outside the Study Area. Most of the structures are single storey double brick on strip footings with timber floor and a tiled roof. Structure Ref. A09a is building is a two storey double brick structure on strip footings with timber floor and a tiled roof. Photographs of this house and the associated structure are provided in Fig. 11.6.

Fig. 11.6 House Structure Ref. A09a (left side) and A09b (right side)

Structure Refs. B04a to B09a are located over 360 m to 400 m to the east of Longwalls 305 to 307 and are outside the Study Area. These houses are one storey structures founded on brick piers and low level perimeter brick walls with timber floors, fibro walls and tiled roofs. Photographs of two of these houses are provided in Fig. 11.7. The houses are currently vacant and have been fenced off in preparation for demolition.

Fig. 11.7 Houses Structure Refs. B06a (left side) and B08a (right side)

The other main structures on the complex include water storage tanks (Refs. B14t01, B14t02, B16t01 to B16t03, B17t01, and B18t01), above ground gas storage tank (Ref. B01t03), and trickle filter tank B15t01. Tanks B16t01 to B16t03, B17t01, B18t01 and B15t01 are located outside the Study Area. Photographs of these features are provided in Fig. 11.8 to Fig. 11.10.

Fig. 11.8 Water Storage Tanks Refs. B14t01 and B14t02 (left side) and Refs. B16t01 to B16t03 (right side)

Fig. 11.9 Water Storage Tanks Refs. B17t01 (poly tank) and B18t01 (steel tank)

Fig. 11.10 Gas Storage Tank B01t03

Other structures on the complex include telecommunications towers and compounds (Refs. B06b and B10a to B12a), potable water and sewer pipelines, powerlines and telecommunications cables. These built features and services are discussed in Sections 6.7 to 6.9.

11.1.2. Predictions for the Garrawarra Complex

The maximum predicted subsidence, tilt and curvature for each of the building structures and tanks, resulting from the extraction of Longwalls 305 to 307 for the Extraction Plan Layout, are provided in Table D.03, in Appendix D. The values are the maxima within a distance of 20 m from the mapped extents of these features.

Summaries of the maximum predicted values of total subsidence, tilt and curvature after the extraction of Longwalls 305 to 307 are provided in Table 11.1.

Table 11.1 Maximum Predicted Total Subsidence, Tilt and Curvature after the Extraction of Longwalls 305 to 307

Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km^{-1})	Maximum Predicted Total Sagging Curvature (km^{-1})
Hospital Building Structures (Refs. A01a to A01k and B03a to B03l)	< 20	< 0.5	< 0.01	< 0.01
Aged Care Building Structures (Refs. B01a to B01q and B02a to B02j)After LW302	40	< 0.5	< 0.01	< 0.01
Northern Houses (Refs. A01m and A02a to A09a)	< 20	< 0.5	< 0.01	< 0.01
Southern Houses (Refs. B04a to B09a)	125	1.0	< 0.01	< 0.01
Water Tanks and Trickle Filter Tank (Refs. B14t01, B14t02, B15t01, B16t01 to B16t03, B17t01 B18t01)	150	1.0	0.1	< 0.01
Gas Storage Tank (Ref. B01t03)	< 20	< 0.5	< 0.01	< 0.01

The majority of the building structure are outside the predicted 20 mm subsidence contour for Longwalls 305 to 307 or outside the Study Area. The predicted subsidence parameters for these structures are therefore less than the expected limits of survey tolerance.

The private roads and the services directly associated with the hospital and residential building structures are located outside the footprint of Longwalls 305 to 307 and are therefore expected to experience low levels of predicted movements, consistent with the above tables. A summary of the maximum predicted subsidence, tilt and curvature for the services located above Longwalls 305 to 307, after the extraction of Longwalls 305 to 307, is provided in Table 11.2.

Table 11.2 Maximum Predicted Total Subsidence, Tilt and Curvature for the Private Roads and Services on the Garrawarra Complex

Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km^{-1})	Maximum Predicted Total Sagging Curvature (km^{-1})
After LW304	300	3.0	0.03	< 0.01
After LW305	325	3.0	0.03	< 0.01
After LW306	350	3.0	0.03	< 0.01
After LW307	350	3.0	0.03	< 0.01

The maximum predicted total subsidence for the private roads and services is 350 mm. The maximum predicted conventional tilt is 3.0 mm/m (i.e. 0.3 %, or 1 in 330). The maximum predicted conventional curvatures are 0.03 km^{-1} hogging and less than 0.01 sagging, which equate to minimum radii of curvature of 33 km and greater than 100 km respectively.

11.1.3. Comparisons of the Predictions for the Garrawarra Complex

The comparisons of the maximum predicted subsidence parameters for the building structures with those based on the Preferred Project Layout are provided in Table 11.3 to Table 11.6. The values are the maxima are the maxima at any time during or after the extraction of the longwalls.

Table 11.3 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Hospital Building Structures (Refs. A01a to A01k and B03a to B03l)

Layout	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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1250	6.0	0.06	0.14
Preferred Project Layout (After LW307) (Report No. MSEC403)	1250	6.0	0.06	0.14
Extraction Plan Layout (Report No. MSEC1057)	< 20	< 0.5	< 0.01	< 0.01

Table 11.4 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Aged Care Building Structures (Refs. B01a to B01q and B02a to B02j)

Layout	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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1200	2.5	0.05	0.14
Preferred Project Layout (After LW307) (Report No. MSEC403)	1200	2.5	0.05	0.14
Extraction Plan Layout (Report No. MSEC1057)	40	< 0.5	< 0.01	< 0.01

Table 11.5 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Northern Houses (Refs. A01m and A02a to A09a)

Layout	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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1300	2.5	0.05	0.13
Preferred Project Layout (After LW307) (Report No. MSEC403)	1300	2.5	0.05	0.13
Extraction Plan Layout (Report No. MSEC1057)	< 20	< 0.5	< 0.01	< 0.01

Table 11.6 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Southern Houses (Refs. B04a to B09a)

Layout	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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1200	1.0	0.03	0.10
Preferred Project Layout (After LW307) (Report No. MSEC403)	1200	1.0	0.03	0.10
Extraction Plan Layout (Report No. MSEC1057)	125	1.0	< 0.01	< 0.01

The maximum predicted subsidence parameters for the building structures, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout. The subsidence parameters have reduced due to the shortened commencing (i.e. northern) ends of Longwalls 302, 303 and 304.

The comparison of the maximum predicted subsidence parameters for the water storage tanks and trickle filter tank with those based on the Preferred Project Layout is provided in Table 11.7. The values are the maxima at any time during or after the extraction of the longwalls.

Table 11.7 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Water Storage Tanks and Trickle Filter Tank based on the Extraction Plan Layout and the Preferred Project Layout

Layout	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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1150	4.5	0.05	0.08
Preferred Project Layout (After LW307) (Report No. MSEC403)	1150	4.5	0.05	0.08
Extraction Plan Layout (Report No. MSEC1057)	150	1.0	0.1	< 0.01

The maximum predicted subsidence parameters for the water storage tanks and trickle filter tank based on the Extraction Plan Layout are less than the maxima predicted based on the Preferred Project Layout.

The comparison of the maximum predicted subsidence parameters for the private roads and services on the Garrawarra Complex with those based on the Preferred Project Layout are provided in Table 11.8. The values are the maxima are the maxima at any time during or after the extraction of the longwalls.

Table 11.8 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Private Roads and Services on the Garrawarra Complex

Layout	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})
Preferred Project Layout (After LW317) (Report No. MSEC403)	1200	5.5	0.05	0.14
Preferred Project Layout (After LW307) (Report No. MSEC403)	1200	5.5	0.05	0.14
Extraction Plan Layout (Report No. MSEC1057)	350	3.0	0.03	< 0.01

The maximum predicted subsidence parameters for the private roads and services, based on the Extraction Plan Layout, are less than the maxima predicted based on the Preferred Project Layout.

11.1.4. Impact Assessments and Recommendations for the Garrawarra Complex

Impact Assessments for the Building Structures

Longwall layouts have been modified in order to minimise predicted subsidence movements at the Garrawarra building structures B01a to B01e, which house aged care patients and administrative support.

The maximum predicted tilts after Longwalls 305 to 307 increase only at the southern houses, which are fenced off for demolition. The predicted tilt curvatures do not increase with the extraction of Longwalls 305 to 307. While there is a slight increase in the predicted subsidence due to Longwalls 305 to 307, the building structures are not expected to experience any measurable tilt and curvature.

The 95 % confidence intervals for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining are 0.4 mm/m tensile and compressive. The 99 % confidence intervals for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining are 0.7 mm/m tensile and 0.6 mm/m compressive.

A structural assessment of the building structures within the Garrawarra Complex was undertaken by John Matheson and Associates Pty Ltd (JMA 2016). A summary of the results of the structural inspection is provided in Table 3 of JMA (2016). The assessment is based on predicted subsidence parameters for Longwall 301 to 303 and indicates that the likelihood of greater than negligible damage developing in the building structures is low, with an assessed probability of exceedance for Category 1 damage (i.e. fine cracks of less than 1mm) of 1 % or less for all buildings with the exception of Building B02c.

The abandoned building B02c has a probability of exceedance of 10 % for Category 1 damage and a probability of exceedance of 1 % for a 2 mm crack in Category 2. The assessed probability exceedance of 1 % is generally associated with large masonry structures. The assessed probability exceedance for the smaller building structures is generally unlikely to remote. A detailed discussion of the structural assessments is provided in the report by JMA (2016). Since the preparation of the structural assessment report, the Longwalls 301 to 303 were shortened by 90 m. The predicted subsidence parameters for the structures after Longwall 305 to 307 are generally unchanged or similar to those assessed in the report by JMA (2016) and the resulting assessments for the structures do not change. The buildings are expected to remain safe and serviceable and potential impacts could be repaired using normal building maintenance techniques. A detailed discussion of the structural assessments is provided in the report by JMA (2016).

No adverse impacts on the building structures were observed due to the extraction of Longwalls 301 to 303.

It is recommended that monitoring and management strategies developed for the extraction of Longwall 304 are updated, in consultation with the infrastructure owner, to manage the potential impacts on the building structures for Longwalls 305-307. It is expected that these structures can be maintained in safe and serviceable conditions with the implementation of the appropriate monitoring and management strategies.

Impact Assessments for the Water Tanks and Trickle Filter Tank

The maximum predicted tilts for the water tanks and trickle filter tank are 1.0 mm/m (i.e. 0.1 %, or 1 in 1000) and curvatures are 0.01 km^{-1} hogging and less than 0.01 km^{-1} sagging. The predicted tilt increases slightly at tanks B15t01 to t03. The predicted tilt at the remaining tanks and trickle filter tank do not change and curvatures do not increase with the extraction of Longwalls 305 to 307. While there is a slight increase in the predicted subsidence due to Longwalls 305 to 307, the water tanks and trickle filter tank are not expected to experience any measurable tilt and curvature.

The tanks are located at distances of 300 m or greater from Longwall 305. The 95 % confidence intervals for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining are 0.4 mm/m tensile and compressive. The 99 % confidence intervals for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining are 0.7 mm/m tensile and 0.6 mm/m compressive.

As assessment of the tanks was undertaken by John Matheson and Associates Pty Ltd (JMA 2016). A summary of the results of the structural inspection is provided in Table 3 of JMA (2016). The assessment is based on predicted subsidence parameters for Longwall 301 to 303 and indicates that the likelihood of greater than negligible damage developing in the water storage tanks is 20% for Category 1 damage (i.e. fine cracks of less than 1mm) of 1 % or less. Since the preparation of the structural assessment report, the Longwalls 301 to 303 were shortened by 90 m. The predicted subsidence parameters for the structures after Longwall 305 to 307 are unchanged or less than those assessed in the report by JMA (2016) and the resulting assessments for the structures therefore do not change. The tanks are expected to remain safe and serviceable and potential impacts could be repaired using normal building maintenance techniques.

It is recommended that monitoring and management strategies developed for the extraction of Longwalls 301 to 304 are updated, in consultation with the infrastructure owner, to manage potential impacts on the water storage tanks and trickle filter tank. It is expected that these tanks can be maintained in safe and serviceable conditions with the implementation of the appropriate monitoring and management strategies.

Impact Assessments for the Gas Storage Tank

The gas storage tank is located more than 330 m from Longwall 305. The maximum predicted subsidence parameters are negligible and therefore unlikely to adversely impact the tank.

The maximum predicted conventional curvatures are less than 0.01 km^{-1} for both hogging and sagging curvature, which equate to minimum radii of curvature of greater than 100 km. The predicted strains are less than 0.5 mm/m tensile and compressive based on the 95 % confidence level.

The gas storage tank is supported on a concrete slab above the ground and therefore is unlikely to experience the mining induced curvatures and strains.

At this distance, it is unlikely that the storage tank and pipework would experience adverse impacts as a result of the extraction of Longwalls 305 to 307.

Impact Assessments for the Private Roads and Services

The private roads in the complex with bitumen seals, and private services within the complex ,are located outside the extents of proposed Longwalls 305 to 307. Experience from the Southern Coalfield indicates that impacts on these roads and services are unlikely.

Short lengths of road comprising chip seal or gravel surface are located above previous Longwall 302. The roads are not well maintained. Potential impacts to these roads include minor and isolated cracks. Impacts can be managed using monitoring (visual or ground survey lines) during active subsidence and remediation using normal road maintenance techniques.

It is expected that the private roads and services can be maintained in safe and serviceable conditions with the development of the appropriate monitoring and management plans.

The predicted subsidence parameters for the built features and services on the Garrawarra Complex, based on the Extraction Plan Layout, are similar to or less than the maxima predicted based on the Preferred Project Layout. Longwalls have been set back a considerable distance from the majority of the structures in the Garrawarra Complex. The recommendations and management strategies for the Garrawarra Complex, therefore, are significantly less than those based on the Preferred Project Layout.

11.2. Any Other Residential Feature

There are no other residential features within the Study Area.

APPENDIX A. GLOSSARY OF TERMS AND DEFINITIONS

Glossary of Terms and Definitions

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

Angle of draw	The angle of inclination from the vertical of the line connecting the goaf edge of the workings and the limit of subsidence (which is usually taken as 20 mm of subsidence).
Chain pillar	A block of coal left unmined between the longwall extraction panels.
Cover depth (H)	The depth from the surface to the top of the seam. Cover depth is normally provided as an average over the area of the panel.
Closure	The reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of *millimetres (mm)*, is the greatest reduction in distance between any two points on the opposing valley sides. It should be noted that the observed closure movement across a valley is the total movement resulting from various mechanisms, including conventional mining induced movements, valley closure movements, far-field effects, downhill movements and other possible strata mechanisms.
Critical area	The area of extraction at which the maximum possible subsidence of one point on the surface occurs.
Curvature	The change in tilt between two adjacent sections of the tilt profile divided by the average horizontal length of those sections, i.e. curvature is the second derivative of subsidence. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of *1/km (km-1)*, but the value of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *km (km)*. Curvature can be either **hogging** (i.e. convex) or **sagging** (i.e. concave).
Extracted seam thickness	The thickness of coal that is extracted. The extracted seam thickness is normally given as an average over the area of the panel.
Effective extracted seam thickness (T)	The extracted seam thickness modified to account for the percentage of coal left as pillars within the panel.
Face length	The width of the coalface measured across the longwall panel.
Far-field movements	The measured horizontal movements at pegs that are located beyond the longwall panel edges and over solid unmined coal areas. Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain.
Goaf	The void created by the extraction of the coal into which the immediate roof layers collapse.
Goaf end factor	A factor applied to reduce the predicted incremental subsidence at points lying close to the commencing or finishing ribs of a panel.
Horizontal displacement	The horizontal movement of a point on the surface of the ground as it settles above an extracted panel.
Inflection point	The point on the subsidence profile where the profile changes from a convex curvature to a concave curvature. At this point the strain changes sign and subsidence is approximately one half of S_{max}.
Incremental subsidence	The difference between the subsidence at a point before and after a panel is mined. It is therefore the additional subsidence at a point resulting from the excavation of a panel.
Panel	The plan area of coal extraction.
Panel length (L)	The longitudinal distance along a panel measured in the direction of (mining from the commencing rib to the finishing rib.
Panel width (Wv)	The transverse distance across a panel, usually equal to the face length plus the widths of the roadways on each side.
Panel centre line	An imaginary line drawn down the middle of the panel.
Pillar	A block of coal left unmined.
Pillar width (Wpi)	The shortest dimension of a pillar measured from the vertical edges of the coal pillar, i.e. from rib to rib.

Shear deformations	The horizontal displacements that are measured across monitoring lines and these can be described by various parameters including; horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index.
Strain	The change in the horizontal distance between two points divided by the original horizontal distance between the points, i.e. strain is the relative differential displacement of the ground along or across a subsidence monitoring line. Strain is dimensionless and can be expressed as a decimal, a percentage or in parts per notation. **Tensile Strains** are measured where the distance between two points or survey pegs increases and **Compressive Strains** where the distance between two points decreases. Whilst mining induced **strains** are measured **along** monitoring lines, ground **shearing** can occur both vertically, and horizontally **across** the directions of the monitoring lines.
Sub-critical area	An area of panel smaller than the critical area.
Subsidence	The vertical movement of a point on the surface of the ground as it settles above an extracted panel, but, 'subsidence of the ground' in some references can include both a vertical and horizontal movement component. The vertical component of subsidence is measured by determining the change in surface level of a peg that is fixed in the ground before mining commenced and this vertical subsidence is usually expressed in units of *millimetres (mm)*. Sometimes the horizontal component of a peg's movement is not measured, but in these cases, the horizontal distances between a particular peg and the adjacent pegs are measured.
Super-critical area	An area of panel greater than the critical area.
Tilt	The change in the slope of the ground as a result of differential subsidence, and is calculated as the change in subsidence between two points divided by the horizontal distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. Tilt is usually expressed in units of *millimetres per metre (mm/m)*. A tilt of 1 mm/m is equivalent to a change in grade of 0.1 %, or 1 in 1000.
Uplift	An increase in the level of a point relative to its original position.
Upsidence	Upsidence results from the dilation or buckling of near surface strata at or near the base of the valley. The magnitude of upsidence, which is typically expressed in the units of *millimetres (mm)*, is the difference between the observed subsidence profile within the valley and the conventional subsidence profile which would have otherwise been expected in flat terrain.

APPENDIX B. REFERENCES

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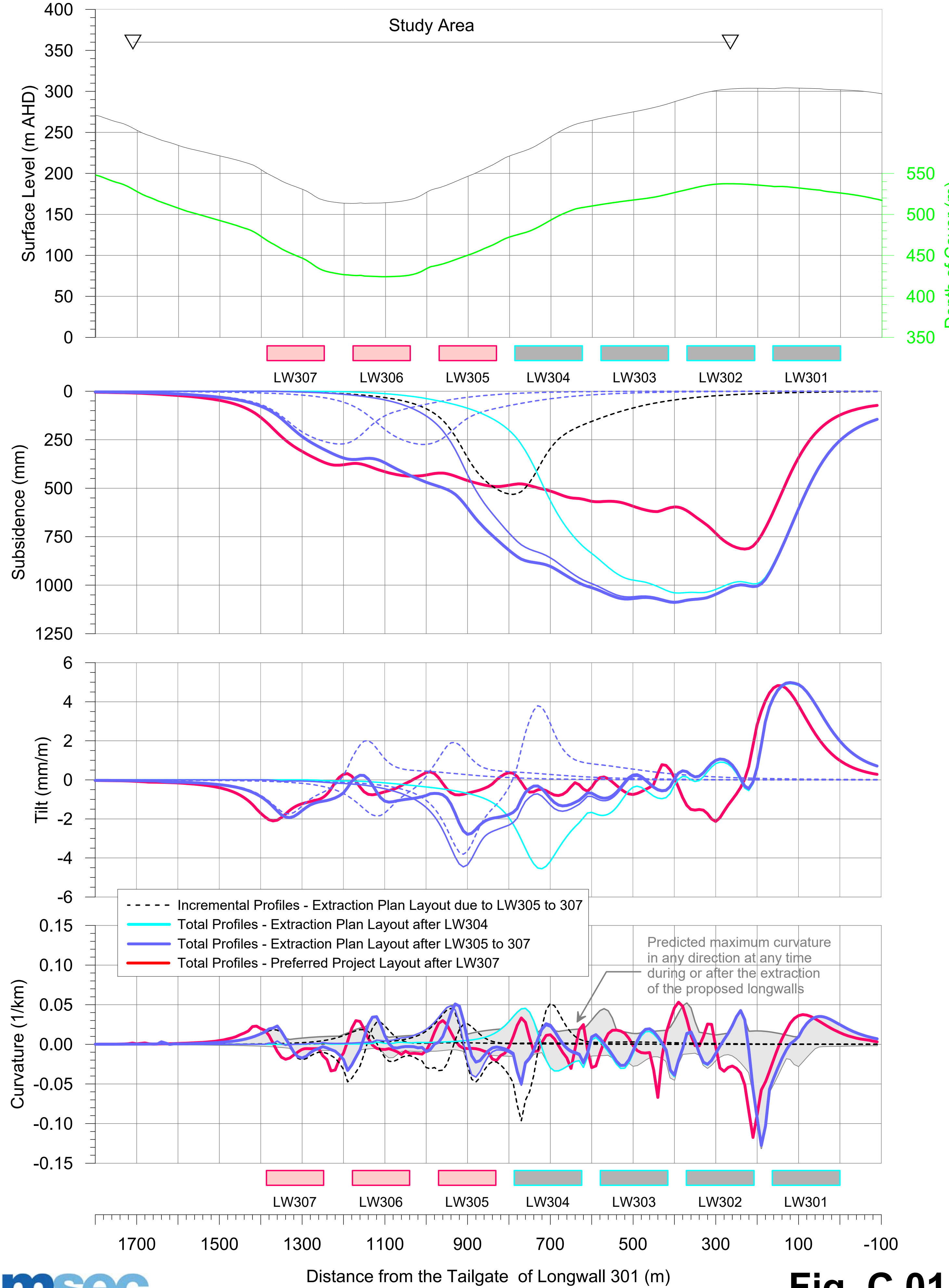
APPENDIX C. FIGURES

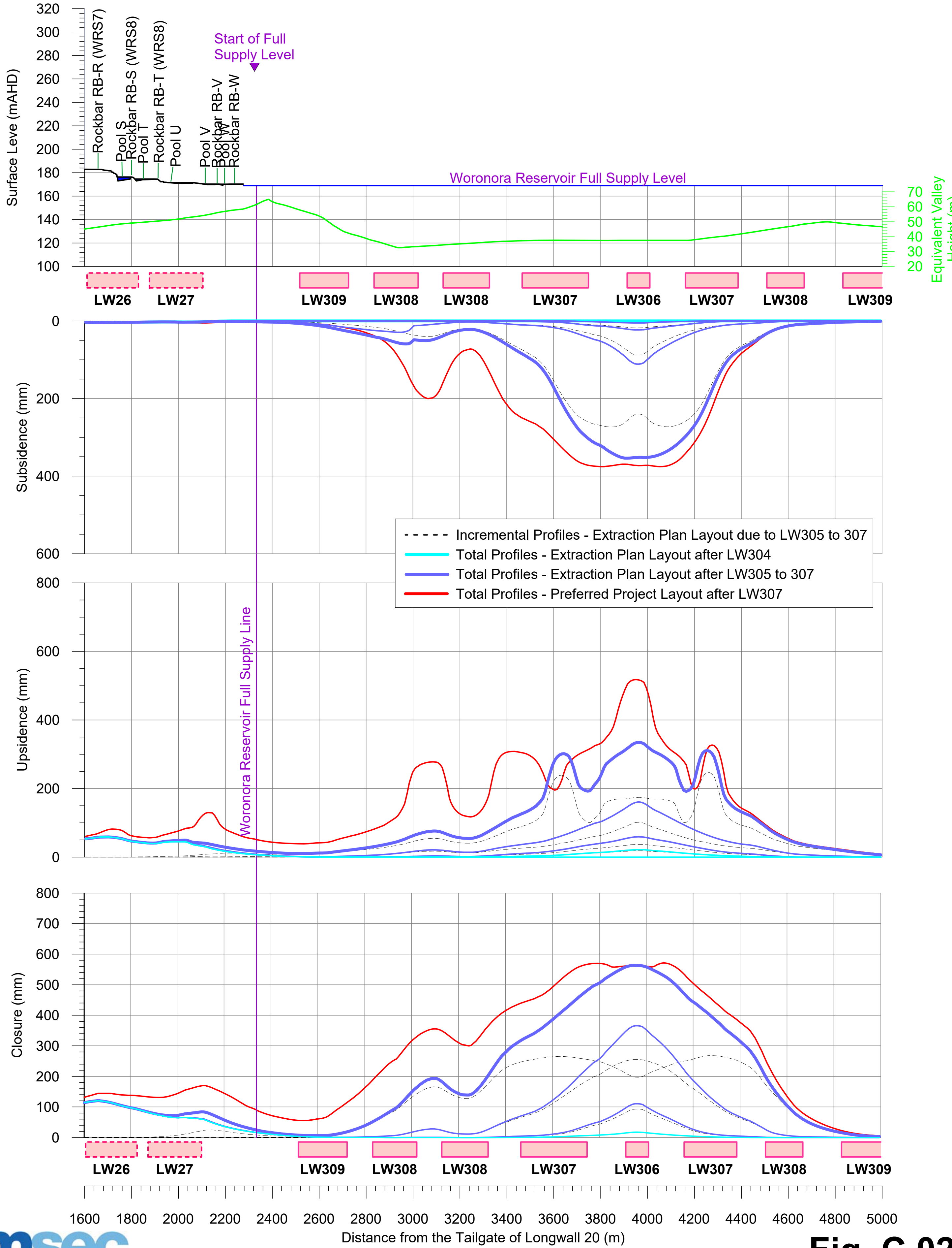
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 1 due to LW305 to 307



msec

Fig. C.01

Predicted Profiles of Subsidence, Upsidence and Closure along the Waratah Rivulet and Woronora Reservoir due to LW305 to 307



msec

Fig. C.02

Predicted Profiles of Subsidence, Upsidence and Closure along the Eastern Tributary and Woronora Reservoir due to LW305 to 307 Extraction Plan Layout

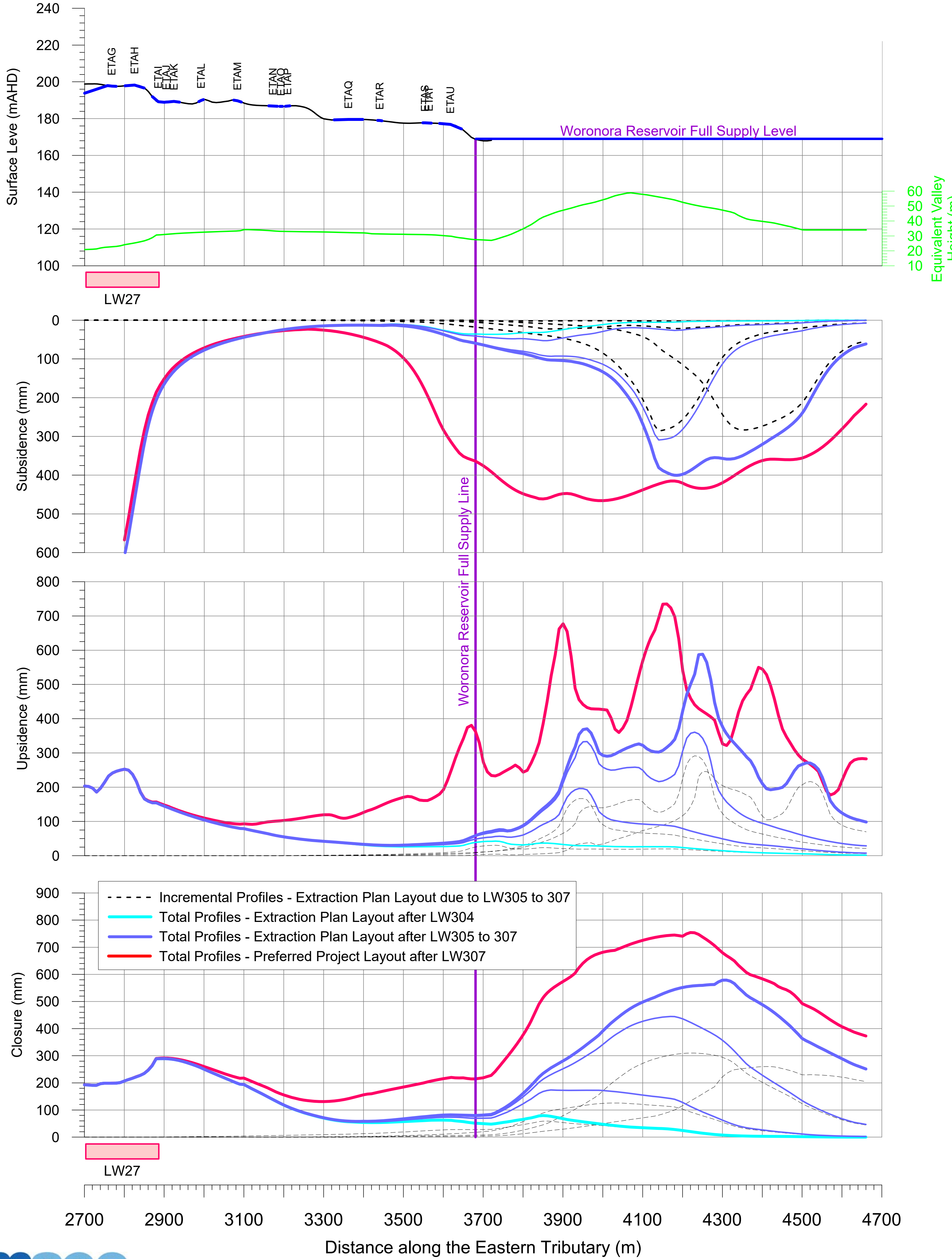


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Fig. C.03

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along the Old Princes Highway due to LW305 to 307

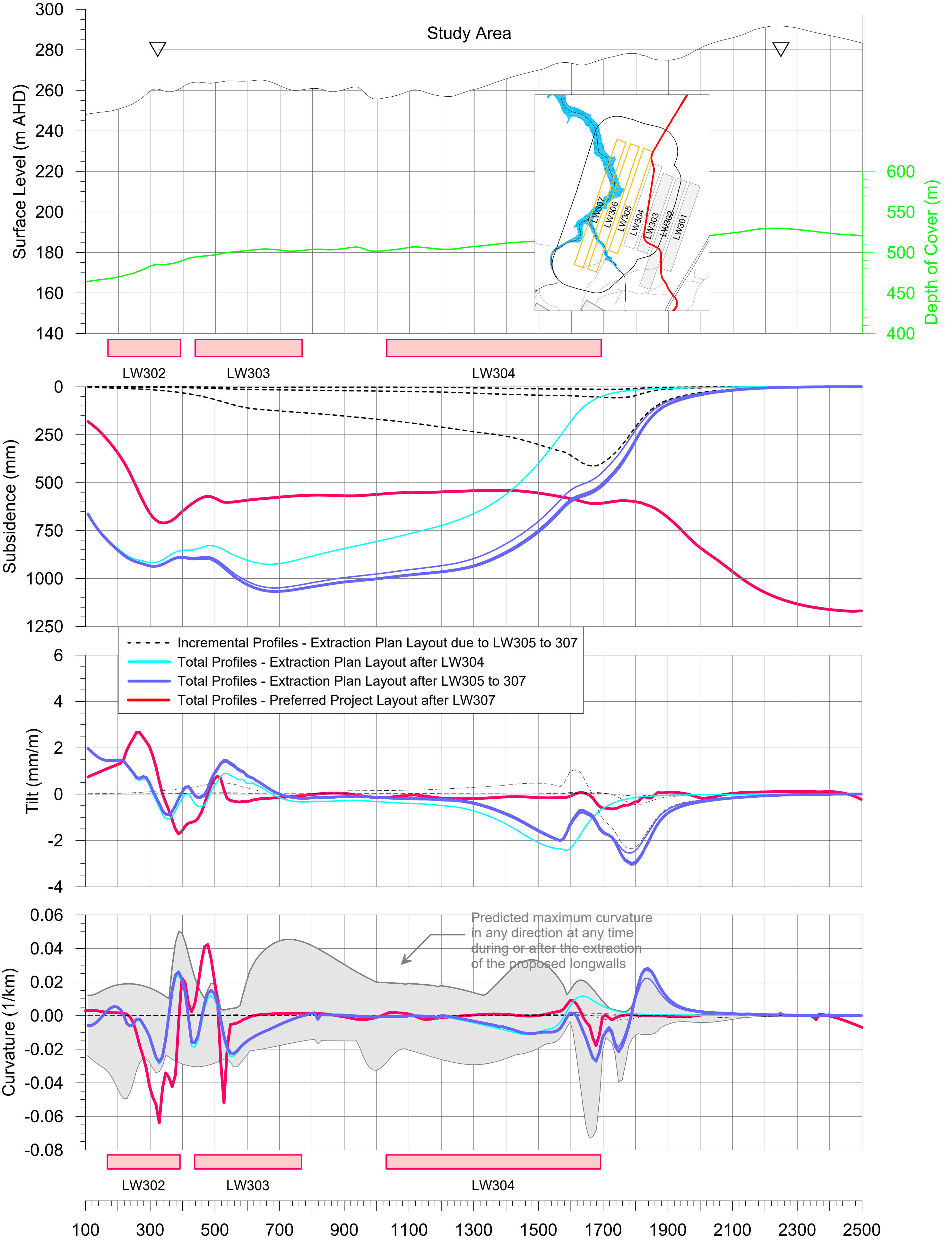

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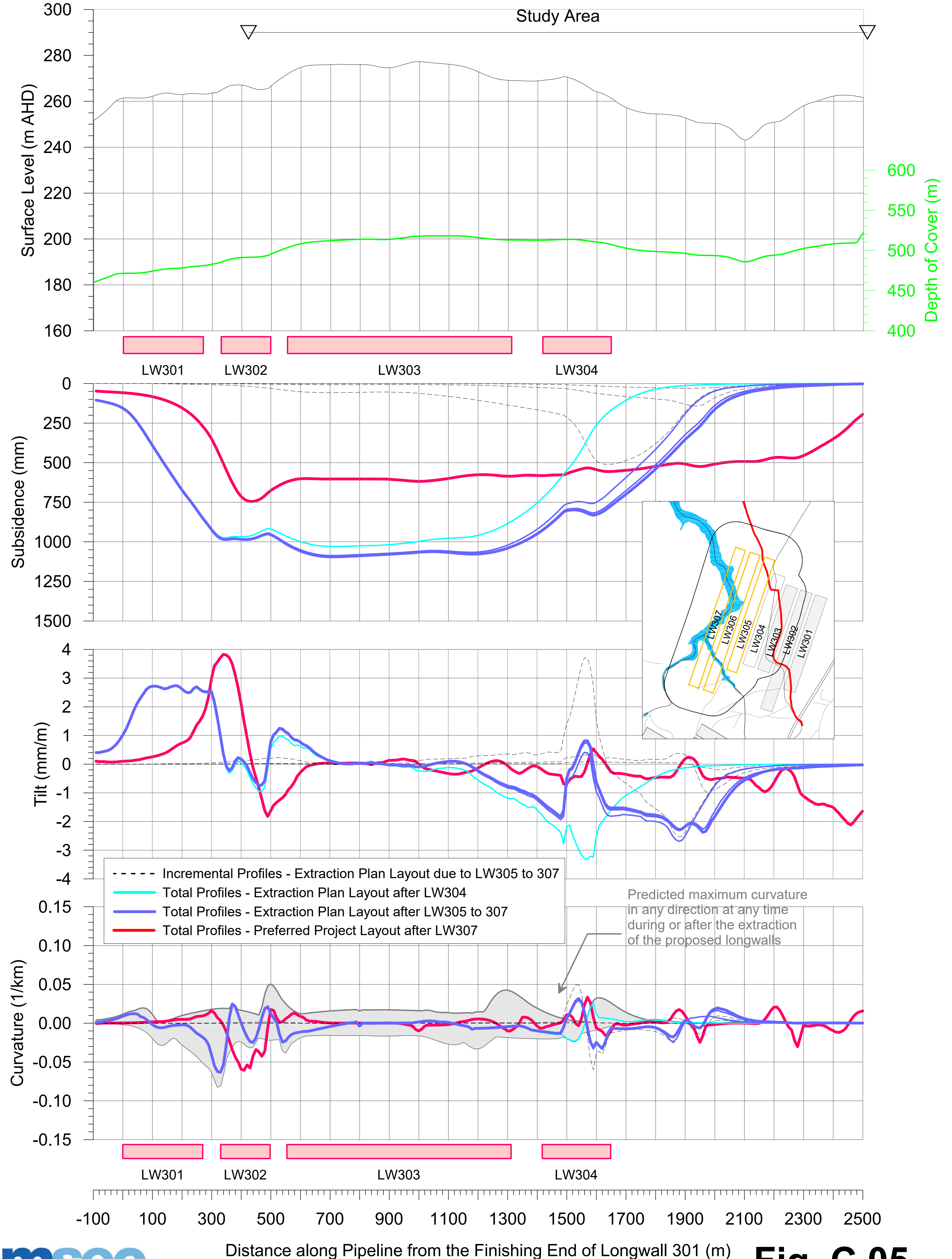
Fig. C.04

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Water Main 1 due to LW305 to 307



msec

Fig. C.05

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Water Main 2 due to LW305 to 307

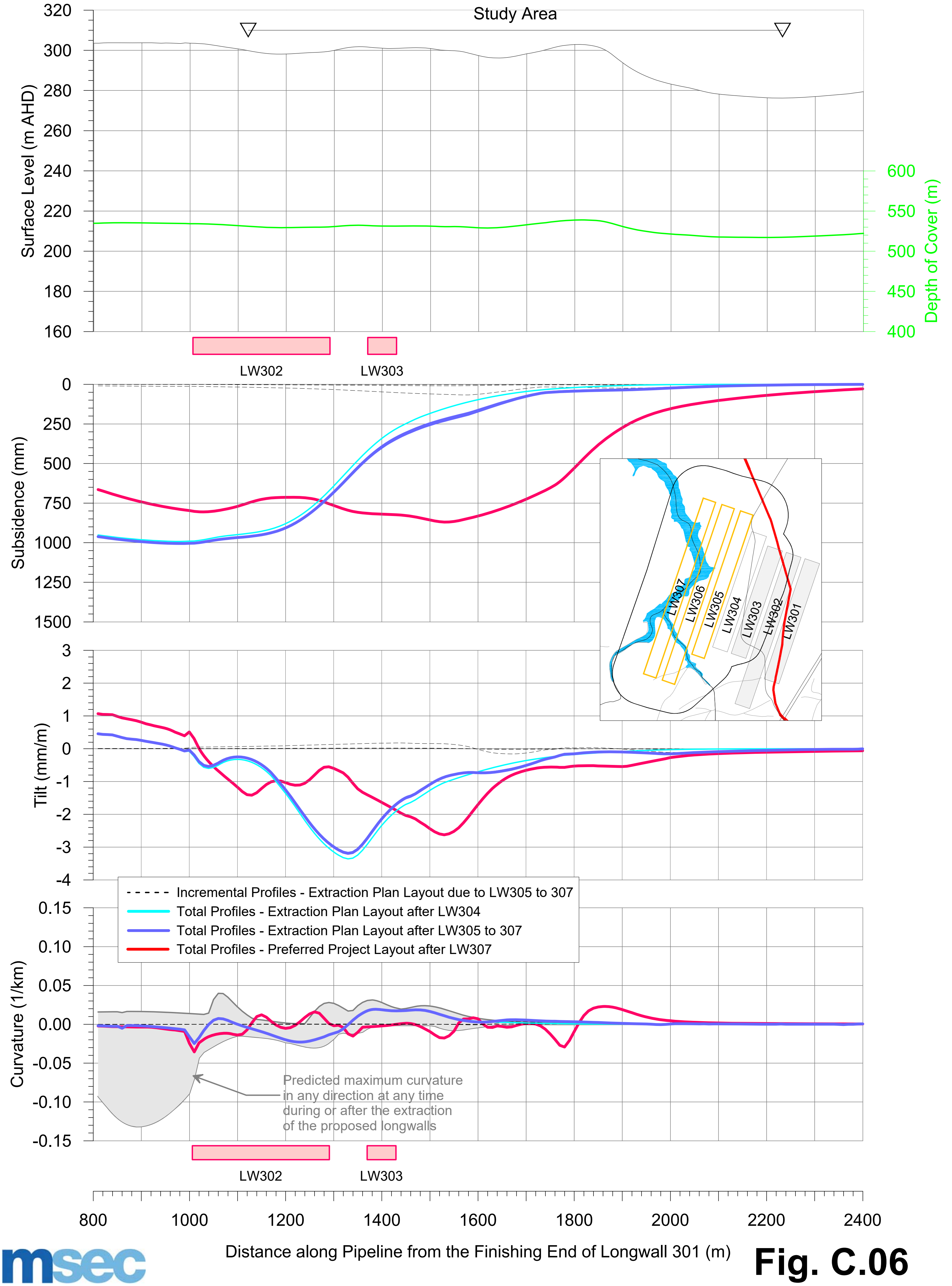


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Fig. C.06

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along the Optus Optical Fibre Cable due to LW305 to 307

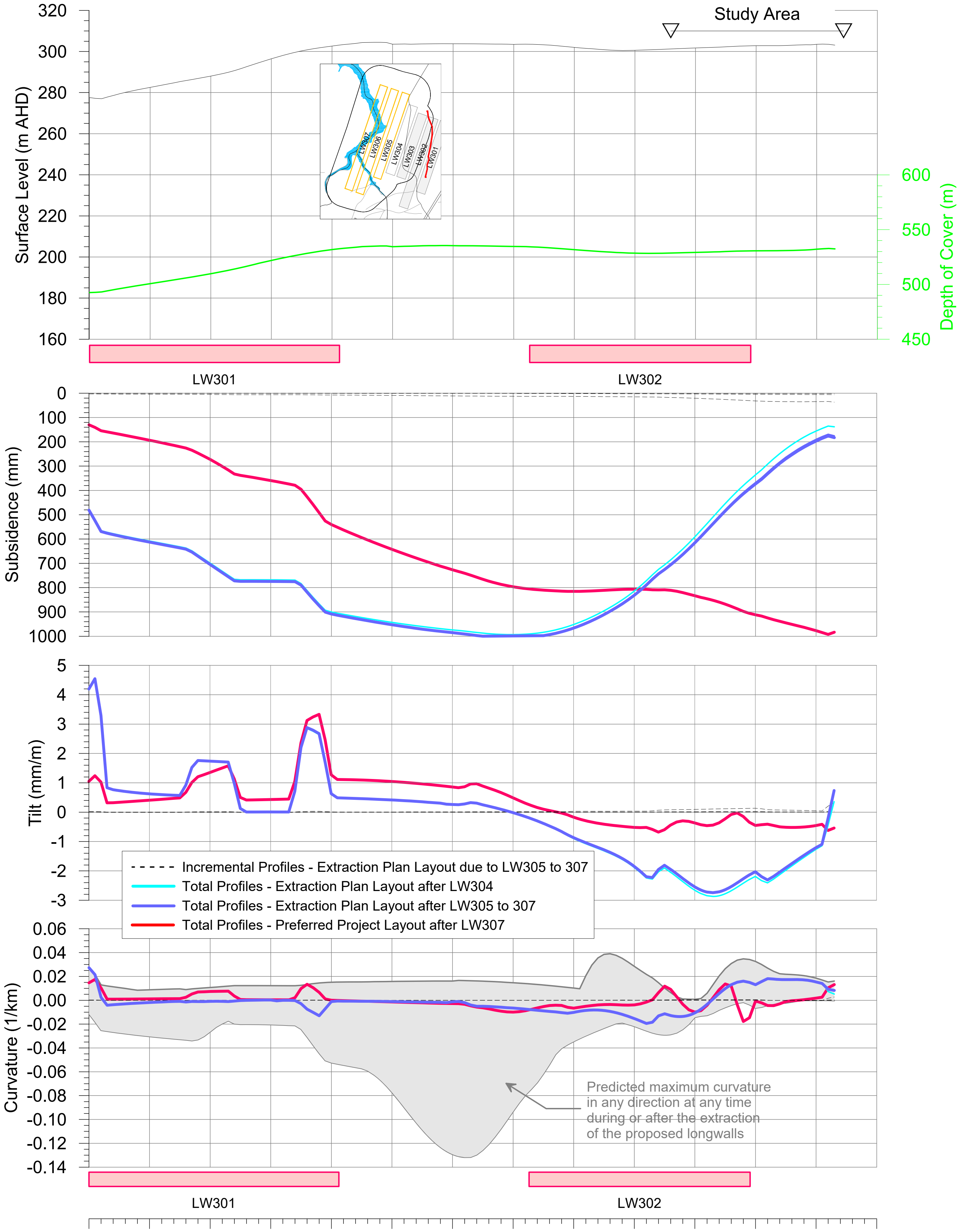
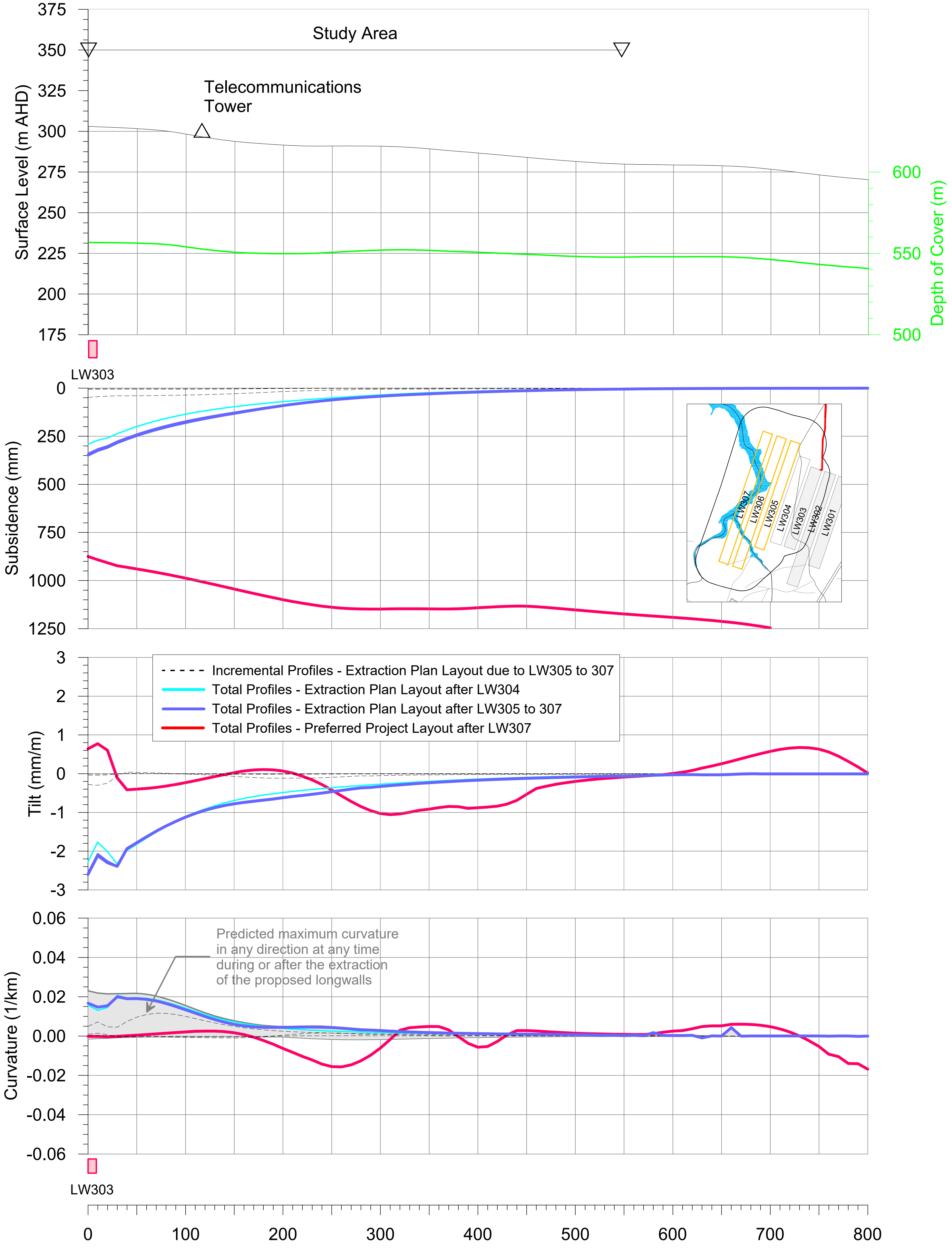


Fig. C.07

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along the Telstra Optical Fibre Cable due to LW305 to 307



msec

Fig. C.08

APPENDIX D. TABLES

Table D.01 - Maximum Predicted Subsidence Parameters for the Swamps

Swamp	*Maximum Predicted Subsidence based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Subsidence based on the Preferred Project Layout after LW307 (mm)*	Maximum Predicted Subsidence based on the Extraction Plan Layout after LW304 (mm)	Maximum Predicted Subsidence based on the Extraction Plan Layout after LW305 (mm)	Maximum Predicted Subsidence based on the Extraction Plan Layout after LW306 (mm)	Maximum Predicted Subsidence based on the Extraction Plan Layout after LW307 (mm)	*Maximum Predicted Tilt based on the Preferred Project Layout after LW317 (mm/m)*	*Maximum Predicted Tilt based on the Preferred Project Layout after LW307 (mm/m)*	Maximum Predicted Tilt based on the Extraction Plan Layout after LW307 (mm/m)
S40	*550*	*550*	825	850	850	850	*3.0*	*3.0*	4.0
S41	*825*	*825*	1000	1050	1050	1050	*5.0*	*5.0*	5.0
S46	*775*	*775*	1050	1100	1100	1100	*2.5*	*2.5*	0.5
S47	*575*	*575*	850	1000	1000	1050	*0.5*	*0.5*	1.5
S48	*500*	*500*	175	675	775	800	*0.5*	*0.5*	3.0
S49	*500*	*500*	450	825	875	900	*0.5*	*0.5*	2.0
S50	*550*	*550*	700	925	950	950	*1.0*	*1.0*	2.0
S51/S52	*650*	*650*	1000	1050	1100	1100	*1.0*	*1.0*	2.0
S53	*750*	*750*	1050	1100	1100	1100	*1.5*	*1.5*	3.0
S58	*975*	*975*	90	200	200	225	*2.0*	*2.0*	2.0
S69	*1150*	*1150*	< 20	< 20	20	20	*2.0*	*2.0*	< 0.5
S70	*1150*	*1150*	< 20	< 20	< 20	< 20	*1.0*	*1.0*	< 0.5
S71a	*975*	*975*	< 20	20	30	40	*2.0*	*2.0*	< 0.5
S71b	*725*	*625*	< 20	< 20	< 20	20	*2.5*	*4.0*	< 0.5
S72	*525*	*400*	< 20	< 20	< 20	< 20	*1.0*	*3.0*	< 0.5
S73	*450*	*50*	< 20	< 20	< 20	< 20	*1.0*	*< 0.5*	< 0.5
S84	*450*	*200*	< 20	< 20	< 20	100	*1.0*	*2.0*	1.5
S86	*450*	*< 20*	< 20	< 20	< 20	< 20	*1.5*	*< 0.5*	< 0.5

Table D.01 - Maximum Predicted Subsidence Parameters for the Swamps

Swamp	*Maximum Predicted Hogging Curvature based on the Preferred Project Layout after LW317 (1/km)*	*Maximum Predicted Hogging Curvature based on the Preferred Project Layout after LW307 (1/km)*	Maximum Predicted Hogging Curvature based on the Extraction Plan Layout after LW307 (1/km)	*Maximum Predicted Sagging Curvature based on the Preferred Project Layout after LW317 (1/km)*	*Maximum Predicted Sagging Curvature based on the Preferred Project Layout after LW307 (1/km)*	Maximum Predicted Sagging Curvature based on the Extraction Plan Layout after LW307 (1/km)	*Predicted Conventional Tensile Strain based on the Preferred Project Layout after LW317 (mm/m)*	*Predicted Conventional Tensile Strain based on the Preferred Project Layout after LW307 (mm/m)*	Predicted Conventional Tensile Strain based on the Extraction Plan Layout after LW307 (mm/m)	*Predicted Conventional Compressive Strain based on the Preferred Project Layout after LW317 (mm/m)*	*Predicted Conventional Compressive Strain based on the Preferred Project Layout after LW307 (mm/m)*	Predicted Conventional Compressive Strain based on the Extraction Plan Layout after LW307 (mm/m)
S40	*0.04*	*0.04*	0.05	*0.09*	*0.09*	0.06	1.00	1.00	1.00	1.50	1.50	1.00
S41	*0.04*	*0.04*	0.04	*0.10*	*0.10*	0.12	1.00	1.00	1.00	2.00	2.00	2.00
S46	*0.06*	*0.06*	0.05	*0.07*	*0.07*	0.06	1.00	1.00	1.00	1.50	1.50	1.00
S47	*0.03*	*0.03*	0.03	*0.04*	*0.04*	0.03	1.00	1.00	1.00	1.00	1.00	< 0.5
S48	*0.03*	*0.03*	0.06	*0.03*	*0.03*	0.05	< 0.5	< 0.5	1.00	1.00	1.00	1.00
S49	*0.04*	*0.04*	0.05	*0.04*	*0.04*	0.08	1.00	1.00	0.50	1.00	1.00	0.50
S50	*0.04*	*0.04*	0.04	*0.04*	*0.04*	0.09	1.00	1.00	1.00	1.00	1.00	1.50
S51/S52	*0.04*	*0.04*	0.04	*0.07*	*0.07*	0.04	1.00	1.00	1.00	1.50	1.50	1.00
S53	*0.06*	*0.06*	0.05	*0.07*	*0.07*	0.05	1.00	1.00	1.00	1.50	1.50	1.00
S58	*0.05*	*0.05*	0.03	*0.05*	*0.05*	0.01	1.00	1.00	< 0.5	1.00	1.00	< 0.5
S69	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	1.00	1.00	< 0.5	1.00	1.00	< 0.5
S70	*0.05*	*0.05*	< 0.01	*0.07*	*0.07*	< 0.01	1.00	1.00	< 0.5	1.00	1.00	< 0.5
S71a	*0.05*	*0.05*	< 0.01	*0.05*	*0.05*	< 0.01	1.00	1.00	< 0.5	1.00	1.00	< 0.5
S71b	*0.07*	*0.04*	< 0.01	*0.06*	*0.05*	< 0.01	1.00	1.00	< 0.5	1.00	1.00	< 0.5
S72	*0.05*	*0.03*	< 0.01	*0.06*	*0.03*	< 0.01	1.00	< 0.5	< 0.5	1.00	< 0.5	< 0.5
S73	*0.05*	*< 0.01*	< 0.01	*0.03*	*< 0.01*	< 0.01	1.00	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
S84	*0.04*	*0.02*	0.02	*0.06*	*< 0.01*	< 0.01	1.00	< 0.5	< 0.5	1.00	< 0.5	< 0.5
S86	*0.05*	*< 0.01*	< 0.01	*0.06*	*< 0.01*	< 0.01	1.00	< 0.5	< 0.5	1.00	< 0.5	< 0.5

Note: Predicted conventional strains are based on 15 times curvature

Table D.01 - Maximum Predicted Subsidence Parameters for the Swamps

Swamp	*Maximum Predicted Upsidence based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Upsidence based on the Preferred Project Layout after LW307 (mm)*	**Maximum Predicted Upsidence based on the Extraction Plan Layout after LW307 (mm)**	*Maximum Predicted Closure based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Closure based on the Preferred Project Layout after LW307 (mm)*	**Maximum Predicted Closure based on the Extraction Plan Layout after LW307 (mm)**
S40	-	-	-	-	-	-
S41	-	-	-	-	-	-
S46	-	-	-	-	-	-
S47	-	-	-	-	-	-
S48	-	-	-	-	-	-
S49	-	-	-	-	-	-
S50	-	-	-	-	-	-
S51/S52	*50*	*50*	90	*40*	*40*	40
S53	*100*	*100*	100	*40*	*40*	40
S58	*40*	*40*	< 20	*30*	*30*	< 20
S69	-	-	-	-	-	-
S70	-	-	-	-	-	-
S71a	-	-	-	-	-	-
S71b	-	-	-	-	-	-
S72	-	-	-	-	-	-
S73	-	-	-	-	-	-
S84	-	-	-	-	-	-
S86	-	-	-	-	-	-

Table D.02 - Maximum Predicted Subsidence Parameters for the Aboriginal Heritage Sites

Site	Description	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW307 (mm)*	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW305 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW306 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW307 (mm)	*Maximum Predicted Total Tilt based on the Preferred Project Layout after LW317 (mm/m)*	*Maximum Predicted Total Tilt based on the Preferred Project Layout after LW307 (mm/m)*	Maximum Predicted Total Tilt based on the Extraction Plan Layout after LW307 (mm/m)	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW317 (1/km)*
FRC 67	Sandstone overhang with artefacts and deposit	*450*	*425*	< 20	150	225	*1.0*	*1.0*	1.5	*0.03*
FRC 68	Sandstone overhang with art, artefacts and deposit	*450*	*450*	< 20	150	275	*1.0*	*1.0*	1.5	*0.02*
FRC 70	Sandstone overhang with art, artefacts and deposit	*450*	*425*	40	175	350	*0.5*	*1.0*	< 0.5	*0.01*
FRC 71	Sandstone overhang with art only	*450*	*450*	70	325	425	*< 0.5*	*< 0.5*	1.0	*0.03*
FRC 76	Sandstone overhang with art only	*550*	*550*	900	950	950	*1.0*	*1.0*	1.5	*0.01*
FRC 77	Sandstone overhang with art, artefacts and deposit	*525*	*525*	725	800	825	*< 0.5*	*< 0.5*	2.0	*0.02*
FRC 78	Sandstone overhang with art only	*525*	*500*	700	800	800	*0.5*	*0.5*	2.0	*0.02*
FRC 85	Sandstone overhang with art, artefacts and deposit	*550*	*525*	325	400	425	*0.5*	*1.0*	2.5	*0.03*
FRC 86	Sandstone overhang with art only	*575*	*575*	725	800	800	*0.5*	*0.5*	1.5	*0.03*
FRC 87	Sandstone overhang with art, artefacts and deposit	*450*	*400*	40	225	325	*0.5*	*1.0*	1.0	*0.03*
FRC 90	Sandstone overhang with artefacts and deposit	*575*	*575*	575	650	675	*1.0*	*1.0*	2.0	*0.01*
FRC 91	Sandstone overhang with art, artefacts and deposit	*600*	*600*	250	300	325	*1.0*	*1.0*	3.0	*0.01*
FRC 93	Sandstone overhang with art only	*400*	*225*	< 20	20	225	*0.5*	*2.5*	2.0	*0.04*
FRC 94	Sandstone overhang with art only	*425*	*< 20*	< 20	< 20	< 20	*< 0.5*	*< 0.5*	< 0.5	*0.01*
FRC 97	Sandstone overhang with art only	*425*	*50*	< 20	< 20	30	*< 0.5*	*< 0.5*	< 0.5	*< 0.01*
FRC 101	Open site with grinding grooves only	*500*	*325*	< 20	< 20	< 20	*1.0*	*3.0*	< 0.5	*0.05*
FRC 117	Sandstone overhang with art and PAD	*325*	*325*	30	50	50	*2.5*	*2.5*	0.5	*< 0.01*
FRC 180	Sandstone overhang with art only	*225*	*200*	< 20	30	80	*2.0*	*2.0*	1.0	*0.02*
FRC 184	Sandstone overhang with artefacts and deposit	*425*	*< 20*	< 20	< 20	< 20	*1.0*	*< 0.5*	< 0.5	*0.04*
FRC 185	Sandstone overhang with art, artefacts and deposit	*425*	*< 20*	< 20	< 20	< 20	*< 0.5*	*< 0.5*	< 0.5	*< 0.01*
FRC 186	Sandstone overhang with art and deposit	*450*	*< 20*	< 20	< 20	< 20	*< 0.5*	*< 0.5*	< 0.5	*< 0.01*
FRC 187	Sandstone overhang with art only	*450*	*< 20*	< 20	< 20	< 20	*< 0.5*	*< 0.5*	< 0.5	*< 0.01*
FRC 191	Sandstone overhang with art only	*400*	*< 20*	< 20	< 20	< 20	*1.5*	*< 0.5*	< 0.5	*0.05*
FRC 198	Sandstone overhang with art only	*375*	*40*	< 20	20	40	*< 0.5*	*< 0.5*	< 0.5	*< 0.01*
FRC 254	Sandstone overhang with artefacts and deposit	*425*	*375*	< 20	70	300	*< 0.5*	*< 0.5*	2.0	*0.02*
FRC 309	Sandstone overhang with artefacts and deposit	*475*	*475*	500	625	650	*1.0*	*1.0*	3.0	*0.01*

Table D.02 - Maximum Predicted Subsidence Parameters for the Aboriginal Heritage Sites

Site	Description	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW307 (mm)*	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW305 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW306 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW307 (mm)	*Maximum Predicted Total Tilt based on the Preferred Project Layout after LW317 (mm/m)*	*Maximum Predicted Total Tilt based on the Preferred Project Layout after LW307 (mm/m)*	Maximum Predicted Total Tilt based on the Extraction Plan Layout after LW307 (mm/m)	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW317 (1/km)*
FRC 310	Sandstone overhang with art only	*500*	*475*	80	325	400	*0.5*	*1.0*	1.5	*< 0.01*
FRC 311	Sandstone overhang with artefacts and deposit	*400*	*30*	< 20	< 20	30	*< 0.5*	*< 0.5*	< 0.5	*0.02*
FRC 316	Sandstone overhang with artefacts and deposit	*475*	*90*	< 20	< 20	< 20	*< 0.5*	*1.0*	< 0.5	*0.02*
FRC 320	Sandstone overhang with artefacts and deposit	*80*	*80*	< 20	< 20	< 20	*1.0*	*1.0*	< 0.5	*0.01*
FRC 321	Sandstone overhang with art, artefacts and deposit	*125*	*125*	< 20	< 20	< 20	*1.5*	*1.5*	< 0.5	*0.02*
FRC 323	Sandstone overhang with artefacts and deposit	*30*	*< 20*	< 20	< 20	< 20	*< 0.5*	*< 0.5*	< 0.5	*< 0.01*
FRC 324	Sandstone overhang with artefacts and deposit	*20*	*< 20*	< 20	< 20	< 20	*< 0.5*	*< 0.5*	< 0.5	*< 0.01*
FRC 325	Sandstone overhang with art only	*450*	*450*	70	125	150	*< 0.5*	*< 0.5*	0.5	*0.03*
FRC 344	Sandstone overhang with artefacts and deposit	*475*	*< 20*	< 20	< 20	< 20	*< 0.5*	*< 0.5*	< 0.5	*0.01*
FRC 345	Sandstone overhang with artefacts and deposit	*475*	*< 20*	< 20	< 20	< 20	*< 0.5*	*< 0.5*	< 0.5	*< 0.01*

Table D.02 - Maximum Predicted Subsidence Parameters for the Aboriginal Heritage Sites

Site	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW307 (1/km)*	Maximum Predicted Total Hogging Curvature based on the Extraction Plan Layout after LW307 (1/km)	*Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW317 (1/km)*	*Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW307 (1/km)*	Maximum Predicted Total Sagging Curvature based on the Extraction Plan Layout after LW307 (1/km)	*Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW317 (mm/m)*	*Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW307 (mm/m)*	Predicted Total Conventional Tensile Strain based on the Extraction Plan Layout after LW307 (mm/m)	*Maximum Predicted Total Compressive Strain based on the Preferred Project Layout after LW317 (mm/m)*	*Maximum Predicted Total Compressive Strain based on the Preferred Project Layout after LW307 (mm/m)*	Predicted Total Conventional Comp. Strain based on the Extraction Plan Layout after LW307 (mm/m)
FRC 67	0.03	< 0.01	0.03	0.03	0.03	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 68	0.02	< 0.01	0.04	0.04	0.03	< 0.5	< 0.5	< 0.5	1.0	1.0	0.5
FRC 70	0.01	0.03	0.02	0.02	0.01	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 71	0.03	< 0.01	0.01	0.01	0.02	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 76	0.01	0.03	0.03	0.03	0.03	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	1.0
FRC 77	0.02	0.03	0.03	0.03	0.02	< 0.5	< 0.5	< 0.5	1.0	1.0	< 0.5
FRC 78	0.02	0.02	0.03	0.03	0.01	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 85	0.03	< 0.01	0.03	0.03	0.05	1.0	< 0.5	< 0.5	< 0.5	< 0.5	1.0
FRC 86	0.03	0.03	0.04	0.04	0.09	< 0.5	< 0.5	< 0.5	1.0	1.0	1.5
FRC 87	0.03	0.03	0.01	0.01	0.02	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 90	0.01	0.02	0.01	0.01	0.02	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 91	< 0.01	0.03	0.03	0.03	0.01	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 93	0.03	< 0.01	0.02	0.02	0.02	1.0	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 94	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 97	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 101	0.02	< 0.01	0.02	0.02	< 0.01	1.0	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 117	< 0.01	< 0.01	0.02	0.02	< 0.01	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 180	0.02	0.02	< 0.01	< 0.01	0.01	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 184	< 0.01	< 0.01	0.01	< 0.01	< 0.01	1.0	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 185	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 186	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 187	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 191	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	1.0	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 198	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 254	0.02	0.01	0.01	0.01	0.01	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
FRC 309	0.01	0.05	0.02	0.02	0.04	< 0.5	< 0.5	1.0	< 0.5	< 0.5	1.0

Table D.02 - Maximum Predicted Subsidence Parameters for the Aboriginal Heritage Sites

Site	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW307 (1/km)*	Maximum Predicted Total Hogging Curvature based on the Extraction Plan Layout after LW307 (1/km)	*Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW317 (1/km)*	*Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW307 (1/km)*	Maximum Predicted Total Sagging Curvature based on the Extraction Plan Layout after LW307 (1/km)	*Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW317 (mm/m)*	*Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW307 (mm/m)*	Predicted Total Conventional Tensile Strain based on the Extraction Plan Layout after LW307 (mm/m)	*Maximum Predicted Total Compressive Strain based on the Preferred Project Layout after LW317 (mm/m)*	*Maximum Predicted Total Compressive Strain based on the Preferred Project Layout after LW307 (mm/m)*	Predicted Total Conventional Comp. Strain based on the Extraction Plan Layout after LW307 (mm/m)
FRC 310	*< 0.01*	0.01	*0.01*	*0.01*	< 0.01	*< 0.5*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5
FRC 311	*< 0.01*	< 0.01	*0.03*	*< 0.01*	< 0.01	*< 0.5*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5
FRC 316	*0.02*	< 0.01	*0.06*	*< 0.01*	< 0.01	*< 0.5*	*< 0.5*	< 0.5	*1.0*	*< 0.5*	< 0.5
FRC 320	*0.01*	< 0.01	*< 0.01*	*< 0.01*	< 0.01	*< 0.5*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5
FRC 321	*0.02*	< 0.01	*< 0.01*	*< 0.01*	< 0.01	*< 0.5*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5
FRC 323	*< 0.01*	< 0.01	*< 0.01*	*< 0.01*	< 0.01	*< 0.5*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5
FRC 324	*< 0.01*	< 0.01	*< 0.01*	*< 0.01*	< 0.01	*< 0.5*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5
FRC 325	*0.03*	< 0.01	*0.01*	*0.01*	< 0.01	*< 0.5*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5
FRC 344	*< 0.01*	< 0.01	*0.01*	*< 0.01*	< 0.01	*< 0.5*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5
FRC 345	*< 0.01*	< 0.01	*0.01*	*< 0.01*	< 0.01	*< 0.5*	*< 0.5*	< 0.5	*< 0.5*	*< 0.5*	< 0.5

Note: Predicted conventional strains are based on 15 times curvature

Table D.03 - Maximum Predicted Subsidence Parameters for the Building Structures

Ref.	Description	Maximum Dimension (m)	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW307 (mm)*	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW305 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW306 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW307 (mm)	Maximum Predicted Total Tilt based on the Preferred Project Layout after LW317 (mm)	*Maximum Predicted Total Tilt based on the Preferred Project Layout after LW307 (mm)*	*Maximum Predicted Total Tilt based on the Extraction Plan Layout after LW307 (mm/m)*
A01a	Hospital	38	1250	1250	< 20	< 20	< 20	2.0	2.0	< 0.5
A01b	Hospital	17	1200	1200	< 20	< 20	< 20	1.5	1.5	< 0.5
A01c	Hospital	5	1150	1150	< 20	< 20	< 20	2.0	2.0	< 0.5
A01d	Hospital	5	1150	1150	< 20	< 20	< 20	2.0	2.0	< 0.5
A01e	Hospital	34	1200	1200	< 20	< 20	< 20	2.0	2.0	< 0.5
A01f	Hospital	5	1200	1200	< 20	< 20	< 20	1.0	1.0	< 0.5
A01g	Hospital	5	1250	1250	< 20	< 20	< 20	1.0	1.0	< 0.5
A01h	Hospital	7	1250	1250	< 20	< 20	< 20	1.0	1.0	< 0.5
A01i	Hospital	5	1250	1250	< 20	< 20	< 20	1.0	1.0	< 0.5
A01j	Hospital	5	1250	1250	< 20	< 20	< 20	< 0.5	< 0.5	< 0.5
A01k	Hospital	5	1250	1250	< 20	< 20	< 20	< 0.5	< 0.5	< 0.5
A01l	Shed	4	1200	1200	< 20	< 20	< 20	< 0.5	< 0.5	< 0.5
A01m	House	18	1300	1300	< 20	< 20	< 20	2.0	2.0	< 0.5
A02a	House	11	1300	1300	< 20	< 20	< 20	2.5	2.5	< 0.5
A02b	Shed	6	1300	1300	< 20	< 20	< 20	2.5	2.5	< 0.5
A03a	House	16	1300	1300	< 20	< 20	< 20	2.5	2.5	< 0.5
A03b	Shed	10	1300	1300	< 20	< 20	< 20	2.5	2.5	< 0.5
A03c	Shed	5	1300	1300	< 20	< 20	< 20	2.5	2.5	< 0.5
A03d	Shed	2	1300	1300	< 20	< 20	< 20	2.5	2.5	< 0.5
A04a	House	14	1300	1300	< 20	< 20	< 20	2.0	2.0	< 0.5
A05a	House	12	1300	1300	< 20	< 20	< 20	1.5	1.5	< 0.5
A06a	House	11	1300	1300	< 20	< 20	< 20	1.5	1.5	< 0.5
A06b	Shed	4	1300	1300	< 20	< 20	< 20	1.5	1.5	< 0.5
A07a	House	16	1250	1250	< 20	< 20	< 20	1.5	1.5	< 0.5
A08a	House	17	1250	1250	< 20	< 20	< 20	1.5	1.5	< 0.5
A08b	Shed	13	1250	1250	< 20	< 20	< 20	1.5	1.5	< 0.5
A08c	Shed	3	1250	1250	< 20	< 20	< 20	1.5	1.5	< 0.5
A08d	Shed	3	1250	1250	< 20	< 20	< 20	1.5	1.5	< 0.5
A08e	Shed	2	1250	1250	< 20	< 20	< 20	1.5	1.5	< 0.5
A08f	Shed	2	1200	1200	< 20	< 20	< 20	2.5	2.5	< 0.5
A09a	House	15	1200	1150	< 20	< 20	< 20	1.0	1.0	< 0.5
A09b	Shed	10	1150	1150	< 20	< 20	< 20	1.0	1.0	< 0.5
B01a	Retirement Home	14	1150	1100	20	30	30	1.5	1.5	< 0.5
B01b	Retirement Home	14	1150	1150	20	20	20	1.5	1.5	< 0.5

Table D.03 - Maximum Predicted Subsidence Parameters for the Building Structures

Ref.	Description	Maximum Dimension (m)	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW307 (mm)*	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW305 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW306 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW307 (mm)	Maximum Predicted Total Tilt based on the Preferred Project Layout after LW317 (mm)	*Maximum Predicted Total Tilt based on the Preferred Project Layout after LW307 (mm)*	*Maximum Predicted Total Tilt based on the Extraction Plan Layout after LW307 (mm/m)*
B01c	Retirement Home	14	*1200*	*1200*	30	30	30	*2.0*	*2.0*	< 0.5
B01d	Retirement Home	15	*1200*	*1200*	40	40	40	*2.0*	*2.0*	< 0.5
B01e	Retirement Home	19	*1150*	*1150*	< 20	< 20	< 20	*1.0*	*1.0*	< 0.5
B01f	Retirement Home	11	*1150*	*1150*	20	20	20	*1.5*	*1.5*	< 0.5
B01g	Retirement Home	21	*1150*	*1150*	< 20	< 20	< 20	*1.0*	*1.0*	< 0.5
B01h	Retirement Home	19	*1150*	*1150*	< 20	20	20	*1.5*	*1.5*	< 0.5
B01i	Retirement Home	12	*1150*	*1150*	20	20	20	*1.0*	*1.0*	< 0.5
B01j	Retirement Home	6	*1100*	*1100*	20	20	20	*1.5*	*1.5*	< 0.5
B01k	Shed	3	*1150*	*1150*	< 20	< 20	< 20	*1.0*	*1.0*	< 0.5
B01l	Shed	5	*1150*	*1150*	< 20	< 20	< 20	*1.0*	*1.0*	< 0.5
B01m	Shed	3	*1150*	*1150*	< 20	< 20	< 20	*1.5*	*1.5*	< 0.5
B01n	Shed	7	*1200*	*1200*	< 20	20	20	*1.5*	*1.5*	< 0.5
B01o	Shed	5	*1200*	*1200*	< 20	< 20	< 20	*1.5*	*1.5*	< 0.5
B01p	Shed	7	*1200*	*1200*	30	30	30	*1.5*	*1.5*	< 0.5
B01q	Shed	5	*1200*	*1200*	30	30	30	*1.5*	*1.5*	< 0.5
B01t01	Tank	4	*1150*	*1150*	< 20	< 20	< 20	*1.0*	*1.0*	< 0.5
B01t02	Tank	4	*1150*	*1150*	< 20	< 20	< 20	*1.0*	*1.0*	< 0.5
B01t03	Tank	6	*1150*	*1150*	< 20	< 20	< 20	*1.0*	*1.0*	< 0.5
B02a	Retirement Home	40	*1200*	*1200*	< 20	< 20	< 20	*2.0*	*2.0*	< 0.5
B02b	Retirement Home	21	*1200*	*1150*	< 20	< 20	< 20	*1.5*	*1.5*	< 0.5
B02c	Retirement Home	83	*1100*	*1100*	< 20	< 20	< 20	*2.0*	*2.0*	< 0.5
B02d	Retirement Home	25	*1100*	*1100*	< 20	< 20	< 20	*1.5*	*1.5*	< 0.5
B02e	Retirement Home	15	*1100*	*1100*	< 20	< 20	< 20	*2.0*	*2.0*	< 0.5
B02f	Retirement Home	18	*1100*	*1100*	< 20	< 20	< 20	*1.5*	*1.5*	< 0.5
B02g	Retirement Home	9	*1100*	*1100*	< 20	< 20	< 20	*1.5*	*1.5*	< 0.5
B02h	Retirement Home	8	*1100*	*1100*	< 20	< 20	< 20	*1.5*	*1.5*	< 0.5
B02i	Shed	5	*1050*	*1050*	< 20	< 20	< 20	*1.5*	*1.5*	< 0.5
B02j	Shed	5	*1050*	*1050*	< 20	< 20	< 20	*2.5*	*2.5*	< 0.5
B03a	Hospital	41	*1050*	*1050*	< 20	< 20	< 20	*3.5*	*3.5*	< 0.5
B03b	Hospital	11	*1050*	*1050*	< 20	< 20	< 20	*1.5*	*1.5*	< 0.5
B03c	Hospital	8	*1050*	*1050*	< 20	< 20	< 20	*1.0*	*1.0*	< 0.5
B03d	Hospital	23	*1050*	*1050*	< 20	< 20	< 20	*4.0*	*4.0*	< 0.5
B03e	Hospital	25	*1050*	*1050*	< 20	< 20	< 20	*1.5*	*1.5*	< 0.5
B03f	Hospital	28	*1050*	*1050*	< 20	< 20	< 20	*1.5*	*1.5*	< 0.5
B03g	Hospital	8	*1050*	*1050*	< 20	< 20	< 20	*1.5*	*1.5*	< 0.5

Table D.03 - Maximum Predicted Subsidence Parameters for the Building Structures

Ref.	Description	Maximum Dimension (m)	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Total Subsidence based on the Preferred Project Layout after LW307 (mm)*	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW305 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW306 (mm)	Maximum Predicted Total Subsidence based on the Extraction Plan Layout after LW307 (mm)	Maximum Predicted Total Tilt based on the Preferred Project Layout after LW317 (mm)	*Maximum Predicted Total Tilt based on the Preferred Project Layout after LW307 (mm)*	*Maximum Predicted Total Tilt based on the Extraction Plan Layout after LW307 (mm/m)*
B03h	Hospital	28	*1050*	*1050*	< 20	< 20	< 20	*3.5*	*3.5*	< 0.5
B03i	Hospital	5	*1050*	*1050*	< 20	< 20	< 20	*2.0*	*2.0*	< 0.5
B03j	Hospital	14	*950*	*950*	< 20	< 20	< 20	*6.0*	*6.0*	< 0.5
B03k	Hospital	15	*1000*	*1000*	< 20	< 20	< 20	*5.5*	*5.5*	< 0.5
B03l	Hospital	11	*1050*	*1050*	< 20	< 20	< 20	*4.5*	*4.5*	< 0.5
B04a	House	14	*1200*	*1200*	50	50	50	*1.0*	*1.0*	< 0.5
B05a	House	11	*1200*	*1200*	60	60	60	*1.0*	*1.0*	0.5
B06a	House	14	*1150*	*1150*	70	70	70	*1.0*	*1.0*	0.5
B06b	Shed	5	*1150*	*1150*	60	60	60	*1.0*	*1.0*	0.5
B07a	House	11	*1150*	*1150*	80	80	80	*0.5*	*0.5*	0.5
B08a	House	11	*1100*	*1100*	100	100	100	*0.5*	*0.5*	1.0
B09a	House	14	*1100*	*1100*	125	125	125	*1.0*	*1.0*	1.0
B09b	Shed	14	*1150*	*1150*	100	100	100	*1.0*	*1.0*	1.0
B10a	Shed	6	*1100*	*1100*	150	175	175	*1.0*	*1.0*	1.5
B10b	Shed	3	*1050*	*1050*	175	175	175	*1.0*	*1.0*	1.5
B11a	Shed	7	*1000*	*1000*	225	225	225	*1.0*	*1.0*	2.0
B11b	Shed	5	*975*	*975*	275	300	300	*1.0*	*1.0*	2.5
B11c	Shed	3	*1050*	*1050*	200	200	200	*1.0*	*1.0*	1.5
B12a	Shed	14	*950*	*950*	425	450	450	*1.0*	*1.0*	3.5
B14t01	Reservoir	12	*1100*	*1100*	125	150	150	*1.0*	*1.0*	1.0
B14t02	Reservoir	8	*1100*	*1100*	150	150	150	*1.0*	*1.0*	1.0
B15t01	Tank	13	*525*	*525*	20	20	20	*4.5*	*4.5*	< 0.5
B16t01	Tank	9	*1150*	*1150*	70	70	70	*1.0*	*1.0*	0.5
B16t02	Tank	9	*1150*	*1150*	70	70	70	*1.0*	*1.0*	0.5
B16t03	Tank	9	*1150*	*1150*	70	70	70	*1.0*	*1.0*	0.5
B17a	Pump house	4	*1150*	*1150*	60	60	60	*1.0*	*1.0*	< 0.5
B17t01	Fire water tank	3	*1150*	*1150*	60	60	60	*1.0*	*1.0*	< 0.5
B18t01	Tank	5	*1150*	*1150*	60	60	60	*1.0*	*1.0*	< 0.5
F01b	Kiln	3	*1100*	*1100*	125	125	125	*1.5*	*1.5*	1.0

Table D.03 - Maximum Predicted Subsidence Parameters for the Building Structures

Ref.	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW307 (mm)*	Maximum Predicted Total Hogging Curvature based on the Extraction Plan Layout after LW307 (1/km)	*Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW317 (mm)*	Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW307 (mm)	*Maximum Predicted Total Sagging Curvature based on the Extraction Plan Layout after LW307 (1/km)*	Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW317 (mm)	*Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW307 (mm)*	*Predicted Total Conventional Tensile Strain based on the Extraction Plan Layout after LW307 (mm/m)*
A01a	*0.05*	*0.05*	< 0.01	*0.08*	*0.08*	< 0.01	*1.0*	*1.0*	< 0.5
A01b	*0.04*	*0.04*	< 0.01	*0.04*	*0.04*	< 0.01	*0.5*	*0.5*	< 0.5
A01c	*0.01*	*0.01*	< 0.01	*0.04*	*0.04*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
A01d	*0.01*	*0.01*	< 0.01	*0.04*	*0.04*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
A01e	*0.05*	*0.05*	< 0.01	*0.03*	*0.03*	< 0.01	*0.5*	*0.5*	< 0.5
A01f	*0.05*	*0.05*	< 0.01	*0.08*	*0.08*	< 0.01	*1.0*	*1.0*	< 0.5
A01g	*0.05*	*0.05*	< 0.01	*0.08*	*0.08*	< 0.01	*1.0*	*1.0*	< 0.5
A01h	*0.05*	*0.05*	< 0.01	*0.08*	*0.08*	< 0.01	*1.0*	*1.0*	< 0.5
A01i	*0.05*	*0.05*	< 0.01	*0.08*	*0.08*	< 0.01	*1.0*	*1.0*	< 0.5
A01j	*0.05*	*0.05*	< 0.01	*0.08*	*0.08*	< 0.01	*0.5*	*0.5*	< 0.5
A01k	*0.04*	*0.04*	< 0.01	*0.04*	*0.04*	< 0.01	*0.5*	*0.5*	< 0.5
A01l	*0.03*	*0.03*	< 0.01	*0.01*	*0.01*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
A01m	*0.04*	*0.04*	< 0.01	*0.13*	*0.13*	< 0.01	*0.5*	*0.5*	< 0.5
A02a	*0.05*	*0.05*	< 0.01	*0.13*	*0.13*	< 0.01	*0.5*	*0.5*	< 0.5
A02b	*0.05*	*0.05*	< 0.01	*0.09*	*0.09*	< 0.01	*0.5*	*0.5*	< 0.5
A03a	*0.03*	*0.03*	< 0.01	*0.13*	*0.13*	< 0.01	*0.5*	*0.5*	< 0.5
A03b	*0.04*	*0.04*	< 0.01	*0.13*	*0.13*	< 0.01	*0.5*	*0.5*	< 0.5
A03c	*0.05*	*0.05*	< 0.01	*0.12*	*0.12*	< 0.01	*0.5*	*0.5*	< 0.5
A03d	*0.05*	*0.05*	< 0.01	*0.12*	*0.12*	< 0.01	*0.5*	*0.5*	< 0.5
A04a	*0.02*	*0.02*	< 0.01	*0.12*	*0.12*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
A05a	*0.04*	*0.04*	< 0.01	*0.12*	*0.12*	< 0.01	*0.5*	*0.5*	< 0.5
A06a	*0.04*	*0.04*	< 0.01	*0.11*	*0.11*	< 0.01	*0.5*	*0.5*	< 0.5
A06b	*0.03*	*0.03*	< 0.01	*0.12*	*0.12*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
A07a	*0.04*	*0.04*	< 0.01	*0.11*	*0.11*	< 0.01	*0.5*	*0.5*	< 0.5
A08a	*0.04*	*0.04*	< 0.01	*0.04*	*0.04*	< 0.01	*0.5*	*0.5*	< 0.5
A08b	*0.04*	*0.04*	< 0.01	*0.09*	*0.09*	< 0.01	*0.5*	*0.5*	< 0.5
A08c	*0.04*	*0.04*	< 0.01	*0.03*	*0.03*	< 0.01	*0.5*	*0.5*	< 0.5
A08d	*0.04*	*0.04*	< 0.01	*0.05*	*0.05*	< 0.01	*0.5*	*0.5*	< 0.5
A08e	*0.02*	*0.02*	< 0.01	*0.12*	*0.12*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
A08f	*0.02*	*0.02*	< 0.01	*0.11*	*0.11*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
A09a	*0.03*	*0.03*	< 0.01	*0.06*	*0.06*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
A09b	*0.03*	*0.03*	< 0.01	*0.07*	*0.07*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
B01a	*0.03*	*0.03*	< 0.01	*0.05*	*0.05*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
B01b	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*0.5*	*0.5*	< 0.5

Table D.03 - Maximum Predicted Subsidence Parameters for the Building Structures

Ref.	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW307 (mm)*	Maximum Predicted Total Hogging Curvature based on the Extraction Plan Layout after LW307 (1/km)	*Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW317 (mm)*	Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW307 (mm)	*Maximum Predicted Total Sagging Curvature based on the Extraction Plan Layout after LW307 (1/km)*	Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW317 (mm)	*Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW307 (mm)*	*Predicted Total Conventional Tensile Strain based on the Extraction Plan Layout after LW307 (mm/m)*
B01c	*0.05*	*0.05*	< 0.01	*0.09*	*0.09*	< 0.01	*0.5*	*0.5*	< 0.5
B01d	*0.05*	*0.05*	< 0.01	*0.10*	*0.10*	< 0.01	*0.5*	*0.5*	< 0.5
B01e	*0.05*	*0.05*	< 0.01	*0.07*	*0.07*	< 0.01	*1.0*	*1.0*	< 0.5
B01f	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*0.5*	*0.5*	< 0.5
B01g	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*1.0*	*1.0*	< 0.5
B01h	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*0.5*	*0.5*	< 0.5
B01i	*0.05*	*0.05*	< 0.01	*0.05*	*0.05*	< 0.01	*0.5*	*0.5*	< 0.5
B01j	*0.03*	*0.03*	< 0.01	*0.01*	*0.01*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
B01k	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*0.5*	*0.5*	< 0.5
B01l	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*0.5*	*0.5*	< 0.5
B01m	*0.03*	*0.03*	< 0.01	*0.06*	*0.06*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
B01n	*0.03*	*0.03*	< 0.01	*0.07*	*0.07*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
B01o	*0.02*	*0.02*	< 0.01	*0.07*	*0.07*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
B01p	*0.03*	*0.03*	< 0.01	*0.08*	*0.08*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
B01q	*0.03*	*0.03*	< 0.01	*0.06*	*0.06*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
B01t01	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*0.5*	*0.5*	< 0.5
B01t02	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*0.5*	*0.5*	< 0.5
B01t03	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*1.0*	*1.0*	< 0.5
B02a	*0.04*	*0.04*	< 0.01	*0.05*	*0.05*	< 0.01	*0.5*	*0.5*	< 0.5
B02b	*0.05*	*0.05*	< 0.01	*0.05*	*0.05*	< 0.01	*1.0*	*1.0*	< 0.5
B02c	*0.05*	*0.05*	< 0.01	*0.13*	*0.13*	< 0.01	*1.0*	*1.0*	< 0.5
B02d	*0.05*	*0.05*	< 0.01	*0.03*	*0.03*	< 0.01	*0.5*	*0.5*	< 0.5
B02e	*0.05*	*0.05*	< 0.01	*0.03*	*0.03*	< 0.01	*1.0*	*1.0*	< 0.5
B02f	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*1.0*	*1.0*	< 0.5
B02g	*0.05*	*0.05*	< 0.01	*0.03*	*0.03*	< 0.01	*1.0*	*1.0*	< 0.5
B02h	*0.05*	*0.05*	< 0.01	*0.03*	*0.03*	< 0.01	*1.0*	*1.0*	< 0.5
B02i	*0.05*	*0.05*	< 0.01	*0.11*	*0.11*	< 0.01	*0.5*	*0.5*	< 0.5
B02j	*0.03*	*0.03*	< 0.01	*0.14*	*0.14*	< 0.01	*< 0.5*	*< 0.5*	< 0.5
B03a	*0.05*	*0.05*	< 0.01	*0.14*	*0.14*	< 0.01	*1.0*	*1.0*	< 0.5
B03b	*0.05*	*0.05*	< 0.01	*0.06*	*0.06*	< 0.01	*1.0*	*1.0*	< 0.5
B03c	*0.05*	*0.05*	< 0.01	*0.07*	*0.07*	< 0.01	*1.0*	*1.0*	< 0.5
B03d	*0.05*	*0.05*	< 0.01	*0.14*	*0.14*	< 0.01	*0.5*	*0.5*	< 0.5
B03e	*0.05*	*0.05*	< 0.01	*0.09*	*0.09*	< 0.01	*1.0*	*1.0*	< 0.5
B03f	*0.06*	*0.06*	< 0.01	*0.11*	*0.11*	< 0.01	*1.0*	*1.0*	< 0.5
B03g	*0.06*	*0.06*	< 0.01	*0.08*	*0.08*	< 0.01	*1.0*	*1.0*	< 0.5

Table D.03 - Maximum Predicted Subsidence Parameters for the Building Structures

Ref.	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW317 (mm)*	*Maximum Predicted Total Hogging Curvature based on the Preferred Project Layout after LW307 (mm)*	Maximum Predicted Total Hogging Curvature based on the Extraction Plan Layout after LW307 (1/km)	*Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW317 (mm)*	Maximum Predicted Total Sagging Curvature based on the Preferred Project Layout after LW307 (mm)	*Maximum Predicted Total Sagging Curvature based on the Extraction Plan Layout after LW307 (1/km)*	Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW317 (mm)	*Maximum Predicted Total Tensile Strain based on the Preferred Project Layout after LW307 (mm)*	*Predicted Total Conventional Tensile Strain based on the Extraction Plan Layout after LW307 (mm/m)*
B03h	0.06	0.06	< 0.01	0.14	0.14	< 0.01	1.0	1.0	< 0.5
B03i	0.05	0.05	< 0.01	0.11	0.11	< 0.01	1.0	1.0	< 0.5
B03j	0.02	0.02	< 0.01	0.09	0.09	< 0.01	< 0.5	< 0.5	< 0.5
B03k	0.02	0.02	< 0.01	0.14	0.14	< 0.01	< 0.5	< 0.5	< 0.5
B03l	0.02	0.02	< 0.01	0.14	0.14	< 0.01	< 0.5	< 0.5	< 0.5
B04a	0.03	0.03	< 0.01	0.10	0.10	< 0.01	< 0.5	< 0.5	< 0.5
B05a	0.03	0.03	< 0.01	0.08	0.08	< 0.01	0.5	0.5	< 0.5
B06a	0.03	0.03	< 0.01	0.05	0.05	< 0.01	< 0.5	< 0.5	< 0.5
B06b	0.03	0.03	< 0.01	0.01	0.01	< 0.01	< 0.5	< 0.5	< 0.5
B07a	0.03	0.03	< 0.01	0.03	0.03	< 0.01	< 0.5	< 0.5	< 0.5
B08a	0.03	0.03	< 0.01	0.02	0.02	< 0.01	< 0.5	< 0.5	< 0.5
B09a	0.03	0.03	< 0.01	0.02	0.02	< 0.01	< 0.5	< 0.5	< 0.5
B09b	0.03	0.03	< 0.01	0.01	0.01	< 0.01	< 0.5	< 0.5	< 0.5
B10a	0.02	0.02	0.01	0.07	0.07	< 0.01	< 0.5	< 0.5	< 0.5
B10b	0.02	0.02	0.01	0.07	0.07	< 0.01	< 0.5	< 0.5	< 0.5
B11a	0.02	0.02	0.02	0.02	0.02	< 0.01	< 0.5	< 0.5	< 0.5
B11b	0.01	0.01	0.03	0.03	0.03	< 0.01	< 0.5	< 0.5	< 0.5
B11c	0.02	0.02	0.02	0.02	0.02	< 0.01	< 0.5	< 0.5	< 0.5
B12a	0.05	0.05	0.03	0.05	0.05	< 0.01	0.5	0.5	0.5
B14t01	0.03	0.03	< 0.01	0.02	0.02	< 0.01	< 0.5	< 0.5	< 0.5
B14t02	0.02	0.02	0.01	0.02	0.02	< 0.01	< 0.5	< 0.5	< 0.5
B15t01	0.03	0.03	< 0.01	0.01	0.01	< 0.01	< 0.5	< 0.5	< 0.5
B16t01	0.03	0.03	< 0.01	0.01	0.01	< 0.01	< 0.5	< 0.5	< 0.5
B16t02	0.04	0.04	< 0.01	0.05	0.05	< 0.01	0.5	0.5	< 0.5
B16t03	0.05	0.05	< 0.01	0.08	0.08	< 0.01	0.5	0.5	< 0.5
B17a	0.03	0.03	< 0.01	0.01	0.01	< 0.01	< 0.5	< 0.5	< 0.5
B17t01	0.03	0.03	< 0.01	0.01	0.01	< 0.01	< 0.5	< 0.5	< 0.5
B18t01	0.03	0.03	< 0.01	0.01	0.01	< 0.01	< 0.5	< 0.5	< 0.5
F01b	0.02	0.02	< 0.01	0.04	0.04	< 0.01	< 0.5	< 0.5	< 0.5

Note: Predicted conventional strains are based on 15 times curvature

APPENDIX E. DRAWINGS

I:\Projects\Metropolitan\MSEC1057 - LW305 to 307 Extraction Plan\AcadData\MSEC1057-01 General Layout.dwg

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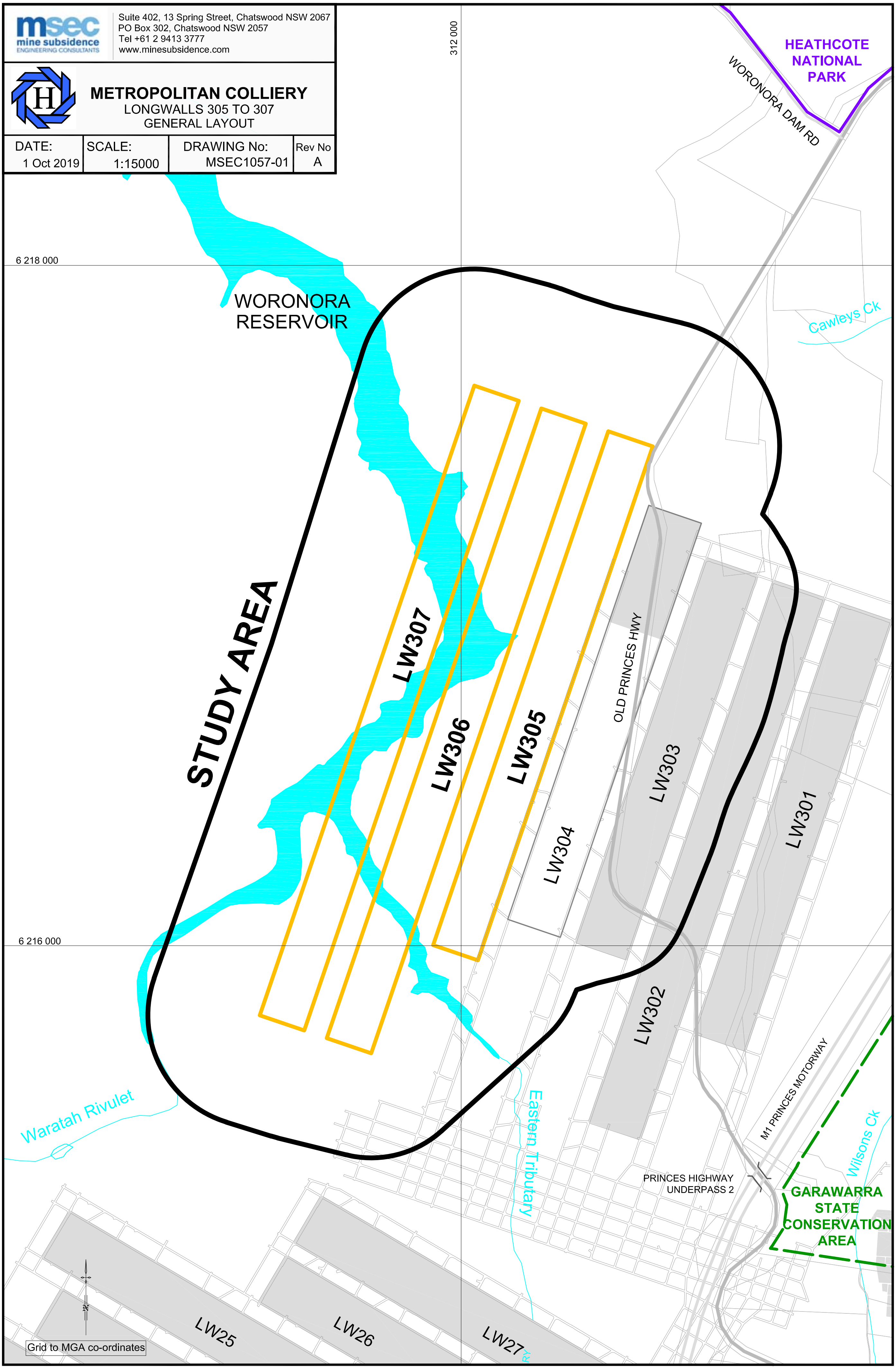
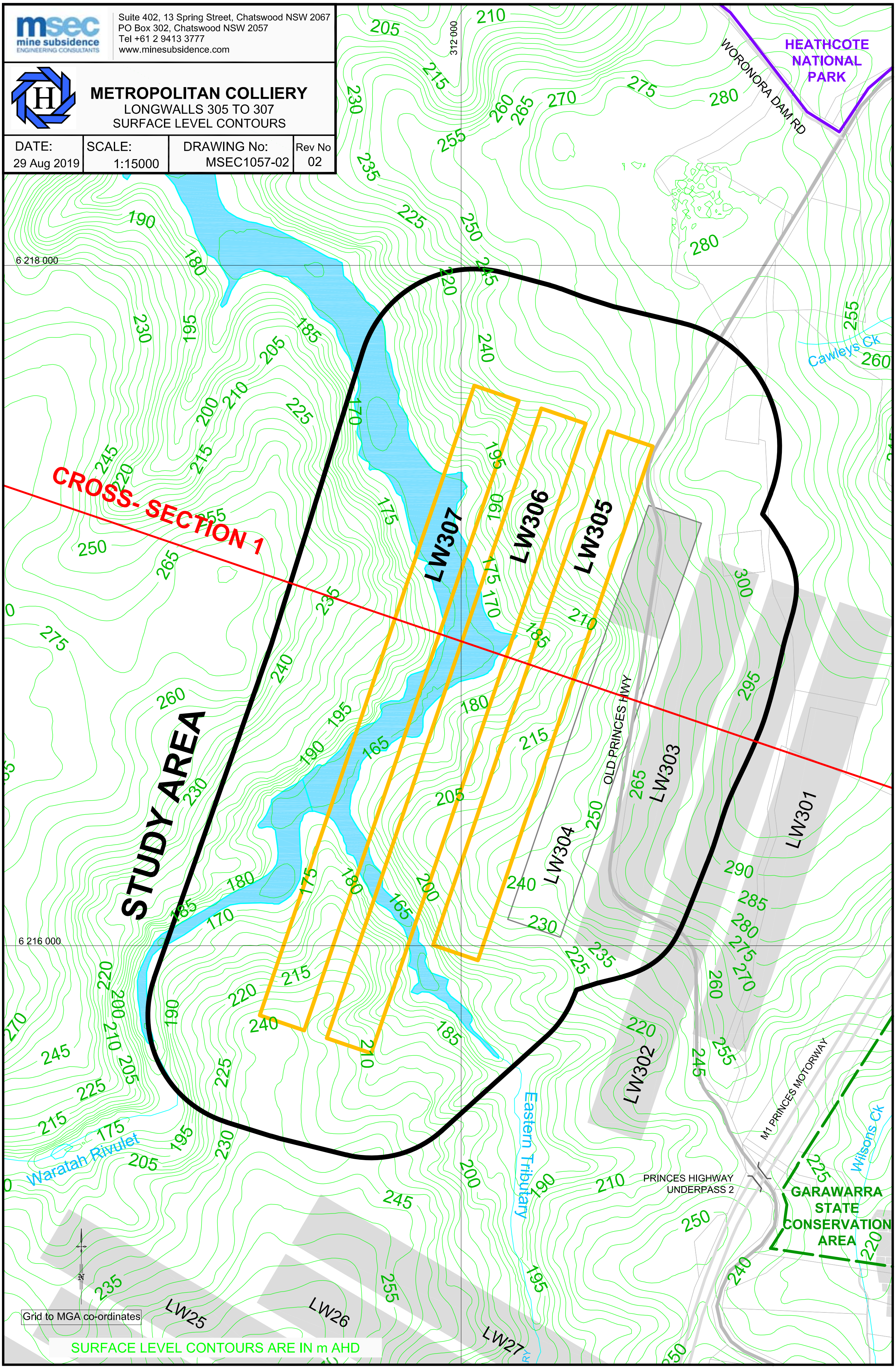
METROPOLITAN COLLIERY
LONGWALLS 305 TO 307
GENERAL LAYOUT

DATE:	SCALE:	DRAWING No:	Rev No
1 Oct 2019	1:15000	MSEC1057-01	A




msec mine subsidence ENGINEERING CONSULTANTS
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PO Box 302, Chatswood NSW 2057
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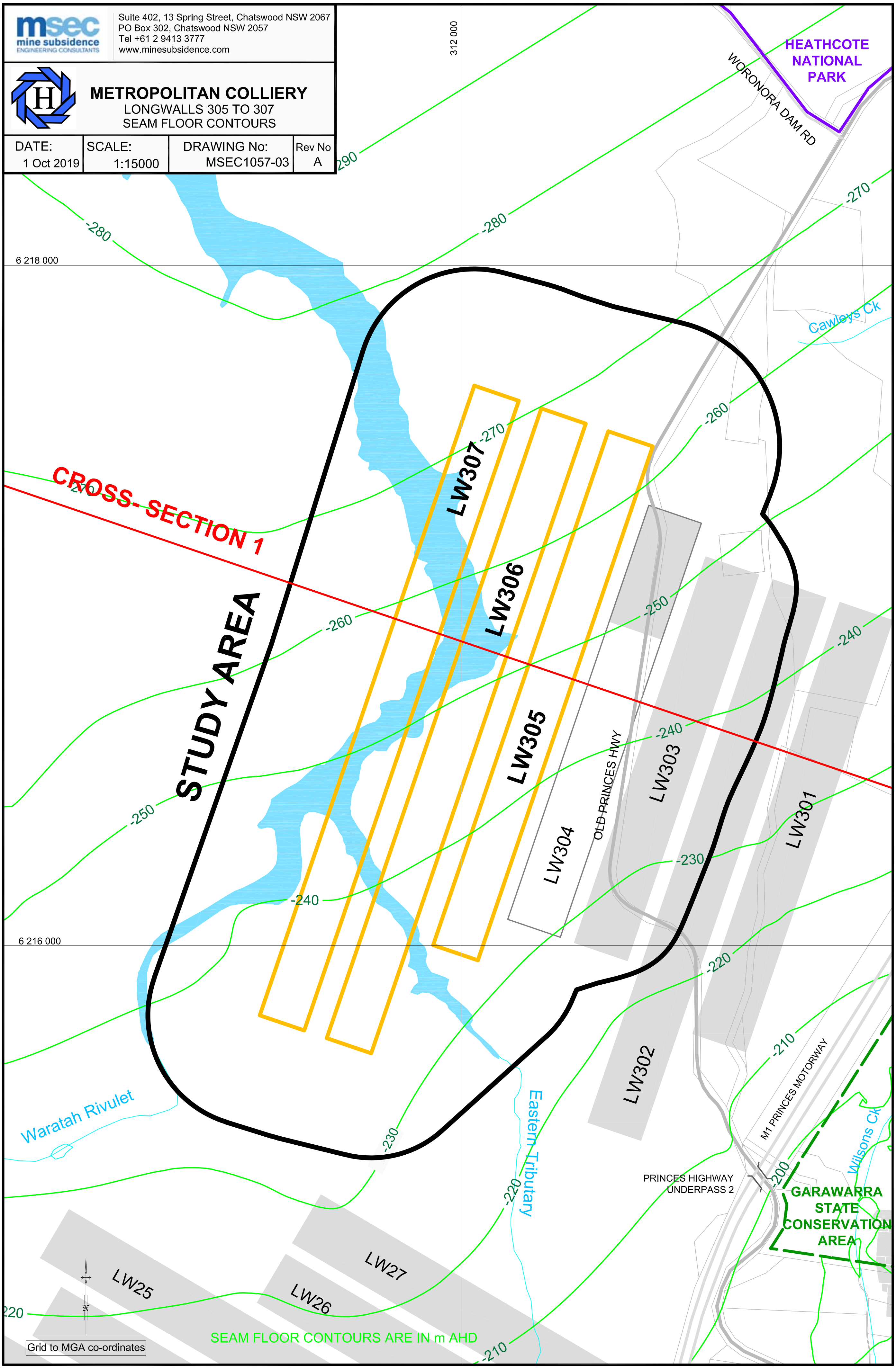
METROPOLITAN COLLIERY
LONGWALLS 305 TO 307
SURFACE LEVEL CONTOURS
DATE: 29 Aug 2019
SCALE: 1:15000
DRAWING No: MSEC1057-02
Rev No 02
HEATHCOTE NATIONAL PARK
WORONORA DAM RD
Cawleys Ck
CROSS- SECTION 1
STUDY AREA
LW307
LW306
LW305
LW304
LW303
LW302
LW301
OLD PRINCES HWY
M1 PRINCES MOTORWAY
PRINCES HIGHWAY UNDERPASS 2
GARAWARRA STATE CONSERVATION AREA
Wilsons Ck
Eastern Tributary
Waratah Rivulet
LW25
LW26
LW27
6 218 000
6 216 000
312 000
Grid to MGA co-ordinates
SURFACE LEVEL CONTOURS ARE IN m AHD

I:\Projects\Metropolitan\MSEC1057 - LW305 to 307 Extraction Plan\AcadData\MSEC1057-03 Seam Floor Contours.dwg



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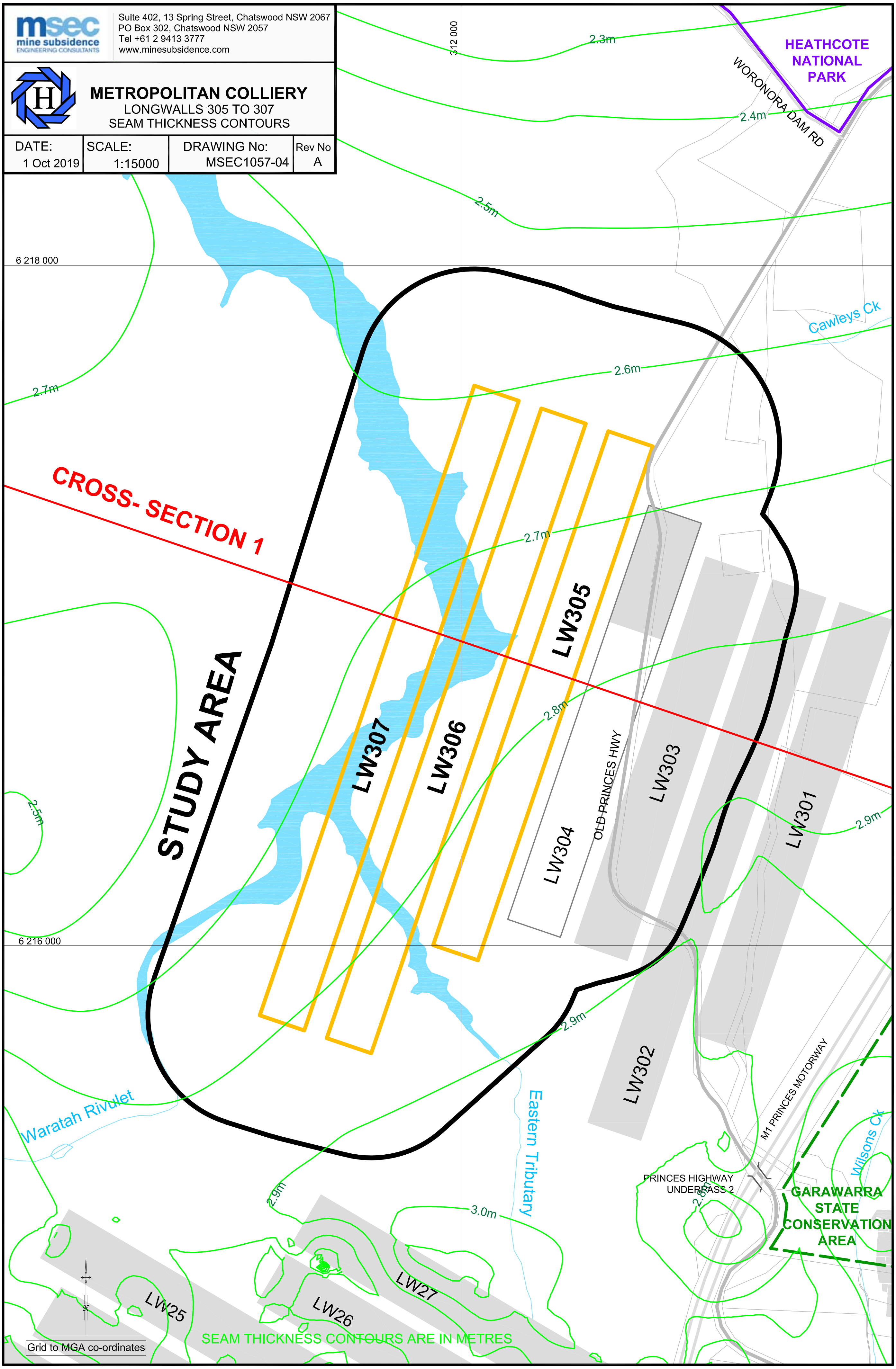
METROPOLITAN COLLIERY
LONGWALLS 305 TO 307
SEAM THICKNESS CONTOURS

DATE:	SCALE:	DRAWING No:	Rev No
1 Oct 2019	1:15000	MSEC1057-04	A



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METROPOLITAN COLLIERY
LONGWALLS 305 TO 307
DEPTH OF COVER CONTOURS

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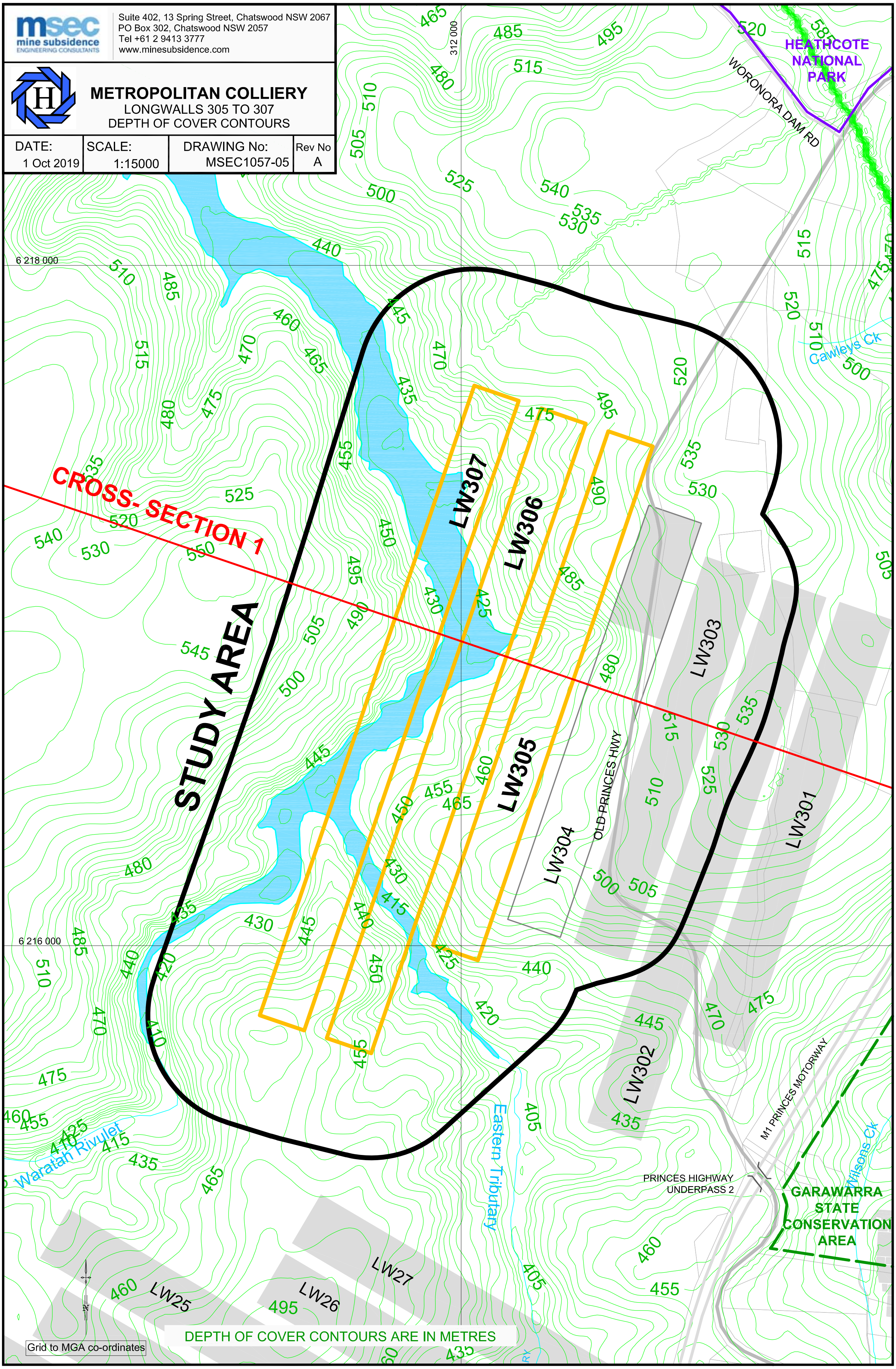

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METROPOLITAN COLLIERY
LONGWALLS 305 TO 307
GEOLOGY

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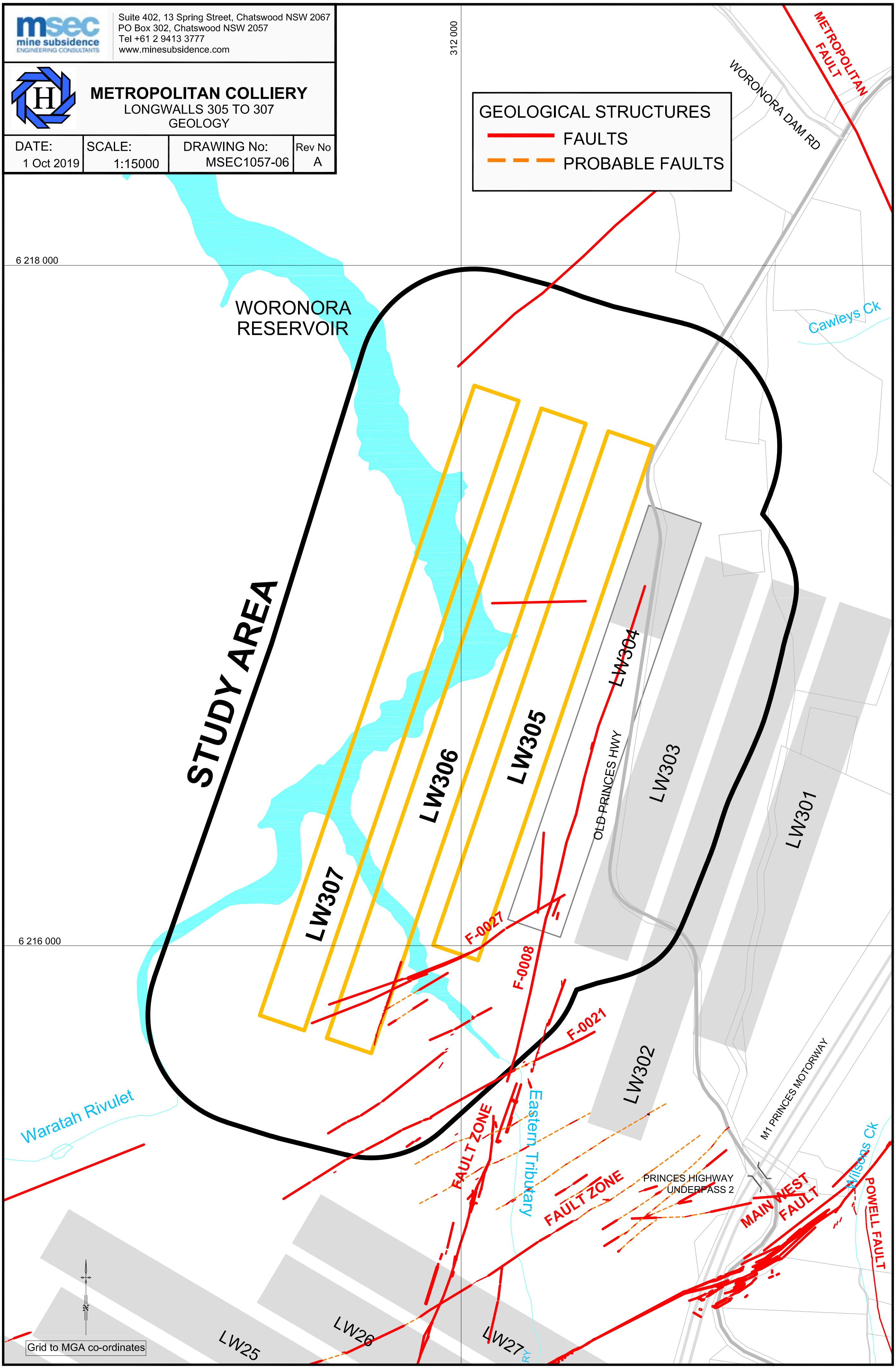

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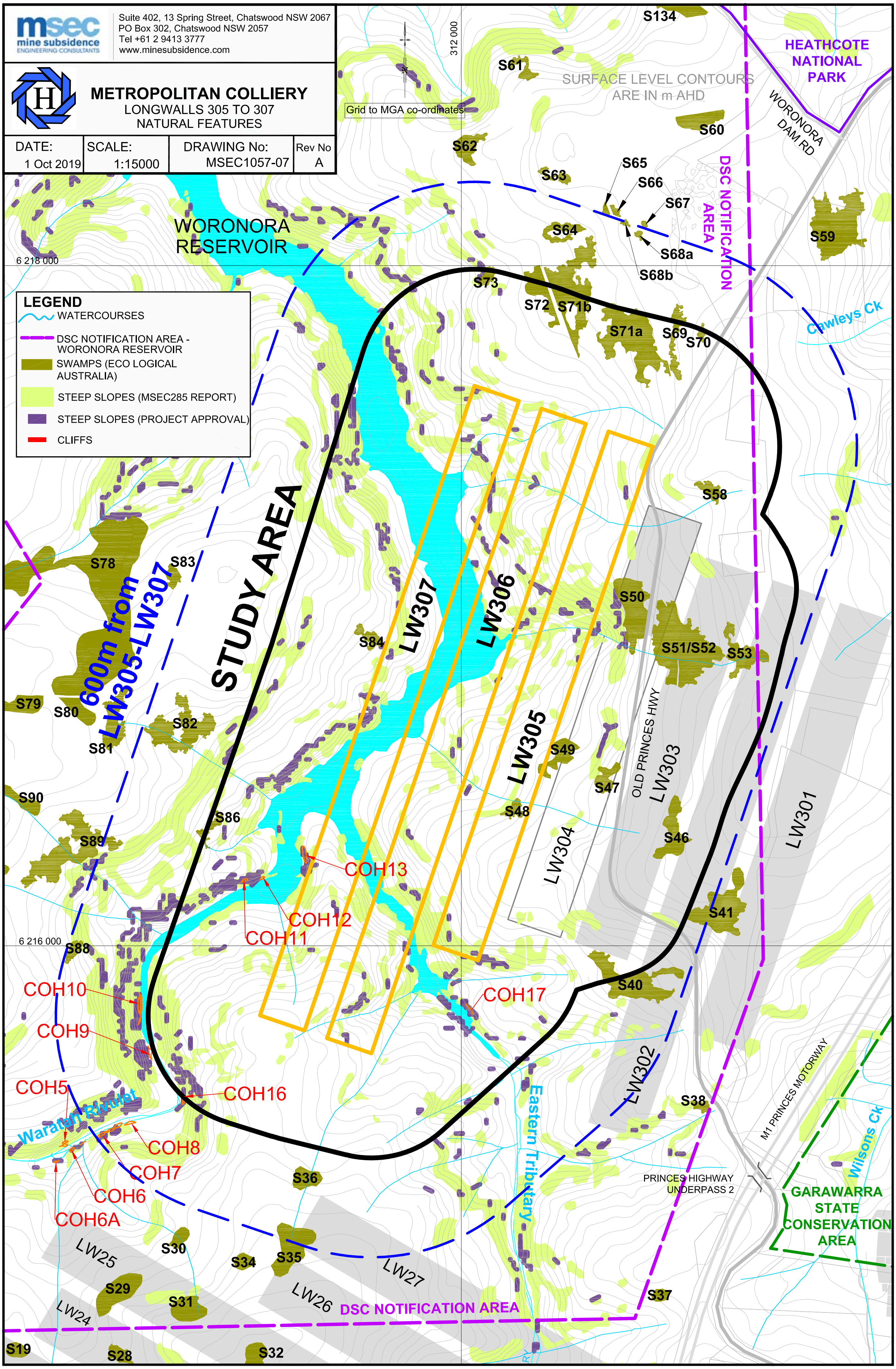

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METROPOLITAN COLLIERY
LONGWALLS 305 TO 307
SURFACE INFRASTRUCTURE

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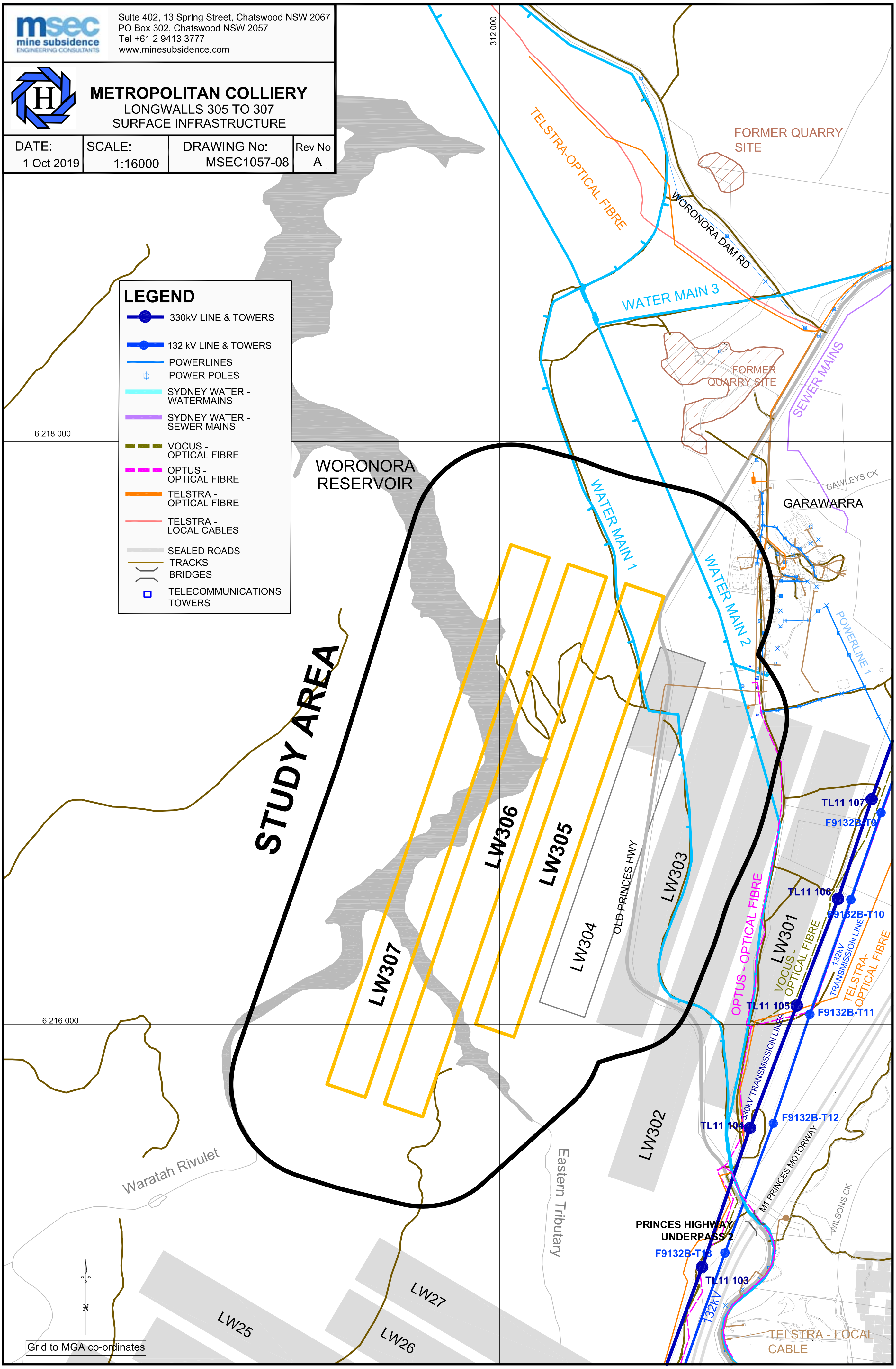
1 Oct 2019	1:16000	MSEC1057-08	A



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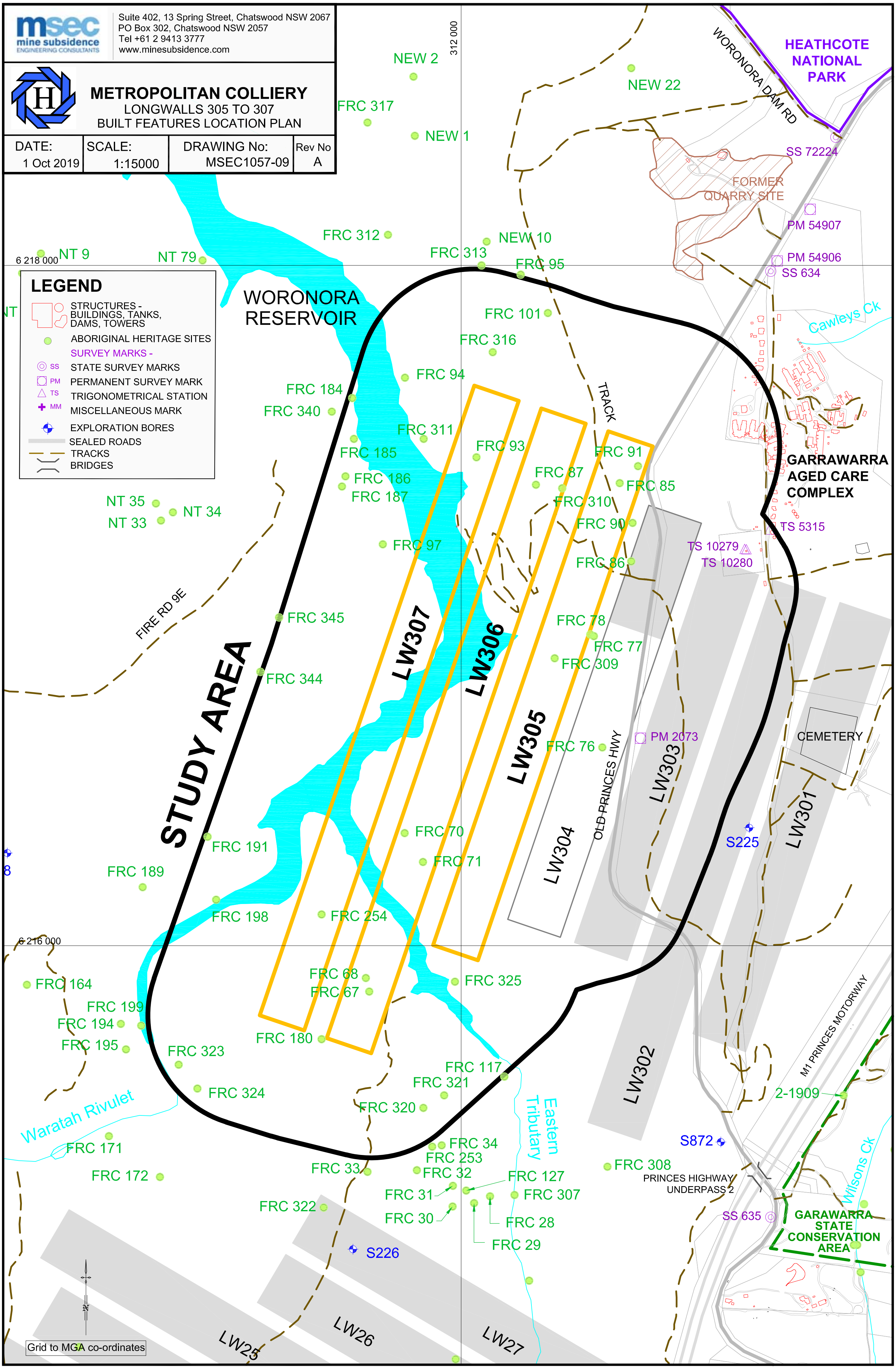

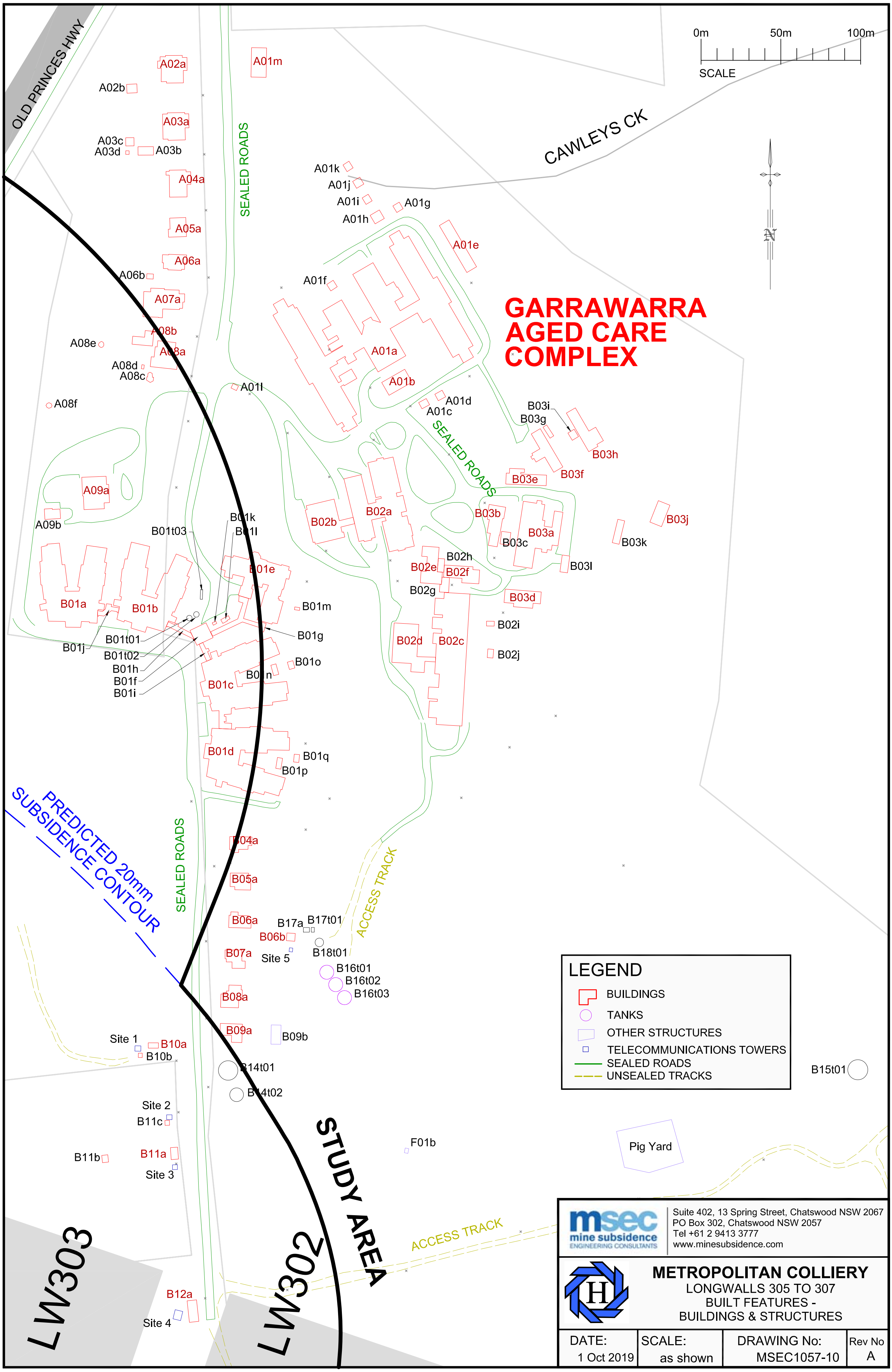
0m
50m
100m
SCALE
OLD PRINCES HWY
CAWLEYS CK
N
GARRAWARRA AGED CARE COMPLEX
SEALED ROADS
SEALED ROADS
SEALED ROADS
ACCESS TRACK
ACCESS TRACK
PREDICTED 20mm SUBSIDENCE CONTOUR
STUDY AREA
LW303
LW302
A01m
A02a
A02b
A03a
A03b
A03c
A03d
A04a
A05a
A06a
A06b
A07a
A08a
A08b
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A08f
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B11c
B12a
B14t01
B14t02
B15t01
B16t01
B16t02
B16t03
B17a
B17t01
B18t01
F01b
Site 1
Site 2
Site 3
Site 4
Site 5
Pig Yard
LEGEND
BUILDINGS
TANKS
OTHER STRUCTURES
TELECOMMUNICATIONS TOWERS
SEALED ROADS
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METROPOLITAN COLLIERY
LONGWALLS 305 TO 307
PREDICTED TOTAL SUBSIDENCE
CONTOURS AFTER LW307

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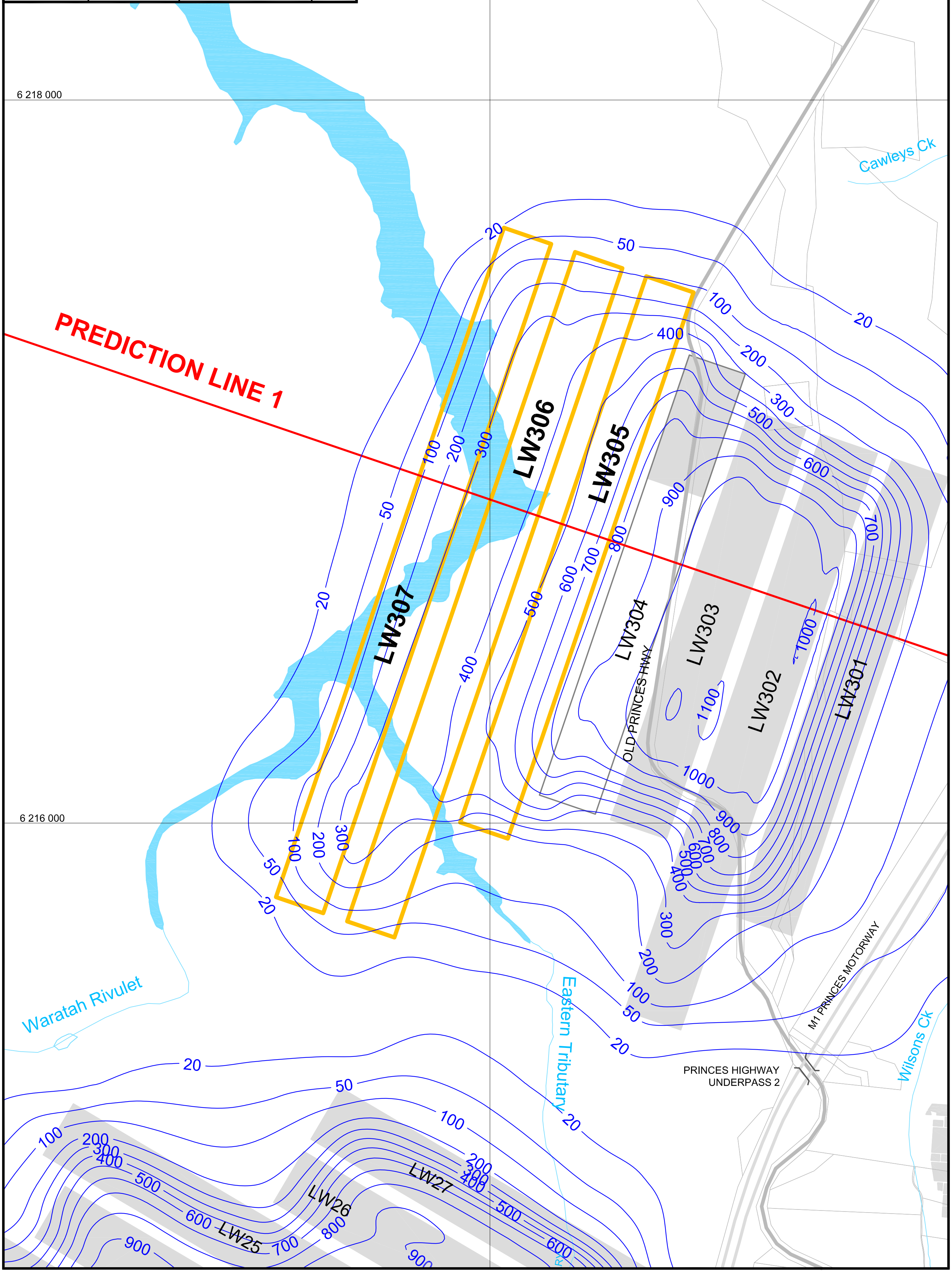


APPENDIX F. ATTACHMENT 1

RE: Subsidence predictions along the Waratah Rivulet based on the Extraction Plan Layout for extraction of Longwalls 305 to 314

Subsidence predictions along the Waratah Rivulet based on the Extraction Plan Layout, for extraction of Longwalls 305 to 314 are provided below.

Table A1 presents the geometry of the longwalls for the Extraction Plan Layout. The geometry of Longwalls 304 to 307 for the Extraction Plan is described in Section 1.1 of the main text of this report. The layout of Longwalls 308 to 314 is consistent with the currently approved layout (i.e. rotated Preferred Project Layout approved April 2015). The layouts of Longwalls 308 to 314 will however be subject to review, assessment and approval in future Extraction Plans.

Table A1 Geometry of the Extraction Plan Layout

Longwall	Overall Void Length Including Installation Heading (m)	Overall Void Width Including First Workings (m)	Overall Tailgate Chain Pillar Width (m)
LW308	3,118	138	70
LW309	3,118	138	70
LW310	3,118	138	70
LW311	3,230	138	70
LW312	3,230	138*/163	70*/45
LW313	3,330	138*/163	70*/45
LW314	3,330	138*/163	70*/45

* Reduced longwall void width and increased pillar width within 500 m of Woronora Reservoir.

Predicted conventional and valley related effects for the Waratah Rivulet for extraction to Longwall 314

The predicted profiles of total vertical subsidence, upsidence and closure for the Waratah Rivulet based on longwall extraction to Longwall 314 for the Extraction Plan Layout are shown in the attached Fig. A01. The predicted profiles after the completion of Longwall 304 are shown as light blue lines. The predicted profiles after the completion of Longwalls 305 to 307 are shown as blue lines and the predicted profiles after the completion of Longwalls 308 to 314 are shown as green lines.

A plan view summary of the predicted total closure at rock bars for the Extraction Plan Layout to Longwall 314 is provided in the attached Fig. A02.

Variations in the magnitude of predicted closure up to approximately 20 mm between layouts is considered to be within the accuracy of the valley closure prediction model.

Predicted Profiles of Subsidence, Upsidence and Closure along the Waratah Rivulet due to LW305 to 314

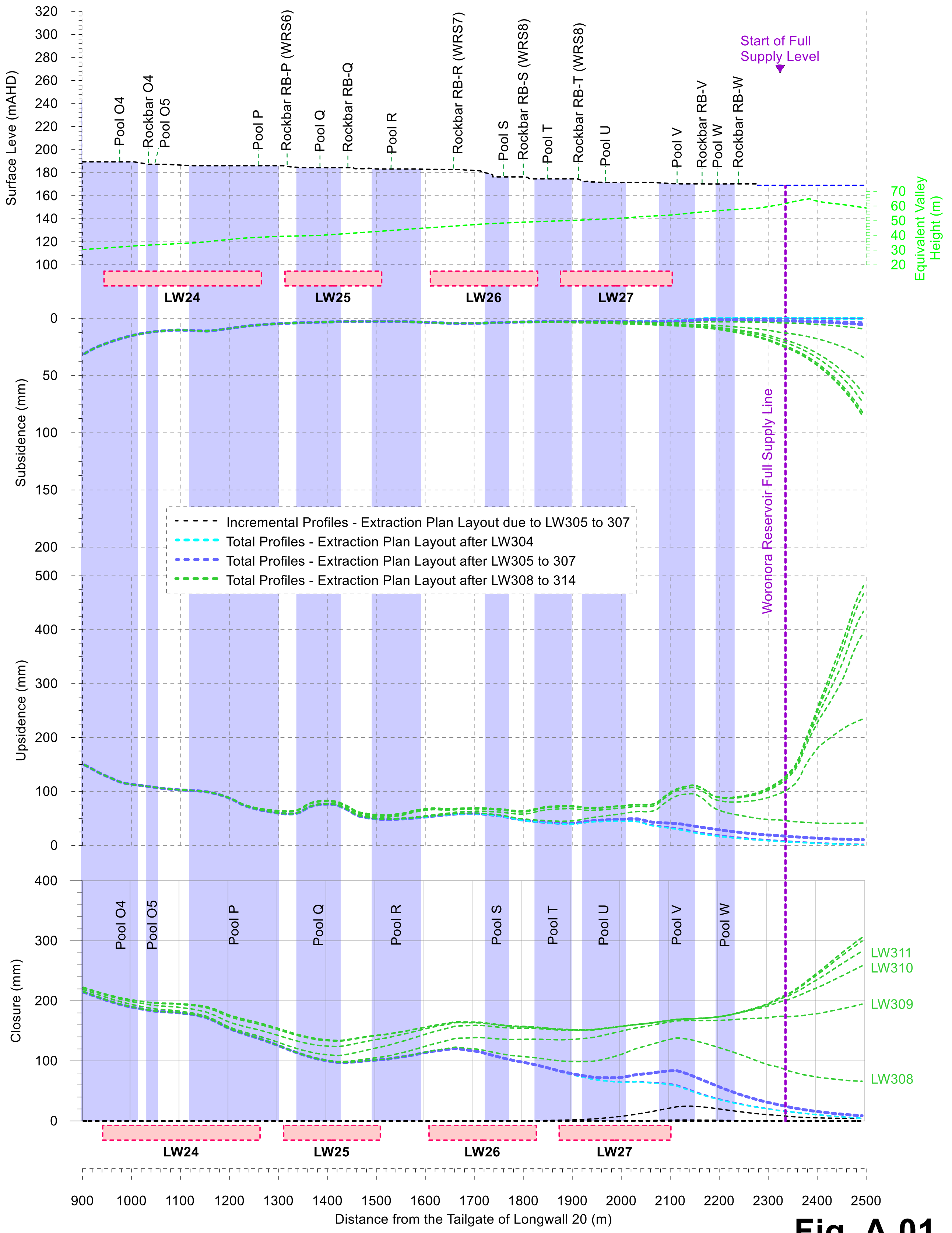
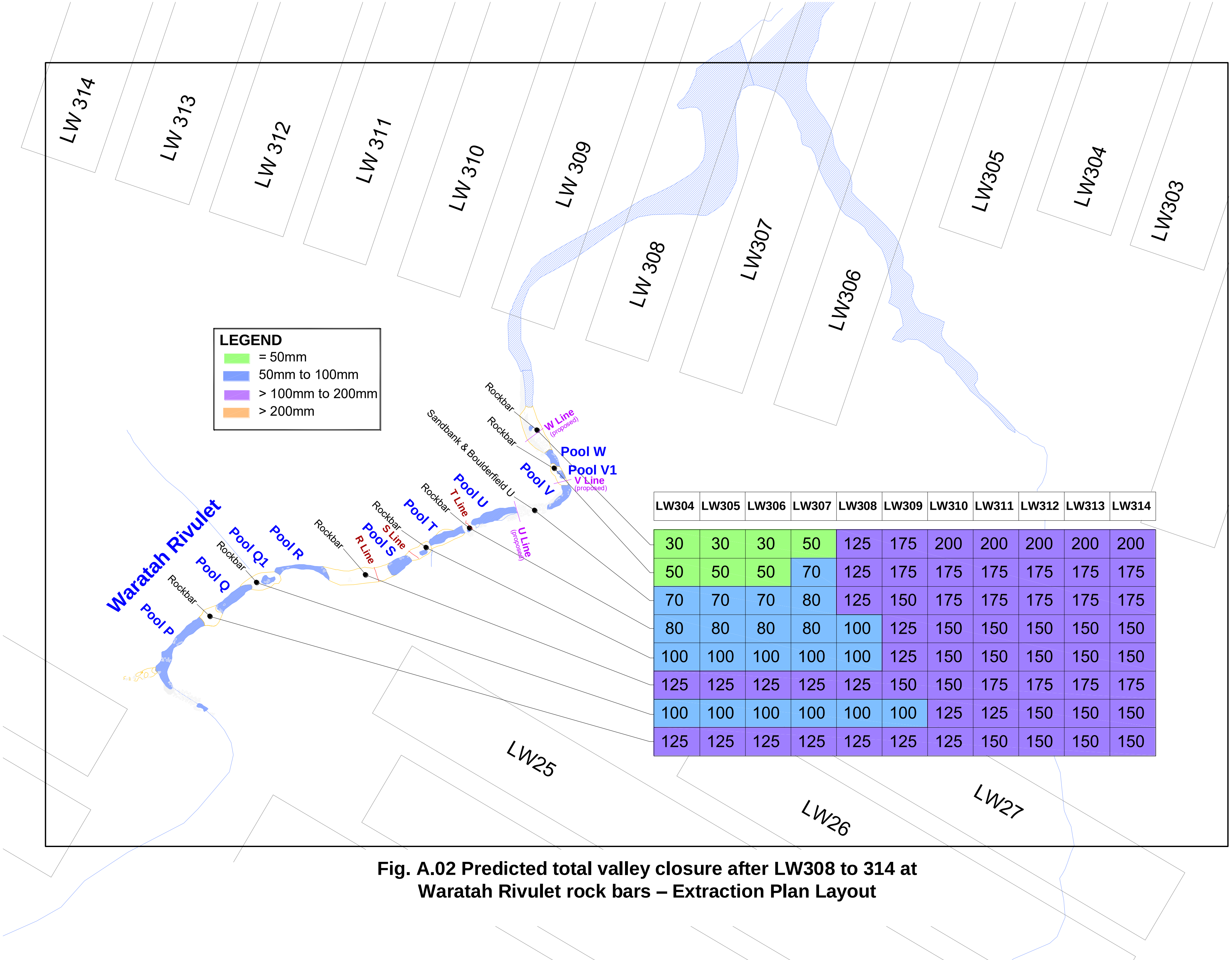


Fig. A.01



LW304	LW305	LW306	LW307	LW308	LW309	LW310	LW311	LW312	LW313	LW314
30	30	30	50	125	175	200	200	200	200	200
50	50	50	70	125	175	175	175	175	175	175
70	70	70	80	125	150	175	175	175	175	175
80	80	80	80	100	125	150	150	150	150	150
100	100	100	100	100	125	150	150	150	150	150
125	125	125	125	125	150	150	175	175	175	175
100	100	100	100	100	100	125	125	150	150	150
125	125	125	125	125	125	125	150	150	150	150

Fig. A.02 Predicted total valley closure after LW308 to 314 at Waratah Rivulet rock bars – Extraction Plan Layout