WAMBO COAL PTY LTD

NORTH WAMBO UNDERGROUND MINE MODIFICATION

ENVIRONMENTAL ASSESSMENT

APPENDIX A

SUBSIDENCE ASSESSMENT

WAMBO COAL:

North Wambo Underground Modification Subsidence Assessment

Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Environmental Assessment for a Section 75W Modification Application for the Proposed Longwalls 9 and 10 in the Wambo Seam

DOCUMENT REGISTER

Revision	Description	Author	Checker	Date
01	Draft Issue	JB	-	31st Aug 12
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B	Minor Updates	JB	PA	17th Oct 12
C	Minor Updates	JB	PA	26th Oct 12

Report produced to:- Support the Environmental Assessment prepared for a Section 75W Modification Application for submission to the Department of Planning and Infrastructure.

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

Introduction to Longwall Mining and Subsidence (Revision A)

General Discussion of Mine Subsidence Ground Movements (Revision A)

Mine Subsidence Damage to Building Structures (Revision A)

EXECUTIVE SUMMARY

Wambo Coal Pty Limited (WCPL) operates the North Wambo Underground Mine (NWUM), which is located in the Hunter Coalfield of New South Wales. WCPL is seeking approval to modify the Wambo Development Consent (DA 305-7-2003) under Section 75W of the *Environmental Planning and Assessment Act 1979* (EP&A Act), by extracting two additional longwalls in the Wambo Seam, referred to as WMLW9 and WMLW10.

Mine Subsidence Engineering Consultants (MSEC) has been commissioned by WCPL to:-

- provide subsidence predictions for the approved and proposed longwalls in the Wambo Seam and the future longwalls in the Arrowfield and Bowfield Seams,
- compare the subsidence predictions with those previously provided in the Wambo Seam Underground Modification Statement of Environmental Effects (WCPL, 2005),
- identify the natural and built features located above and in the vicinity of the proposed longwalls, and to
- provide subsidence predictions and impact assessments, in conjunction with other specialist consultants, for these natural and built features.

This report has been prepared to support the Modification Application to be submitted to the Department of Planning and Infrastructure.

The predicted subsidence for the proposed longwalls has been determined using the Incremental Profile Method, which has calibrated for multi-seam mining conditions using the available monitoring data from the NWUM and from elsewhere in the NSW Coalfields. The maximum predicted additional subsidence, due to the extraction of the proposed Longwalls WMLW9 and WMLW10, is 2600 mm which represents 100 % of the proposed extraction height.

The Study Area has been defined, as a minimum, as the surface area enclosed by a 26.5 degree angle of draw line from the extents of proposed WMLW9 and WMLW10 and by the predicted additional 20 mm subsidence contour resulting from the extraction of the proposed longwalls. Other features which could be subjected to far-field or valley related movements and could be sensitive to such movements have also been assessed in this report.

A number of natural and built features have been identified within or in the vicinity of the Study Area, including Wollombi Brook and associated alluvium, North Wambo, Wambo and Stony Creeks, unsealed roads, 11 kilovolt (kV) powerlines, water pipelines, fences, farm dams, exploration bores, a water storage dam and archaeological sites. The land directly above the proposed longwalls has generally been cleared and is used for light grazing.

The assessments and recommendations provided in this report should be read in conjunction with those provided in the reports by other specialist consultants on the project. The main findings from this report are as follows:-

- Wollombi Brook is located 450 metres east of WMLW10, at its closest point to the proposed longwalls. At this distance, the brook is not expected to experience any measurable tilts, curvatures or strains. In addition to this, the predicted additional 20 mm subsidence contour, due to the extraction of the proposed WMLW9 and WMLW10, is located well outside the mapped limit of alluvium for the brook.

  It is unlikely, therefore, that Wollombi Brook or the associated alluvium would be adversely impacted as a result of the extraction of the proposed WMLW9 and WMLW10. That is, the potential impacts on the brook, based on the *Modified Layout*, are the same as those assessed based on the *Approved Layout*.

  Further discussions on the potential impacts on the alluvial aquifer associated with Wollombi Brook are provided in the report by *Heritage Computing* (2012).

  It is recommended that monitoring should be established, where the proposed longwalls are closest to the brook, which could include the installation of additional piezometers to measure the groundwater levels, and ground monitoring lines to measure the actual limit of vertical subsidence.

- North Wambo and Wambo Creeks are located at distances of 190 metres from WMLW9 and WMLW10, respectively, at their closest points to the proposed longwalls. Whilst these creeks could experience very low levels of subsidence, they are not expected to experience any measurable tilts, curvatures or strains resulting from the extraction of the proposed longwalls.

  Stony Creek is also located outside the extents of the proposed longwalls, but it is situated immediately adjacent to the southern corner of the proposed WMLW10. The creek could experience small additional subsidence in the vicinity of the proposed longwalls, however, this is negligible when compared with the total subsidence where the creek is located directly above the longwalls in the Wambo, Arrowfield and Bowfield Seams further upstream.

  The potential impacts on North Wambo, Wambo and Stony Creeks, based on the *Modified Layout*, are the same as those assessed based on the *Approved Layout*.

  Management strategies have previously been developed for the sections of the creeks which have already been directly mined beneath at the NWUM. It is recommended that the existing management strategies for the creeks be reviewed and, where required, are revised to include the affects of the proposed longwalls.

- There were no steep slopes identified within the Study Area, apart from the localised areas around the creek banks and the walls of the farm dams and water storage dam. The Wollemi Escarpment is located at a distance greater than 1 kilometre west of the proposed longwalls, at its closest point.

- The unsealed roads used for the mining operations are located across the Study Area. It is expected that these roads could be maintained in safe and serviceable conditions using normal road maintenance techniques. It is recommended that these roads are visually monitored during active subsidence.

- The water pipelines are shallow buried or resting on the natural ground and supply water for mining activities. Any impacts on these polyethylene pipelines are expected to be of a minor nature which could be readily remediated. It is recommended that these pipelines are visually monitored during active subsidence.

- The 11 kV powerlines are located across the Study Area. It is expected that these powerlines could be maintained in safe and serviceable conditions with the implementation of the necessary management strategies, which could include the installation of cable rollers, guy wires or additional poles, or the adjustment of cable catenaries.

  It is recommended that the appropriate preventive measures are established for the powerlines prior to the longwalls mining directly beneath them. Also, the powerlines should be visually monitored during active subsidence.

- Farm dams are located across the Study Area. It is expected that the potential impacts on the dams could be remediated, if required, by excavating and re-establishing cohesive material in the beds of the farm dams to reduce permeability. It is recommended that the farm dams are visually monitored during active subsidence.

- The South Wambo Dam is owned by WCPL and supplies water for mining activities. The dam is located directly above the proposed longwalls and has been approved by the NSW Dams Safety Committee.

  It will be necessary to develop management strategies for the dam, which could include lowering the water level or completely draining the dam prior to directly mining beneath it. It is recommended that a ground monitoring line be established, following the base of the dam wall, to measure the actual subsidence movements and to detect any localised or irregular ground movements.

- The archaeological sites within the Study Area comprise artefact scatters, isolated finds and a scarred tree. Surface cracking due to mine subsidence is unlikely to adversely affect the artefact scatters or isolated finds themselves. It has also been found, from past longwall mining experience, that the incidence of impacts on trees is extremely rare where the depths of cover and natural grades are similar to those within the Study Area.

The assessments provided in this report indicate that the levels of impact on the natural and built features can be managed by the preparation and implementation of the appropriate management strategies. It should be noted, however, that more detailed assessments of some natural and built features have been undertaken by other specialist consultants, and the findings in this report should be read in conjunction with the findings in all other relevant reports.

The appropriate management strategies and monitoring for the natural and built features will be developed during the Extraction Plan stage for the proposed longwalls.

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Tables

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

Figures

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

Drawings

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

1.0 INTRODUCTION

1.1. Background

Wambo Coal Pty Limited (WCPL) operates the North Wambo Underground Mine (NWUM), which is located in the Hunter Coalfield of New South Wales. The mine was approved under Part 4 of the *Environmental Planning and Assessment Act 1979*, in February 2004, which included the extraction of eight longwalls in the Wambo Seam, referred to as WMLW1 to WMLW8 in this report, and 13 longwalls in each of the Arrowfield and Bowfield Seams, referred to as AFLW1 to AFLW13 and BFLW1 to BFLW13 in this report.

Subsequently, the longwalls in the Wambo Seam were re-orientated, which was addressed in the Wambo Seam Underground Modification Statement of Environmental Effects (WCPL, 2005). The mining layout indicated in this application, including the longwalls in the Wambo, Arrowfield and Bowfield Seams, is referred to as the *Approved Layout* in this report.

WCPL is seeking approval to modify the Wambo Development Consent (DA 305-7-2003) under Section 75W of the *Environmental Planning and Assessment Act 1979* (EP&A Act), by extracting two additional longwalls in the Wambo Seam, referred to as WMLW9 and WMLW10. The mining layout including the approved and proposed longwalls in the Wambo Seam, as well as the future longwalls in the Arrowfield and Bowfield Seams, is referred to as the *Modified Layout* in this report.

The locations of the approved and proposed longwalls in the Wambo Seam are shown in Drawing No. MSEC495-01, which together with all other drawings, is included in Appendix F at the end of this report. The longwalls are located beneath the existing Homestead/Wollemi workings in the overlying Whybrow Seam, which are also shown in this drawing. The future longwalls in the underlying Arrowfield and Bowfield Seams are indicated in Drawing No. MSEC495-02.

Mine Subsidence Engineering Consultants (MSEC) has been commissioned by WCPL to:-

- provide subsidence predictions for the approved and proposed longwalls in the Wambo Seam and the future longwalls in the Arrowfield and Bowfield Seams, based on the *Modified Layout*,
- compare the subsidence predictions, based on the *Modified Layout*, with those previously provided in the Wambo Seam Underground Modification Statement of Environmental Effects (2005 SEE), based on the *Approved Layout*,
- identify the natural and built features located above and in the vicinity of the proposed longwalls,
- provide subsidence predictions for these natural and built features, based on the *Modified Layout*,
- compare the subsidence predictions for the natural and built features, based on the *Modified Layout*, with those previously provided in the 2005 SEE, based on the *Approved Layout*, and to
- provide impact assessments, in conjunction with other specialist consultants, for each of these natural and built features, based on the *Modified Layout*.

This report has been prepared to support the Modification Application to be submitted to the Department of Planning and Infrastructure.

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

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

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

Chapter 4 provides the maximum predicted subsidence parameters resulting from the extraction of the approved, proposed and future longwalls, based on the *Modified Layout*, and compares these with the parameters predicted based on the *Approved Layout*.

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

The proposed WMLW9 and WMLW10 and the Study Area, as defined in Section 2.1, have been overlaid on an orthophoto of the area, which is shown in Fig. 1.1. The major natural and built features in the vicinity of the proposed longwalls are indicated in this figure.

Fig. 1.1 Aerial Photograph Showing Locations of the Proposed WMLW9 and WMLW10

1.2. Mining Geometry

The longwalls WMLW9 and WMLW10 are proposed to be extracted in the Wambo Seam immediately to the south-east of the approved WMLW1 to WMLW8. The longwalls in the Wambo Seam are being extracted beneath the existing Homestead/Wollemi workings in the overlying Whybrow Seam.

The layout of longwalls in the Wambo Seam is shown in Drawing No. MSEC495-01. The existing workings in the Whybrow Seam are also shown in this drawing. A summary of the dimensions for the proposed WMLW9 and WMLW10 is provided in Table 1.1.

Table 1.1 Geometry of the Proposed Longwalls

Longwall	Overall Void Length Including Installation Heading (m)	Overall Void Width Including First Workings (m)	Overall Tailgate Chain Pillar Width (m)
WMLW9	1700	263	-
WMLW10	1700	263	26

The widths of the longwall extraction faces (i.e. excluding the first workings) are around 253 metres. The longwalls are proposed to be extracted from the south-west towards the north-east.

WCPL has approval to extract future longwalls in the Arrowfield and Bowfield Seams beneath the currently active series of longwalls in the Wambo Seam. Whilst these future longwalls are not proposed to be modified, as part of this application, the predicted subsidence for these future longwalls has been included in this report to show the predicted total subsidence at the completion of all seams.

The layouts of longwalls in the Arrowfield and Bowfield Seams are shown in Drawing No. MSEC495-02. The future AFLW6 to AFLW13 and BFLW6 to BFLW13 have overall void widths (i.e. including the first workings) of 255 metres, chain pillar widths of 45 metres and overall lengths varying between 1435 metres and 2740 metres.

1.3. Surface and Seam Levels

The surface levels and the levels for the Whybrow, Wambo, Arrowfield and Bowfield Seams are illustrated along Cross-sections 1 and 2 in Fig. 1.2 and Fig. 1.3, respectively. The locations of these cross-sections are shown in Drawing Nos. MSEC495-03 to MSEC495-06.

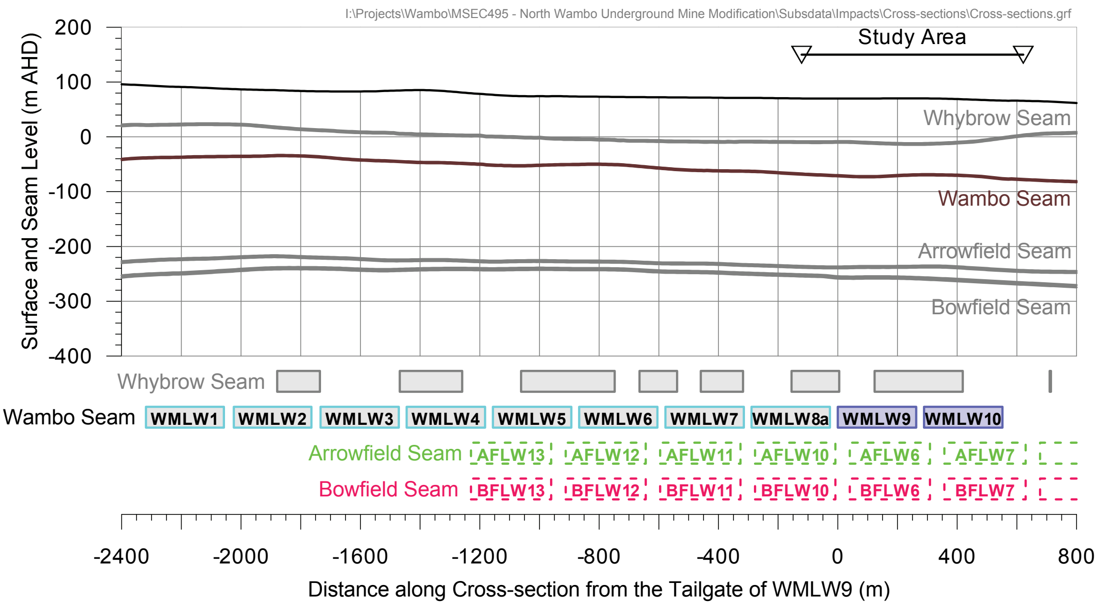

Fig. 1.2 Surface and Seam Levels along Cross-section 1

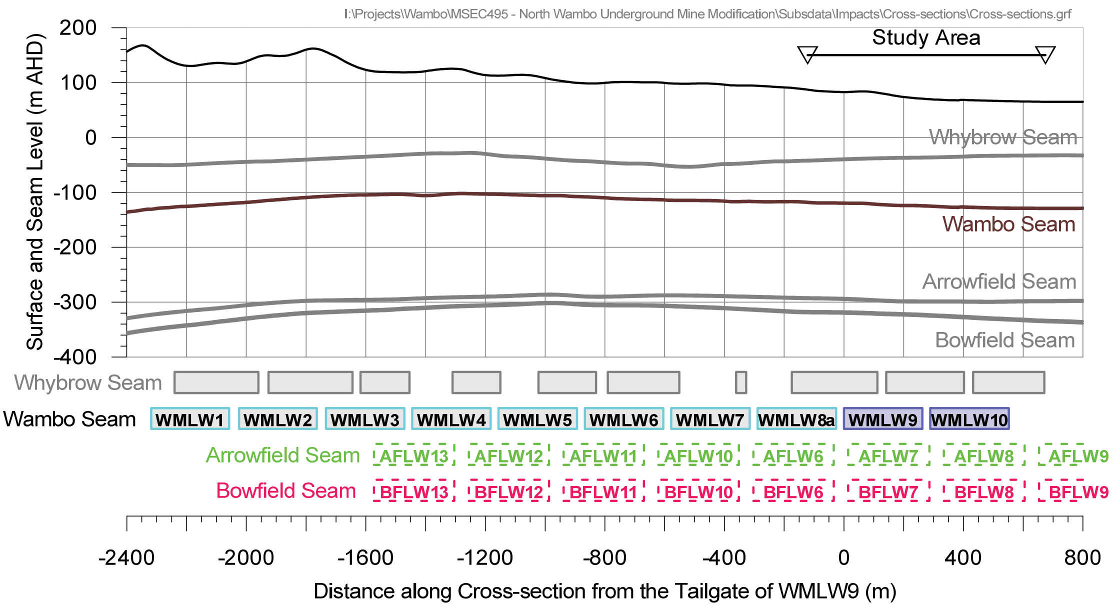

Fig. 1.3 Surface and Seam Levels along Cross-section 2

The surface level contours in the vicinity of the proposed longwalls are shown in Drawing No. MSEC495-03. The natural surface has a shallow natural fall from the west towards the east between approximately 1 % (i.e. 1 in 100) and 3 % (i.e. 1 in 300). A small spur is located immediately to the west of the proposed longwalls. The Wollemi Escarpment is located further to the west and is at a distance of more than 1 kilometre from the proposed longwalls, at its closest point.

The surface levels directly above the proposed longwalls vary from a low point of approximately 65 metres above Australian Height Datum (mAHD), above the maingate of WMLW10, to a high point of approximately 85 mAHD, above the tailgate of WMLW9. The low point in the area is the Wollombi Brook, located more than 450 metres east of the proposed longwalls, which is at around 60 mAHD.

The seam floor contours, seam thickness contours and depth of cover contours for the Wambo Seam are shown in Drawings Nos. MSEC495-04, MSEC495-05, and MSEC495-06, respectively. The contours are based on the latest seam information provided by WCPL.

The depth of cover to the Wambo Seam, directly above the proposed WMLW9 and WMLW10, varies between a minimum of 120 metres above the finishing (north-eastern) ends of the longwalls, and a maximum of 230 metres above the commencing (south-western) ends of the longwalls.

The seam floor within the mining area generally dips from the north-east towards the south-west, having an average dip around 5 %, or 1 in 20. The seam dip is relatively uniform over the lengths of the proposed longwalls. The thickness of the Wambo Seam, within the extents of the proposed longwalls, varies between 2.1 metres and 2.6 metres. WCPL is proposed to extract the full seam thickness.

The depth of cover contours for the Whybrow, Arrowfield and Bowfield Seams are shown in Drawing No. MSEC495-08, MSEC495-09 and MSEC495-10, respectively.

The depth of cover to the Whybrow Seam, directly above the proposed longwalls, varies between a minimum of 60 metres above the finishing (north-eastern) ends, and a maximum of 130 metres above the commencing (south-western) ends. The interburden thickness between the Whybrow and Wambo Seam varies between around 55 metres and 95 metres within the extents of the proposed longwalls.

The future longwalls in the Arrowfield and Bowfield Seams will be extracted directly beneath the proposed WMLW9 and WMLW10. The depths of cover to these seams, within the extents of the proposed longwalls, vary between approximately 290 metres and 395 metres for the Arrowfield Seam, and between approximately 310 metres and 420 metres for the Bowfield Seam.

The interburden thicknesses, within the extents of the proposed longwalls, are around 160 metres to 170 metres between the Wambo and Arrowfield Seams, and around 15 metres and 30 metres between the Arrowfield and Bowfield Seams. The mining heights vary between 3.2 metres and 4.2 metres for the future longwalls in the Arrowfield Seam, and between 3.0 metres and 4.5 metres for the longwalls in the Bowfield Seam.

1.4. Geological Details

The NWUM lies in the Hunter Coalfield, within the Northern Sydney Basin. A typical stratigraphic section of the Hunter Coalfield, reproduced from the Department of Mineral Resources *Hunter Coalfield Regional 1:100 000 Geology Map*, is shown in Table 1.2 (DMR, 1993). It is noted, that the DMR is now referred to as the Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS).

The Whybrow, Wambo, Arrowfield and Bowfield Seams all lie within the Jerrys Plains Subgroup of the Wittingham Coal Measures. The rocks of the Wittingham Coal Measures mainly comprise frequently bedded sandstones and siltstones, but also include isolated thinner beds of conglomerate and tuff. The beds are generally less than 10 metres in thickness.

The Denman Formation marks the top of the Wittingham Coal Measures, which is overlain by the Wollombi Coal Measures. The Wollombi Coal Measures comprise the Watts Sandstone and the Apple Tree Flat, Horseshoe Creek, Doyles Creek and Glen Gallic Subgroups.

Table 1.2 Stratigraphy of the Hunter Coalfield (DMR, 1993)

Supergroup	Group	Subgroup	Formation	Seam
Singleton Supergroup	Narrabeen Group	Widden Brook Conglomerate		
	Wollombi Coal Measures	Glen Gallic Subgroup	Greigs Creek Coal	
			Redmanvale Creek Formation	
			Dights Creek Coal	
		Doyles Creek Subgroup	Waterfall Gully Formation	
			Pinegrove Formation	
		Horseshoe Creek Subgroup	Lucernia Coal	
			Strathmore Formation	
			Alcheringa Coal	
			Clifford Formation	
		Appletree Flat Subgroup	Charlton Formation	
			Abbey Green Coal	
		Watts Sandstone		
	Wittingham Coal Measures	Denman Formation		
		Jerrys Plains Subgroup	Mount Leonard Formation	**Whybrow Seam**
			Althorpe Formation	
			Malabar Formation	Redbank Creek Seam
				Wambo Seam
				Whynot Seam
				Blakefield Seam
			Mount Ogilvie Formation	Glen Munro Seam
				Woodlands Hill Seam
			Milbrodale Formation	
			Mount Thorley Formation	**Arrowfield Seam**
				Bowfield Seam
				Warkworth Seam
			Fairford Formation	
			Burnamwood Formation	Mount Arthur Seam
				Piercefield Seam
				Vaux Seam
				Broonie Seam
				Bayswater Seam
		Archerfield Sandstone		
		Vane Subgroup	Bulga Formation	
			Foybrook Formation	
			Saltwater Creek Formation	

WCPL provided four typical boreholes in the mining area, being DDH 516 and DDH 535 which are located above the proposed WMLW10, DDH WA64 which is located above the chain pillar between the proposed WMLW9 and WMLW10, and DDH WA91 which is located above the proposed WMLW9. The geological section for borehole DDH WA91 (to just below the Wambo Seam), based on the drill log information provided by *Earth Data* (2011), is provided in Table 1.3.

It can be seen from this table, that the overburden to the Wambo Seam primarily consists of intermittent sandstone and siltstone layers, with a conglomerate layer (around 3 metres thick) identified at less than 10 metres depth of cover, and two tuffaceous layers (around 5 metres and 20 metres thick) identified at less than 60 metres depth of cover.

The immediate roof of the Wambo Seam, above Ply A, comprises a sandstone layer which is approximately 25 metres thick up to the underside of the Wambo Seam Rider Ply C. The floor of the Wambo Seam, beneath Ply B, comprises interbedded sandstone and siltstone layers having thicknesses between 0.5 metres and 5 metres

The geological features which have been identified at seam level are shown in Drawing No. MSEC495-07. There are two minor faults identified within the extents of the proposed longwalls, being a north to south trending fault with a throw around 1 metre, and a south-west to north-east fault with a throw around 3 metres. There is also a third fault projected through the finishing (i.e. north-eastern) end of the proposed WMLW9.

The largest structure in the area is the *Redmanvale Fault*, which has a throw greater than 20 metres. This fault is located more than 1.5 kilometres south-west of the proposed longwalls and, therefore, is unlikely to have any significant effect on the subsidence movements.

Table 1.3 Geological Section of Borehole DDH WA91 (Earth Data, 2011)

Depth (m)	Thickness (m)	Lithology	Geological Description
0 ~ 6	6	Soil	Red brown, coarse grained, weathered
6 ~ 9	3	Conglomerate	Brown, pebbly, weathered, very low strength
9 ~ 13	4	Sandy Clay	Buff, medium grained, weathered, low strength (base of alluvials)
13 ~ 15	2	Sandstone	Buff, medium grained, slightly clayey, medium strength (base of weathering)
15 ~ 22	7	Sandstone	White grey, medium grained, medium strength
22 ~ 27	5	Tuff	White, sandy, low strength
27 ~ 35	8	Banded coal, mudstone and siltstone	White to grey, tuffaceous, muddy, low to medium strength
35 ~ 54	19	Tuff	White to grey, sandy, medium strength
54 ~ 69	15	Siltstone	Grey to white, slightly sandy to moderately muddy, medium strength
69 ~ 74	5	Sandstone	White, fine grained, medium strength
74 ~ 85	11	Siltstone	Light grey, moderately sandy, medium strength
85 ~ 108	23	Sandstone	Grey-brown to grey-black, fine to medium grained, medium strength
108 ~ 111	3	Coal	Whybrow Seam Plies A to C, with 0.2 metre intermediate tuff layer
111 ~ 114	3	Sandstone	Dark grey, fine grained to medium grained, coaly in part, medium strength
114 ~ 115	1	Coal	Whybrow Seam Ply D, with 0.6 metre intermediate sandstone layer
115 ~ 158	43	Sandstone	Light to dark grey, fine to medium grained, medium strength
158 ~ 162	4	Coal and sandstone	Redbank Creek Plies A to E, with interbedded sandstone layers
162 ~ 163	1	Sandstone	Light grey, fine grained to medium grained, medium strength
163 ~ 173	10	Coal and sandstone	Wambo Seam Rider Plies A to C, with interbedded sandstone layers
173 ~ 198	25	Sandstone	Black to grey, medium grained, moderately coaly
198 ~ 200	2	Coal	Wambo Seam Plies A and B, with 0.15 metre intermediate sandstone layer
200 ~ 201	1	Coal	Whynot Seam Ply A, with interbedded with 0.4 metre sandstone layer
201 ~ 202	1	Sandstone	Grey, fine grained to medium grained, slightly silty
202 ~ 206	4	Siltstone	Dark grey, slightly sandy
206 ~ 211	5	Sandstone	Grey, fine to medium grained
211 ~ 213	2	Coal	Whynot Seam Ply B

The surface lithology in the area can be seen in Fig. 1.4, which shows the proposed longwalls and the 26.5 degree angle of draw line overlaid on the *Geological Map of Doyles Creek 9032I*, which was published by the Department of Mineral Resources (DMR, 1988), now known as DTIRIS.

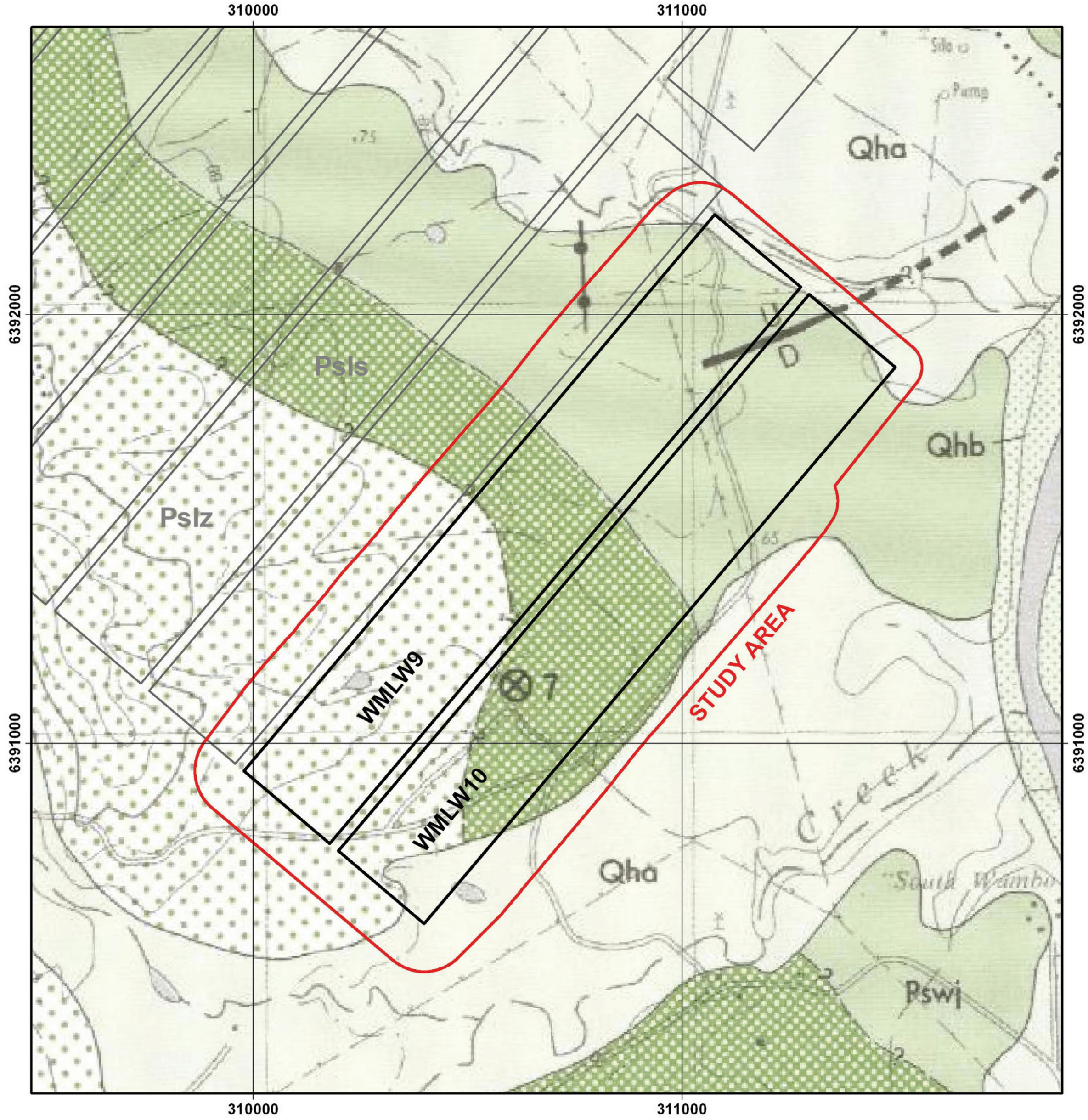

Fig. 1.4 Proposed WMLW9 and WMLW10 Overlaid on Geological Map Doyles Creek 9032I

It can be seen from the above figure, that the surface lithology above the north-eastern ends of the proposed longwalls comprises the Jerrys Plains Subgroup of the Wittingham Coal Measures (Pswj). The surface lithology above the central and south-western ends of the proposed longwalls predominately comprises the Watts Sandstone (Psls) and the overlying subgroups from the Wollombi Coal Measures (Pslz). Quaternary Alluvium (Qha) is also present in the south-east part of the Study Area adjacent to Stony Creek.

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 modification, being the addition of the proposed WMLW9 and WMLW10 and the subsequent effects on the future longwalls in the Arrowfield and Bowfield Seams. The extent of the Study Area has been calculated by combining the areas bounded by the following limits:-

- The 26.5 degree angle of draw line from the extents of the proposed WMLW9 and WMLW10, and
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour resulting from the extraction of the proposed longwalls.

The 26.5 degree angle of draw line is described as the "*surface area defined by the cover depths, angle of draw of 26.5 degrees and the limit of the proposed extraction area in mining leases for all other NSW Coalfields*" (i.e. other than the Southern Coalfield), as stated in Section 6.2 of the Guideline for Applications for Subsidence Management Approvals (DMR, 2003).

The depth of cover contours are shown in Drawing No. MSEC495-06. It can be seen from this drawing that the depth of cover to the Wambo Seam, directly above the proposed WMLW9 and WMLW10, varies between a minimum of 120 metres above the finishing (north-eastern) ends of the longwalls, and a maximum of 230 metres above the commencing (south-western) ends of the longwalls. The 26.5 degree angle of draw line, therefore, has been determined by drawing a line that is a horizontal distance varying between 60 metres and 115 metres around the limits of the proposed extraction areas.

The predicted limit of vertical subsidence, taken as the predicted 20 mm subsidence contour due to the extraction of WMLW9 and WMLW10, has been determined using the calibrated Incremental Profile Method, which is described in Chapter 3. The predicted additional conventional subsidence contours due to the extraction of the proposed longwalls only are shown in Drawing No. MSEC495-13.

A line has therefore been drawn defining the Study Area, based upon the 26.5 degree angle of draw line and the predicted 20 mm subsidence contour, whichever is furthest from the proposed longwalls, and is shown in Drawings Nos. MSEC495-01 and MSEC495-02.

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

2.2. Overview of the Natural Features and Items of Surface Infrastructure within the Study Area

A number of the major natural features and items of surface infrastructure within the Study Area can be seen in the 1:25,000 Topographic Map of the area, published by the Central Mapping Authority (CMA), numbered Doyles Creek 90321-N. The proposed longwalls and the Study Area have been overlaid on an extract of this CMA map in Fig. 2.1.

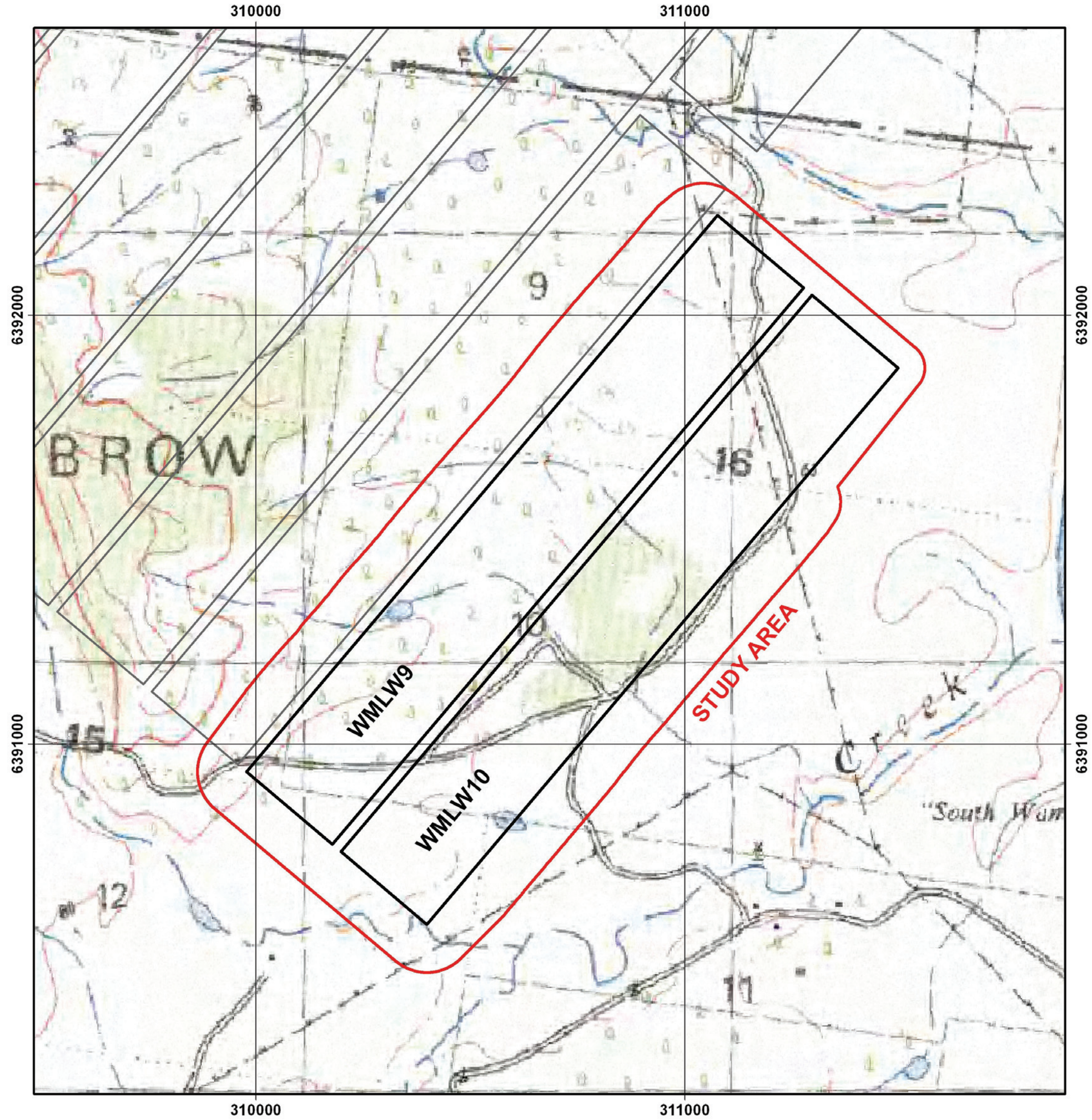

Fig. 2.1 Proposed WMLW9 and WMLW10 Overlaid on CMA Map No. Doyles Creek 90321-N

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. MSEC495-11 and MSEC495-12. The descriptions, predictions and impact assessments for each of the natural and built features are provided in Chapters 5 and 6.

Table 2.1 Natural and Built Features within the Study Area

Item	Within Study Area	Section Number
NATURAL FEATURES		
Catchment Areas or Declared Special Areas	×	
Streams	✓	5.2 & 5.3
Aquifers or Known Groundwater Resources	✓	5.4
Springs or Groundwater Seeps	×	
Sea or Lake	×	
Shorelines	×	
Natural Dams	×	
Cliffs or Pagodas	×	
Steep Slopes	×	
Escarpments	×	
Land Prone to Flooding or Inundation	✓	5.7
Swamps or Wetlands	×	
Water Related Ecosystems	✓	5.8
Threatened or Protected Species	✓	5.9
Lands Defined as Critical Habitat	×	
National Parks	×	
State Forests	×	
State Recreation or Conservation Areas	×	
Natural Vegetation	✓	5.11
Areas of Significant Geological Interest	×	
Any Other Natural Features Considered Significant	×	
PUBLIC UTILITIES		
Railways	×	
Roads (All Types)	✓	6.2
Bridges	×	
Tunnels	×	
Culverts	✓	6.2
Water, Gas or Sewerage Infrastructure	✓	6.3
Liquid Fuel Pipelines	×	
Electricity Transmission Lines or Associated Plants	✓	6.4
Telecommunication Lines or Associated Plants	×	
Water Tanks, Water or Sewage Treatment Works	×	
Dams, Reservoirs or Associated Works	×	
Air Strips	×	
Any Other Public Utilities	×	
PUBLIC AMENITIES		
Hospitals	×	
Places of Worship	×	
Schools	×	
Shopping Centres	×	
Community Centres	×	
Office Buildings	×	
Swimming Pools	×	
Bowling Greens	×	
Ovals or Cricket Grounds	×	
Race Courses	×	
Golf Courses	×	
Tennis Courts	×	
Any Other Public Amenities	×	

Item	Within Study Area	Section Number
FARM LAND AND FACILITIES		
Agricultural Utilisation or Agricultural Suitability of Farm Land	✓	6.7
Farm Buildings or Sheds	×	
Tanks	×	
Gas or Fuel Storages	×	
Poultry Sheds	×	
Glass Houses	×	
Hydroponic Systems	×	
Irrigation Systems	×	
Fences	✓	6.8
Farm Dams	✓	6.9
Wells or Bores	✓	6.10
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	✓	6.12
Buildings, Equipment or Operations that are Sensitive to Surface Movements	×	
Surface Mining (Open Cut) Voids or Rehabilitated Areas	×	
Mine Related Infrastructure Including Exploration Bores and Gas Wells	✓	6.12.6
Any Other Industrial, Commercial or Business Features	×	
AREAS OF ARCHAEOLOGICAL SIGNIFICANCE	✓	6.14
AREAS OF HISTORICAL SIGNIFICANCE	×	
ITEMS OF ARCHITECTURAL SIGNIFICANCE	×	
PERMANENT SURVEY CONTROL MARKS	✓	6.15
RESIDENTIAL ESTABLISHMENTS		
Houses	×	
Flats or Units	×	
Caravan Parks	×	
Retirement or Aged Care Villages	×	
Associated Structures such as Workshops, Garages, On-Site Waste Water Systems, Water or Gas Tanks, Swimming Pools or Tennis Courts	×	
Any Other Residential Features	×	
ANY OTHER ITEM OF SIGNIFICANCE	×	
ANY KNOWN FUTURE DEVELOPMENTS	×	

3.1. Introduction

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

3.2. The Incremental Profile Method

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

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

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

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

Based on the extensive empirical data, MSEC has developed standard subsidence prediction curves for the Southern, Newcastle and Hunter Coalfields. The predictions curves can then be further refined, for the local geology and local conditions, based on the available monitoring data from the area. Discussions on the calibration of the Incremental Profile Method for the proposed WMLW9 and WMLW10, at the NWUM, are provided in Section 3.3.

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

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

The shapes of the incremental subsidence profiles are then determined using the large empirical database of observed incremental subsidence profiles from the Hunter Coalfield. The profile shapes are derived from the normalised subsidence profiles for monitoring lines where the mining geometry and overburden geology are similar to that for the proposed longwalls. The profile shapes can be further refined, based on local monitoring data, which is discussed further in Section 3.3.

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

3.3. Calibration of the Incremental Profile Method

The proposed WMLW9 and WMLW10 are generally located beneath the existing Homestead/Wollemi workings in the overlying Whybrow Seam (i.e. multi-seam conditions). The north-eastern corner of the proposed WMLW10, however, is located outside the extents of the existing workings (i.e. single-seam conditions).

The Incremental Profile Method has been calibrated to local conditions using ground monitoring data from the NWUM and from other nearby collieries. This has been achieved by comparing the observed mine subsidence movements along monitoring lines with those back-predicted using the standard Incremental Profile Method for the Hunter Coalfield.

WCPL provided MSEC with monitoring data along a number of monitoring lines above the currently active longwalls in the Wambo Seam at the NWUM. These longwalls are being extracted beneath the Homestead/Wollemi workings in the Whybrow Seam and above the United Collieries longwalls in the Woodlands Hill Seam (as defined by United Collieries, which is the Arrowfield Seam as defined by WCPL and DTIRIS). The existing and active workings at the NWUM and the locations of the monitoring lines are shown in Drawing No. MSEC495-01.

The following sections describe the calibration of the Incremental Profile Method for single-seam and multi-seam conditions.

3.3.1. Calibration for Single-seam Mining Conditions

The depth of cover above the north-eastern end of the proposed WMLW10 (i.e. single-seam mining conditions) is around 130 metres and, therefore, the panel width-to-depth ratio is 2.0 (i.e. supercritical in width). The maximum achievable subsidence in the Hunter Coalfield, for single-seam super-critical conditions, is generally 60 % to 65 % of the effective extracted thickness.

The standard Incremental Profile Method for the Hunter Coalfield has been used to predict the mine subsidence movements for the monitoring lines at the NWUM and at a number of other nearby collieries, including United, South Bulga, Beltana, Blakefield South and Glennies Creek. Comparisons between the observed and predicted movements indicate that the standard prediction model generally provides reasonable, if not slightly conservative, predictions of the mine subsidence parameters for single-seam mining conditions.

For example, the comparisons between the observed and predicted profiles of subsidence, tilt and curvature for the XL3-Line at the NWUM, where there are no existing overlying workings (i.e. single-seam conditions), is shown in Fig. C.03, in Appendix C. The comparisons for monitoring lines at other nearby collieries in the Hunter Coalfield, where the panel width-to-depth ratios are around 2.0 and 3.0 are also shown in C.05 and C.06, respectively, in Appendix C.

It can be seen from these figures, that the observed profiles of subsidence, tilt and curvature along these monitoring lines reasonably match those predicted using the standard Incremental Profile Method for the Hunter Coalfield. In some locations, there are small lateral shifts between the observed and predicted profiles, which could be the result of surface dip, seam dip, or variations in the overburden geology.

The magnitudes of the maximum observed subsidence along the XL3-Line were similar to the maxima predicted using the standard Incremental Profile Method, and represent around 65 % of the extracted seam thicknesses. The magnitudes of the maximum observed subsidence along the other two monitoring lines from the Hunter Coalfield (i.e. Figs. C.05 and C.06) were less than the maxima predicted, and represent between 40 % and 50 % of the extracted seam thicknesses.

The magnitudes of the observed tilts and curvatures along the monitoring lines were also reasonably similar to those predicted using the standard Incremental Profile Method for the Hunter Coalfield. It can be seen, however, that the observed tilts and curvatures were less than those predicted, in some locations, whilst the observed tilts and curvatures exceeded those predicted in other locations. This demonstrates the difficulty in predicting tilts and curvatures at a point, especially at shallow depths of cover. It is important then to recognise that there is greater potential for variation between observed and predicted movements at a point, as the depth of cover decreases.

Based on these comparisons, it would appear that the standard Incremental Profile Method for the Hunter Coalfield provides reasonable predictions of subsidence, tilt and curvature in these cases, for single-seam mining conditions, where the panel width-to-depth ratios were 2.0, or greater. It has not been considered necessary, therefore, to provide any specific calibration of the standard model for the proposed WMLW9 and WMLW10 based on single-seam mining conditions.

3.3.2. Calibration for Multi-seam Mining Conditions

Monitoring data from multi-seam longwall mining in the coalfields of New South Wales and overseas show that the maximum subsidence, as proportions of the extracted seam heights, are greater than those for equivalent single-seam mining cases. The monitoring data from the multi-seam cases also show that the shapes of the subsidence profiles are affected by the locations and stabilities of the goafs and chain pillars in the previously extracted seam as the longwalls are extracted beneath the existing workings.

Multi-seam Calibration for the Proposed WMLW9 and WMLW10

The interburden thickness between the Wambo and Whybrow Seams, within the extents of the proposed WMLW9 and WMLW10, varies between a minimum of 55 metres above the finishing (i.e. north-eastern) ends, and a maximum of 95 metres above the commencing (i.e. south-western) ends of the longwalls.

Multi-seam monitoring data was gathered during the extraction of WMLW1 to WMLW5 at the NWUM. The main transverse lines were the XL1-Line, XL2-Line and the SC1-Line and a summary of the mining geometries and observed subsidence due to the extraction of the Wambo Seam is provided in Table 3.1. It is noted, that the XL1-Line was located above the existing United longwalls in the Woodlands Hill Seam, and that the XL2-Line and SC1-Line were located above the existing Homestead/Wollemi workings in the Whybrow Seam.

Table 3.1 Multi-seam Monitoring Data from the NWUM

Monitoring Line	Wambo Seam Longwall	Void Width (m)	Average Depth of Cover (m)	Average Mining Height (m)	Interburden Thickness (m)	Maximum Observed Incremental Subsidence (m)	Longwall Width-to-Depth Ratio	Incremental Subsidence / Mining Height
XL1-Line	LW2	260	80	2.3	45	1.6	3.3	0.69
	LW3	260	80	2.3	40	1.5	3.2	0.67
	LW4	260	85	2.3	40	1.9	3.1	0.82
XL2-Line	LW1	260	165	2.2	65	2.5	1.6	1.16
	LW2	260	160	2.2	60	1.6	1.7	0.74
	LW3	260	155	2.2	55	2.0	1.7	0.92
	LW4	260	145	2.2	45	2.1	1.8	0.97
SC1-Line	LW2	260	255	2.5	80	2.2	1.0	0.87
	LW3	260	235	2.5	75	2.0	1.1	0.79
	LW4	260	220	2.5	75	2.4	1.2	0.97

It can be seen from the above table, that the observed incremental subsidence due to the extraction of the longwalls in the Wambo Seam represented between 0.67 and 1.16 of the mining height, with an average around 0.86 of the mining height. It is noted, that the XL1-Line was located near the ends of the United Longwalls and, therefore, end effects could have reduced the multi-seam influence of the existing workings along this monitoring line.

As described in the paper by Li et al (2007), entitled "*A Case Study on Multi-seam Subsidence with Specific Reference to Longwall Mining under Existing Longwall Goaf*", the maximum additional subsidence resulting from the extraction of longwalls, for multi-seam mining conditions, can be estimated from the following equation:-

Equation 1 $S_2 = a_2 T_2$ (Li, et al, 2007)

where $a_2 = (a_m - a_1)(T_1 / T_2) + a_m$

a_1 = Maximum subsidence resulting from the extraction of the first seam (single-seam conditions) as a proportion of the extracted seam thickness

a_m = Maximum total subsidence resulting from the extraction of the first seam (single-seam conditions) plus the extraction of the second seam (multi-seam conditions) as a proportion of total extracted seam thickness of both seams

T_1 = Extracted seam thickness in first seam

T_2 = Extracted seam thickness in second seam

The value of 'a_1' can be calculated from the predicted subsidence resulting from the extraction of the proposed longwalls in the first seam (i.e. single-seam conditions).

The value of "a_m" can be determined from the observations from previous multi-seam longwall mining cases. There is limited multi-seam monitoring data from the coalfields of New South Wales, especially where longwalls have been extracted directly beneath or above existing longwalls or panels. Historical information on multi-seam mining include the following cases:-

- Newstan Colliery Longwall 8 in the Fassifern Seam – below LW6 in the Great Northern Seam
- Newstan Colliery Longwalls 1, 2, 3 and 4 – below extracted pillar workings
- Wyee Colliery Longwalls 1, 2, 3, 4, 7 and 9 – below extracted pillar workings
- John Darling Colliery Longwall 1 – below extracted pillar workings
- Teralba Colliery Longwalls 6, 7, 8 and 9 – below extracted pillar workings
- Kemira Colliery Longwalls 1 to 6 – below extracted pillar workings
- Blakefield South Longwall 1 in the Blakefield Seam – below LW3 to LW6 in the Whybrow Seam

The observations from a number of additional multi-seam cases were also provided in the paper by Li et al (2007), which included the following:-

- Sigma Colliery, South Africa – LW4A extracted beneath LW4
- Liddell Colliery, NSW – LW3 extracted beneath LW1
- Cumnock Colliery, NSW – LW17 extracted above LW3

A summary of the details, observed subsidence and extraction heights for the multi-seam mining case studies where longwalls were mined beneath or above previous longwalls is provided in Table 3.2 below.

Table 3.2 Multi-seam Mining Cases for Longwalls Mining Beneath or Above Previously Extracted Longwalls

Colliery (Location)	Seam	Longwall	Depth of Cover (m)	Subsidence	Seam Thickness	a_1 / a_2	a_m
NWU Mine (XL1-Line)	Woodlands Hill Wambo	LW2 to LW7 LW2 to LW4	30 ~ 45 80 ~ 85	N/A 1.5 ~ 1.9	3.0 2.3	$a_1 = 0.65^{\#}$ 0.67 ~ 0.82	0.66 ~ 0.72
NWU Mine (XL2-Line)	Whybrow Wambo	LW10 and B&P LW1 to LW4	95 ~ 100 145 ~ 165	N/A 1.6 ~ 2.5	3.0 2.2	$a_1 = 0.65^{\#}$ 0.74 ~ 1.16	0.69 ~ 0.87
NWU Mine (SC1-Line)	Whybrow Wambo	LW10 to LW13 LW2 to LW4	100 ~ 175 220 ~ 255	N/A 2.0 ~ 2.4	3.0 2.2 ~ 2.5	$a_1 = 0.65^{\#}$ 0.79 ~ 0.97	0.71 ~ 0.80
Sigma Colliery (Trans Line)	No. 3 No. 2B	LW4 LW4A	135 150	S_1 = 1.1m S_2 = 2.92m	T_1 = 2.75m T_2 = 3.05m	a_1 = 0.40 a_2 = 0.96	0.69
Liddell Colliery (LW Centreline)	Up. Liddell Mid. Liddell	LW1 & LW2 LW3	160 200	S_1 = 1.6m S_2 = 2.0m	T_1 = 2.72m T_2 = 2.65m	a_1 = 0.59 a_2 = 0.76	0.67*
Cumnock Colliery (LW17CLB)	Liddell Lower Pikes	LW3 LW17	135 90	S_1 = 1.25m S_2 = 1.72m	T_1 = 2.50m T_2 = 2.20m	a_1 = 0.50 a_2 = 0.78	0.63
Newstan Colliery	Great Northern Fassifern	Panel 6 Panel 8		S_1 = 2.03m S_2 = 3.22m	T_1 = 3.4m T_2 = 3.2m	a_1 = 0.60 a_2 = 1.01	0.80

Notes: * denotes that the value of "a_m" of 67 % for Liddell Colliery is based on the most recent seam extraction information provided by the colliery and, hence, is less than that provided in the paper by Li et al (2007) of 83 %. # denotes subsidence due to the extraction of the United Longwalls and Homestead/Wollemi workings has been estimated to be 65 % of the mining height based on supercritical conditions.

Detailed ground monitoring was also undertaken during the extraction of Blakefield South Longwall 1 (BSLW1) beneath the previously extracted longwalls in the overlying Whybrow Seam. The additional subsidence observed along the monitoring lines, resulting from the extraction of BSLW1, typically varied between 80 % and 100 % of the mining height (i.e. a_2 = 0.8 ~ 1.0) and, on average, was around 90 % of the mining height (i.e. a_2 = 0.9). In some cases, the observed subsidence was greater than the mining height, but this was very localised and the observed subsidence elsewhere along the monitoring lines was less than the mining height.

The interburden thickness between the proposed WMLW9 and WMLW10 and the existing Homestead/Wollemi workings in the overlying Whybrow Seam typically varies between 55 metres and 95 metres. It is considered, therefore, that the most relevant case studies are the XL2-Line and SC1-Line at the NWUM, as well as Liddell, Cumnock and Blakefield South Mines. Based on these case studies, it appears that adopting a value of "a_m" of 80 % would provide a reasonable, if not, slightly conservative estimate of the multi-seam subsidence for the proposed WMLW9 and WMLW10.

The extraction height for the existing Homestead/Wollemi workings in the overlying Whybrow Seam was around 3.0 metres (i.e. T_1 = 3.0). The proposed extraction height for WMLW9 and WMLW10 varies between 2.3 metres and 2.6 metres, with an average extraction height around 2.4 metres (i.e. T_2 = 2.4).

The maximum predicted additional subsidence resulting from the extraction of the proposed WMLW9 and WMLW10, as a proportion of the extracted seam thickness, therefore, has been calculated as follows:-

Equation 2 $a_2 = (0.80 - 0.65)(3.0/2.4) + 0.80 = 0.99$

The maximum additional subsidence, due to the extraction of the proposed WMLW9 and WMLW10, therefore, has been taken as 100 % of the mining height (i.e. a_2 = 1.0). This is reasonably consistent with the observations along the XL2-Line and SC1-Line at the NWUM, as shown in Table 3.1.

Multi-seam Calibration for the Future Longwalls in the Arrowfield and Bowfield Seams

WCPL has approval to extract future longwalls in the Arrowfield and Bowfield Seams beneath the currently active series of longwalls in the Wambo Seam. Whilst these future longwalls are not proposed to be modified, as part of this application, the predicted subsidence for these future longwalls has been included in this report to show the predicted total subsidence at the completion of all seams.

The extraction of the future longwalls on the Arrowfield Seam will reactivate the existing goafs above the Wambo Seam and, to a lesser extent, the Whybrow Seam. Similarly, the extraction of the future longwalls in the Bowfield Seam will reactive the existing goafs above the Arrowfield Seam and, to lesser extents, the Wambo and Whybrow Seams.

The interburden thickness between the Arrowfield Seam and Wambo Seam varies between 160 metres and 170 metres, which is greater than the interburden thickness between the Wambo and Whybrow Seams, which varies between 55 metres and 95 metres. The multi-seam interaction due to the future mining in the Arrowfield Seam, therefore, is expected to be less than that observed due to the extraction of the current series of longwalls in the Wambo Seam.

The interburden thickness between the Arrowfield and Bowfield Seams varies between 15 metres and 30 metres. Whilst the interburden thickness is less than that between the Wambo and Whybrow Seams, the depth of cover to the Bowfield Seam is around double of that to the Wambo Seam.

The calibration of the Incremental Profile Method for the Arrowfield and Bowfield Seams, therefore, has been undertaken using the available multi-seam data from the NSW Coalfields. The empirical multi-seam data for these cases are illustrated in Fig. 3.1, below, which shows the maximum observed subsidence, as a proportion of the extracted seam thickness, versus the longwall width-to-depth ratio. The multi-seam cases from the NWUM are shown as the blue diamonds, and the multi-seam cases from elsewhere in the NSW Coalfields are shown as the green and red diamonds. Single-seam mining cases are also shown in this figure, for comparison, as the light grey diamonds.

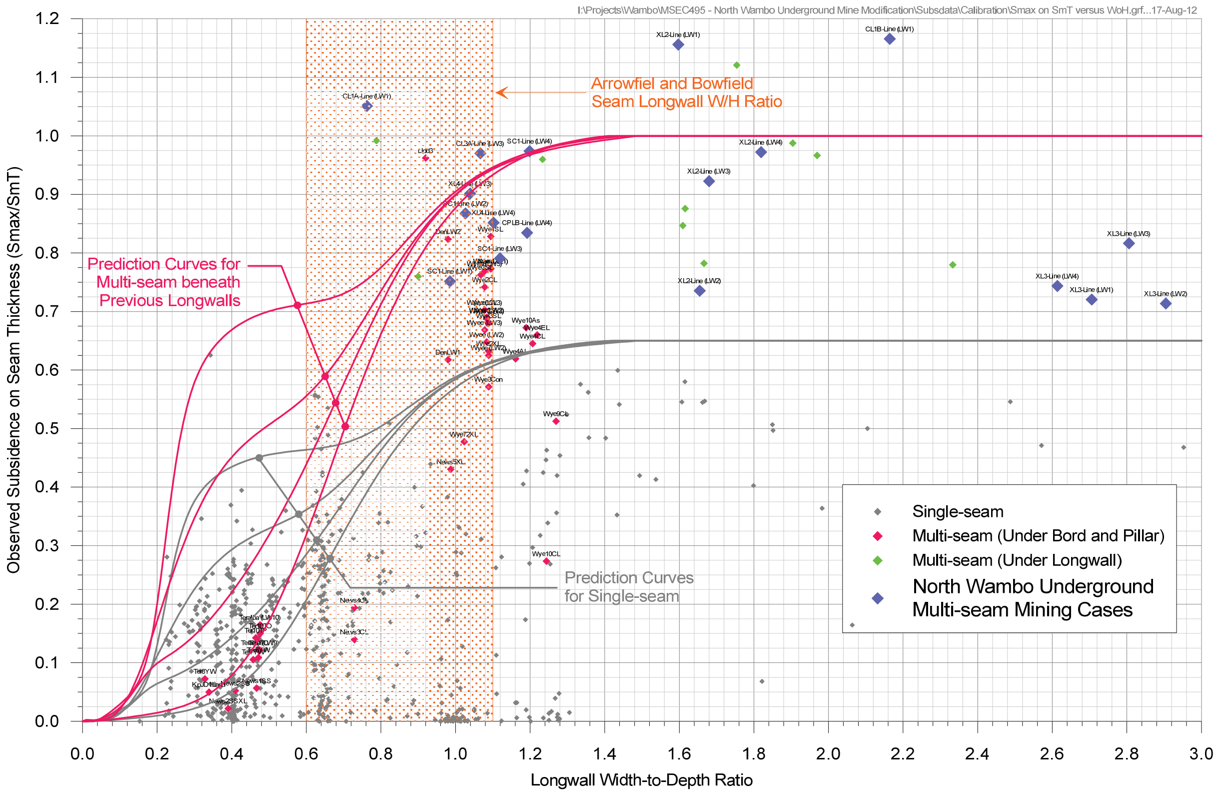

Fig. 3.1 Maximum Observed Subsidence versus Longwall Width-to-Depth Ratio for Historical Multi-seam Mining Cases

The typical prediction curves used for single-seam mining conditions are shown as the grey lines, in the above Fig. 3.1, for various mine geometries. These prediction curves have been scaled up, so as to achieve a maximum predicted incremental subsidence of 100 % of extracted seam thickness, which are shown as the red curves in this figure.

It can be seen, that these prediction curves provide reasonable estimates of the maximum subsidence for the multi-seam cases for longwalls beneath longwalls (i.e. green and blue diamonds). In some cases, the maximum observed subsidence exceeds the prediction curves, however, in many of these cases the maximum subsidence was localised and the subsidence elsewhere was below the prediction curves.

The multi-seam prediction curves provide subsidence around 55 % greater than those obtained using the standard single-seam prediction curves. In reality, the additional subsidence, due to multi-seam mining conditions, will be dependent on a number of factors, including the interburden thickness, the extraction heights in both seams, the conditions of the remnant pillars in the overlying seam.

It is considered, that the multi-seam prediction curves, illustrated in Fig. 3.1 as the red curves, should provide reasonable predictions of the maximum subsidence, as a proportion of the extraction height, for the future longwalls in the Arrowfield and Bowfield Seams.

Shapes of the Multi-seam Subsidence Profiles

It has been found from past longwall mining experience, that the shapes of multi-seam subsidence profiles depend on, amongst other factors, the depths of cover, interburden thickness, extraction heights and the relative locations between the longwalls within each seam.

In the cases where the chain pillars within the lower seam are located directly beneath the chain pillars or panel edges in the overlying seam, which are referred to as *Stacked Cases*, the observed subsidence profiles are steeper and more localised above the longwalls when compared with those for similar single-seam conditions. In the cases where the chain pillars within the lower seam are offset from the chain pillars or panel edges in the overlying seam, which are referred to as *Staggered Cases*, the subsidence profiles are flatter and extend further when compared with those for similar single-seam conditions.

The shapes of the multi-seam subsidence profiles were calibrated using the available monitoring data from the NWUM, Blakefield South Mine and other collieries described previously. The comparisons between the observed and predicted profiles of subsidence, tilt and curvature for the XL1-Line, XL2-Line and SC1-Line at the North Wambo Underground Mine are shown in Figs. C.01, C.02 and C.04, respectively, in Appendix C.

It can be seen from these figures, that the observed profiles of subsidence, tilt and curvature along these monitoring lines reasonably match those predicted using the calibrated Incremental Profile Method for multi-seam conditions. There are some locations where there is locally increased subsidence, due to the reactivation of the existing workings, but in most cases the observed subsidence is less than that predicted.

The magnitudes of the maximum observed subsidence along the XL1-Line were less than the maxima predicted using the calibrated Incremental Profile Method, and represent between 67 % to 82 % of the extracted seam thicknesses. The magnitudes of the maximum observed subsidence along the XL2-Line and SC1-Line were generally similar to the maxima predicted and represent between 74 % to 116 % of the extracted seam thicknesses.

The magnitudes of the observed tilts and curvatures along the monitoring lines were also reasonably similar to those predicted using the calibrated Incremental Profile Method for multi-seam conditions. It can be seen, however, that the observed tilts and curvatures were greater than those predicted, in some locations, due to the reactivation of the existing workings. It is important then to recognise that there is greater potential for variation between observed and predicted movements at a point for multi-seam conditions.

Based on these comparisons, it would appear that the calibrated Incremental Profile Method for multi-seam conditions provides reasonable predictions of subsidence, tilt and curvature in these available cases.

3.4. Reliability of the Predicted Conventional Subsidence Parameters

The Incremental Profile Method is based upon a large database of observed subsidence movements in the NSW Coalfields and has been found, in most cases, to give reasonable, if not, slightly 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.

In this case, the Incremental Profile Method was calibrated using local monitoring data from the NWUM, as well as from other nearby collieries in the Hunter Coalfield. The subsidence model was also calibrated using the available multi-seam monitoring data from the NWUM and from elsewhere in the NSW Coalfields.

The prediction of the conventional subsidence parameters at specific points is more difficult than the prediction of the maxima anywhere above extracted longwalls. 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 are less than those predicted in other locations.

Notwithstanding the above, the Incremental Profile Method provides 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.

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.

It is also likely that some localised irregularities will occur in the subsidence profiles due to near surface geological features and multi-seam mining conditions. 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, including both conventional and non-conventional anomalous strains, which is discussed in Section 4.4.

3.5. Reliability of the Predicted Upsidence and Closure Movements

The predicted valley related movements resulting from the proposed mining 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 development of the predictive methods for upsidence and closure are the result of recent and ongoing research and the methods do not, at this stage, have the same confidence level as conventional subsidence prediction techniques. As further case histories are studied, the method will be improved, but it can be used in the meantime, so long as suitable factors of safety are applied. This is particularly important where the predicted levels of movement are small, and the potential errors, expressed as percentages, can be higher.

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

4.1. Introduction

The following sections provide the maximum predicted conventional subsidence parameters resulting from the extraction of the approved and proposed longwalls in the Wambo Seam, and the future longwalls in the Arrowfield and Bowfield Seams. The predicted subsidence parameters and the impact assessments for the natural and built features are provided in Chapters 5 and 6.

The predicted subsidence, tilt and curvature have been obtained using the Incremental Profile Method, which has been calibrated for multi-seam conditions, as described in Section 3.3. The predicted strains have been determined by analysing the strains measured at the North Wambo Underground Mine, and other NSW Collieries, where the mining geometries are similar to those for the proposed longwalls.

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

The reliability of the predictions of subsidence, tilt and curvature, obtained using the Incremental Profile Method, is discussed in Sections 3.4.

4.2. Maximum Predicted Conventional Subsidence, Tilt and Curvature

4.2.1. Predictions for the Existing Workings in the Whybrow Seam

The existing Homestead/Wollemi workings were extracted in the Whybrow Seam. The widths of the longwalls and total extraction panels in the Whybrow Seam, within the Study Area, vary between 160 metres and 190 metres. The depth of cover directly above these workings varies between 90 metres and 140 metres and, therefore, the panel width-to-depth ratios were 1.1 to 2.1.

The existing workings in the Whybrow Seam were critical to supercritical in width and, therefore, the maximum subsidence is expected to have been 60 % to 65 % of the working height, which is the maximum achievable for single-seam mining conditions in the Hunter Coalfield. The maximum predicted subsidence for the existing Homestead/Wollemi workings within the Study Area, therefore, is 1,800 mm to 2,000 mm based on a working height of 3.0 metres.

The SC1-Line was established prior to longwalls in the Whybrow Seam mining directly beneath it. One survey was carried out in September 2007, after Longwalls 10 to 13 had been extracted directly beneath this monitoring line. The longwall void widths were 210 metres and the depth of cover along this monitoring line varied between 140 metre and 200 metres and, therefore, the panel width-to-depth ratios were 1.0 and 1.5.

The subsidence parameters measured along the SC1-Line should, therefore, provide a reasonable guide to the movements which occurred within the Study Area as a result of mining in the Whybrow Seam. In the survey carried out in September 2007, the maximum observed subsidence directly above the longwalls varied between 1,500 mm to 1,750 mm and the subsidence observed directly above the chain pillars was around 200 mm. The maximum observed tilts varied between 20 mm/m and 30 mm/m. The observed strains were typically between 5 mm/m and 10 mm/m, with localised elevated strains around 20 mm/m.

The predicted subsidence parameters and the predicted subsidence contours provided in this report do not include the subsidence which occurred as a result of mining in the Whybrow Seam. That is, the current conditions within the Study Area (i.e. post mining in the Whybrow Seam) have been taken as the baseline for the predictions and impact assessments provided in this report. Whilst the predicted subsidence parameters resulting from the mining in the Whybrow Seam have not been included, the affects of these existing workings on the subsidence resulting from mining in the Wambo, Arrowfield and Bowfield Seams have been considered.

4.2.2. Predictions for the Approved Layout

The predicted conventional subsidence parameters due to mining in the Wambo, Arrowfield and Bowfield Seams, based on the *Approved Layout*, were originally provided in a report by Holt (2003) which supported the 2003 EIS, and then in a subsequent report by Holt (2005) which supported the 2005 SEE.

The maximum predicted subsidence resulting from the extraction of the longwalls in the Wambo Seam only, provided in the 2005 SEE, was 1,300 mm to 1,800 mm (Holt, 2005). The maximum predicted total subsidence due to mining in the Wambo, Arrowfield and Bowfield Seams, provided in the 2005 SEE, was 4,500 mm to 5,200 mm (Holt, 2005).

The original subsidence predictions provided in the 2003 EIS and the 2005 SEE used the methods outlined in the DMR Newcastle Guidelines (Holla, 1987). It was stated in the subsidence report by Holt (2003) that the method is:-

> "*based on real subsidence monitoring of single seam workings*", and that

> "*the massive nature of sandstone interburden between seams suggests that a 60% of mined-height factor be used for maximum subsidence prediction for the proposed longwall operations*".

It was also stated in the subsidence report by Holt (2005) that:-

> "*Experience with other multi-seam operations also suggests that the 60% of mined height for maximum subsidence prediction is appropriate where seams are widely separated. Where seams are more closely spaced the figure increases to 65% of mined height*".

Since the 2005 SEE, more detailed multi-seam monitoring data has been gathered from the NSW Coalfields, including at the NWUM, which indicates that the subsidence which develops from multi-seam mining is greater than 60 % of the mining height, as described in Section 3.3.2.

The maximum predicted tilts and strains due to mining in the Wambo, Arrowfield and Bowfield Seams were also provided in the 2003 EIS and the 2005 SEE. It was described in the subsidence report by Holt (2003) that:-

> "*Surface strains have been calculated using the empirical formulae provided in the Newcastle Subsidence Guideline. The empirical formula for tilt that is provided in the Newcastle Guideline is known to predict strains much lower than that measured for shallow workings. In the absence of more detailed prediction methods the Newcastle Guideline formulae have been adopted*",

> "*The values quoted are for single seam workings*", and

> "*Multi-seam workings would change the amount of surface strain because of likely re-working of previously subsided ground. The amounts cannot be accurately predicted by the methods set down in the Newcastle Coalfield Guideline because it is restricted to single seam workings*".

It was stated in the 2005 SEE, however, that the standard empirical formulae were modified based on the observed tilts and strains resulting from the extraction of United Collieries Panels 1 and 2. It was described in the subsidence report by Holt (2005) that:-

> "*Surface strains have been calculated using site specific empirical formulae of the same form developed for the published subsidence guidelines. The predictions are based on actual strain and tilt measurements and are not derived from smoothed subsidence data, so represent realistic maximum predicted values*".

It appears from the above extracts, that the predicted tilts and strains provided in the 2005 SEE were obtained using modified empirical formulae based on the DMR Newcastle Guidelines (Holla, 1987). Whilst these empirical formulae have been improved, based on the limited available multi-seam data, they are essentially based on higher depth of cover single-seam workings and, hence, are less reliable.

Based on this, it is difficult to compare the predicted tilts and strains provided in the 2005 SEE with those predicted based on the *Modified Layout*, as the Incremental Profile Method has been calibrated for multi-seam conditions using the more detailed local monitoring data.

For the above reasons, the predicted subsidence parameters, based on both the *Approved Layout* and the *Modified Layout*, have been determined using the calibrated Incremental Profile Method, which is described in Section 3.3. In this way, the predicted subsidence parameters based on these layouts can be directly compared.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature due to mining in the Wambo, Arrowfield and Bowfield Seams, based on the *Approved Layout*, is provided in Table 4.1. The values are the maxima within the Study Area obtained using the calibrated Incremental Profile Method, as described in Section 3.3.

Table 4.1 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature due to Mining in the Wambo, Arrowfield and Bowfield Seams Based on Approved Layout

Seams	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})
Wambo Seam	2250	50	2.0	2.0
Wambo and Arrowfield Seam	4750	70	2.5	2.5
Wambo, Arrowfield and Bowfield Seams	7600	90	3.0	3.0

The maximum predicted total subsidence within the Study Area due to mining in the Wambo, Arrowfield and Bowfield Seams, based on the *Approved Layout*, is 7600 mm, which represents around 76 % of the total extraction height of 10 metres.

The maximum predicted conventional tilt is 90 mm/m (i.e. 9 %), which represents a change in grade of greater than 1 in 11. The maximum predicted conventional hogging and sagging curvatures are both 3.0 km^{-1}, which represents a minimum radius of curvature of 0.3 kilometres.

4.2.3. Predictions for the Modified Layout

The predicted additional conventional subsidence contours due to the extraction of WMLW9 and WMLW10 only are shown in Drawing No. MSEC495-13. The predicted total conventional subsidence contours due to the extraction of WMLW1 to WMLW10, based on the *Modified Layout*, are shown in Drawing No. MSEC495-14. The contours include the affects of the previously extracted Homestead/Wollemi workings in the overlying Whybrow Seam.

A summary of the maximum predicted values of incremental conventional subsidence, tilt and curvature, due to the extraction of each of the proposed longwalls, is provided in Table 4.2. A summary of the maximum predicted total conventional subsidence parameters due to mining in the Wambo Seam, based on the *Modified Layout*, is provided in Table 4.3. The values are the maxima within the Study Area including the predictions due to the extraction of the approved WMLW1 to WMLW8.

Table 4.2 Maximum Predicted Incremental Conventional Subsidence, Tilt and Curvature due to the Extraction of the Proposed Longwalls in the Wambo Seam

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})
WMLW9 Only	2300	50	2.0	2.0
WMLW10 Only	2500	50	2.0	2.0

Table 4.3 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature after the Extraction of the Proposed Longwalls in the Wambo Seam

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 WMLW9	2300	50	2.0	2.0
After WMLW10	2600	50	2.0	2.0

The maximum predicted subsidence within the Study Area, resulting from the extraction of the proposed longwalls in the Wambo Seam, is 2600 mm which represents 100 % of the proposed extraction height of 2.6 metres. The maximum predicted subsidence occurs at the south-western (i.e. commencing) end of the proposed WMLW10.

The maximum predicted conventional tilt is 50 mm/m (i.e. 5 %), which represents a change in grade of greater than 1 in 20. The maximum predicted conventional hogging and sagging curvatures are both 2.0 km^{-1}, which represents a minimum radius of curvature of 0.5 kilometres.

WCPL has approval to extract future longwalls in the Arrowfield and Bowfield Seams beneath the currently active series of longwalls in the Wambo Seam. Whilst these future longwalls are not proposed to be modified, as part of this application, the predicted subsidence for these future longwalls has been included in this report to show the predicted total subsidence at the completion of all seams.

The predicted total conventional subsidence contours due to mining in the Wambo, Arrowfield and Bowfield Seams, based on the *Modified Layout*, are shown in Drawing No. MSEC495-15. The contours include the affects of the previously extracted Homestead/Wollemi workings in the overlying Whybrow Seam.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature due to mining in the Wambo, Arrowfield and Bowfield Seams, based on the *Modified Layout*, is provided in Table 4.4. The values are the maxima within the Study Area obtained using the calibrated Incremental Profile Method, as described in Section 3.3.

Table 4.4 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature due to Mining in the Wambo, Arrowfield and Bowfield Seams Based on Modified Layout

Seams	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})
Wambo Seam	2600	50	2.0	2.0
Wambo and Arrowfield Seam	5000	70	2.5	2.5
Wambo, Arrowfield and Bowfield Seams	7900	90	3.0	3.0

The maximum predicted total subsidence within the Study Area due to mining in the Wambo, Arrowfield and Bowfield Seams, based on the *Modified Layout*, is 7900 mm, which represents around 80 % of the total extraction height of 10 metres. The maximum predicted subsidence occurs towards the north-eastern (i.e. finishing) end of the proposed WMLW10.

The maximum predicted conventional tilt is 90 mm/m (i.e. 9 %), which represents a change in grade of greater than 1 in 11. The maximum predicted conventional hogging and sagging curvatures are both 3.0 km^{-1}, which represents a minimum radius of curvature of 0.3 kilometres.

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

The comparison of the maximum predicted total conventional subsidence parameters within the Study Area, based on the *Approved Layout* and the *Modified Layout*, is provided in Table 4.5. The values are the maxima within the Study Area obtained using the calibrated Incremental Profile Method, as described in Section 3.3.

Table 4.5 Comparison of Maximum Predicted Subsidence Parameters due to Mining in the Wambo, Arrowfield and Bowfield Seams

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})
Approved Layout	7600	90	3.0	3.0
Modified Layout	7900	90	3.0	3.0

It is noted, that the predictions for the *Approved Layout* are greater than that previously provided in the report by Holt (2005), which supported the 2005 SEE, as the Incremental Profile Method has been calibrated to the local monitoring data from the NWUM, whereas the original predictions had to rely on the prediction method outlined in the DMR Newcastle Guidelines (Holla, 1987). Also, more detailed multi-seam monitoring data from the NSW Coalfields has been gathered, since the 2005 SEE, which has allowed further calibration of the Incremental Profile Method, as described in Section 3.3.

It can be seen from Table 4.5, that the maximum predicted total vertical subsidence within the Study Area, based on the *Modified Layout*, of 7900 mm is similar to but slightly greater (i.e. 4 %) than that predicted based on the *Approved Layout* using the calibrated Incremental Profile Method.

The maximum predicted total tilt, hogging curvature and sagging curvature within the Study Area, based on the *Modified Layout*, are similar to those predicted based on the *Approved Layout* using the calibrated Incremental Profile Method.

The predicted profiles of conventional subsidence, tilt and curvature along Prediction Lines 1 and 2, based on the *Approved Layout* and *Modified Layout*, are illustrated in Fig. E.01 and E.02, respectively, in Appendix E. The locations of these prediction lines are shown in Drawing No. MSEC495-15. The predicted profiles have been based on those obtained using the calibrated Incremental Profile Method.

The predicted profiles resulting from the extraction of the approved WMLW1 to WMLW8 are shown as the solid cyan lines in these figures. The predicted profiles after the completion of the proposed WMLW9 and WMLW10 are shown as the solid blue lines.

The predicted profiles after the completion of the future longwalls in the Arrowfield Seam are shown as the dashed green lines (*Approved Layout*) and solid green lines (*Modified Layout*) in these figures. The predicted profiles after the completion of the future longwalls in the Bowfield Seam are shown as the dashed red lines (*Approved Layout*) and solid red lines (*Modified Layout*) in these figures.

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, the depth of bedrock and, in this case, multi-seam mining conditions. 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.

It has been found that, for single-seam mining conditions, applying a constant factor to the predicted maximum curvatures provides a reasonable prediction for the normal or conventional 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 Hunter Coalfield, it has been found that a factor of 10 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains for single-seam conditions. 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.

It is not simple to provide a similar relationship between curvature and strain for multi-seam mining conditions, since there is very limited empirical data to establish this relationship. In addition to this, localised strains also develop in multi-seam mining conditions, as the result of remobilising the existing goaf and chain pillars in the overlying seam, which are not directly related to curvature.

The magnitudes of the strains for the proposed WMLW9 and WMLW10 are expected to be similar to those observed, for multi-seam conditions, during the previously extracted WMLW1 to WMLW4 at the NWUM. These monitoring lines include the XL1-Line, XL2-Line and SC1-Line.

Extensive ground monitoring data has also been measured at Blakefield South Mine (BSM) where Longwalls 1 and 2 (BSLW1 and BSLW2) mined directly beneath the existing South Bulga longwalls in the overlying Whybrow Seam. The width-to-depth ratios for BSLW1 and BSLW2 vary between 2.0 and 3.0, which are similar to or greater than those for the proposed WMLW9 and WMLW10, which vary between 1.2 and 2.0. The interburden thickness between the BSLW1 and BSLW2 and the overlying workings in the Whybrow Seam vary between 70 metres and 90 metres, which is also similar to that for the proposed longwalls, which varies between 55 metres and 95 metres.

The range of potential strains above the proposed WMLW9 and WMLW10 has been determined using monitoring data from the previously extracted WMLW1 to WMLW4 at the NWUM, as well as from BSLW1 and BSLW2 at the BSM, where the mining geometry is reasonably similar to those for the proposed longwalls. The range of strains measured during the extraction of these longwalls should, therefore, provide a reasonable indication of the range of potential strains for the proposed longwalls.

The data used in the analysis of observed strains included those resulting from both conventional and non-conventional anomalous movements, but did not include those resulting from valley related 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 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 monitoring lines have been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of the previous longwalls at the NWUM and BSM, for survey bays that were located directly above goaf or the chain pillars that are located between the extracted longwalls, which has been referred to as "*above goaf*".

The strain distributions were analysed with the assistance of the centre of Excellence for Mathematics and Statistics of Complex Systems (MASCOS). A number of probability distribution functions were fitted to the empirical data. It was found that a *Generalised Pareto Distribution (GPD)* provided a good fit to the raw strain data.

The histograms of the maximum observed tensile and compressive strains measured for the survey bays located directly above goaf is provided in Fig. 4.1. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

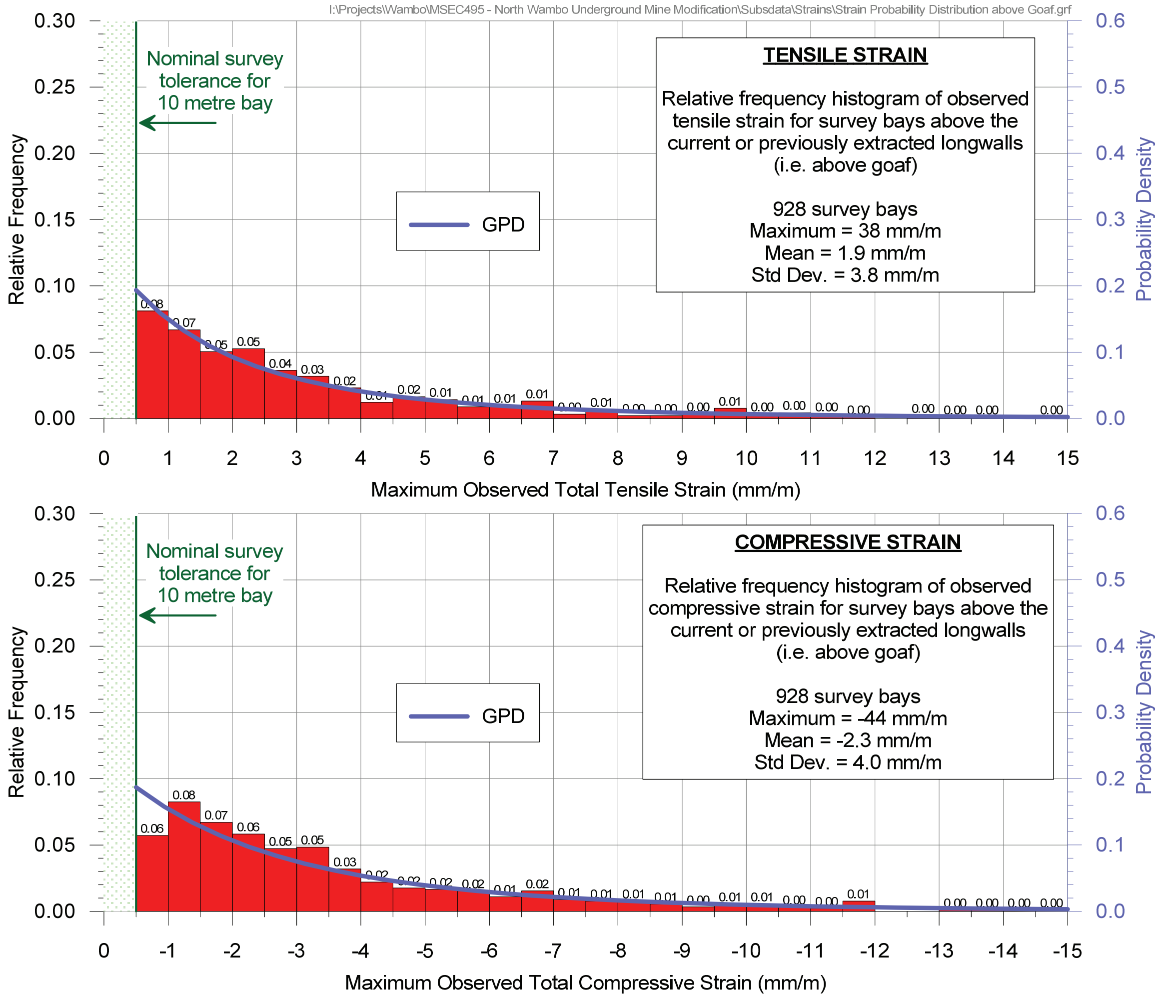

Fig. 4.1 Distributions of the Measured Maximum Tensile and Compressive Strains for Survey Bays Located Directly Above Goaf at the NWUM and BSM

Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during the longwall extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay).

The 95 % confidence levels for the maximum strains that the individual survey bays experienced at any time during mining were 8 mm/m tensile and 10 mm/m compressive. The 99 % confidence levels for the maximum strains that the individual survey bays experienced at any time during mining were 18 mm/m tensile and compressive.

4.4.2. Analysis of Strains 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 total tensile and compressive strains measured anywhere along the monitoring lines, for the monitoring lines at the NWUM and BSM, is provided in Fig. 4.2.

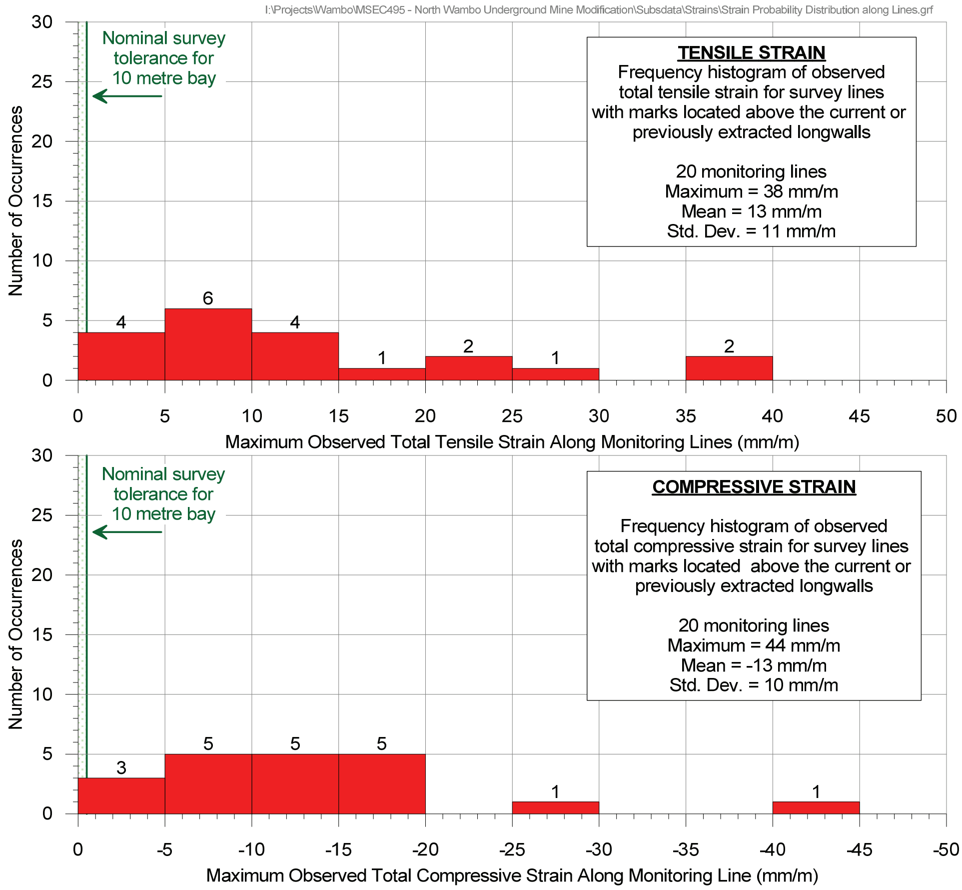

Fig. 4.2 Distributions of Measured Maximum Tensile and Compressive Strains along the Monitoring Lines at the NWUM and BSM

It can be seen from Fig. 4.2, that 10 of the 20 monitoring lines (i.e. 50 %) have recorded maximum total tensile strains of 10 mm/m, or less, and that 15 of the monitoring lines (i.e. 75 %) have recorded maximum total tensile strains of 20 mm/m, or less. It can also be seen, that 8 of the 20 monitoring lines (i.e. 40 %) have recorded maximum compressive strains of 10 mm/m, or less, and that 18 of the monitoring lines (i.e. 90 %) have recorded maximum compressive strains of 20 mm/m, or less.

4.5. Predicted Far-field Horizontal Movements

In addition to the conventional subsidence movements that have been predicted above and adjacent to the proposed longwalls, 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 predominately 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.

The observed incremental far-field horizontal movements, resulting from the extraction of a single longwall, are provided in Fig. 4.3. The confidence levels, based on fitted *Generalised Pareto Distributions* (GPDs), have also been shown in this figure to illustrate the spread of the data.

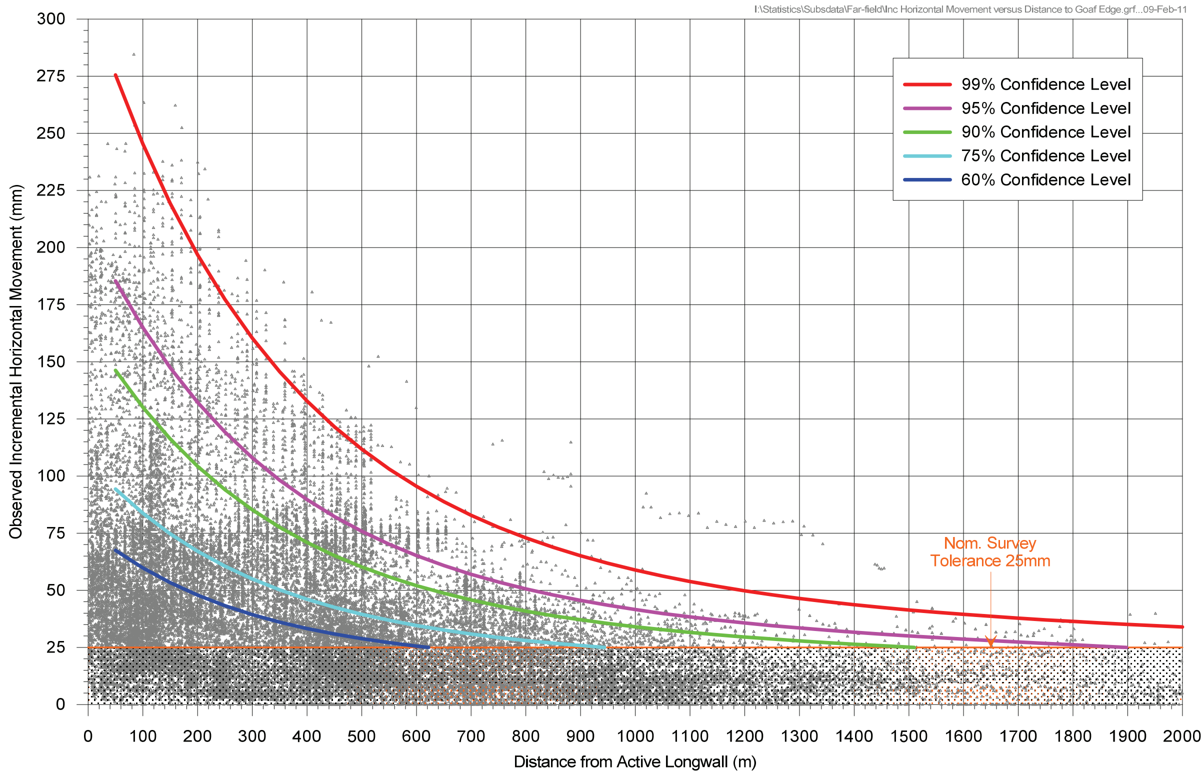

Fig. 4.3 Observed Incremental Far-Field Horizontal Movements

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 very small and could only be detected by precise surveys. Such movements tend to be bodily movements towards the extracted goaf area, and are accompanied by very low levels of strain, which are generally less than the order of survey tolerance (i.e. less than 0.3 mm/m).

The far-field horizontal movements, based on the *Modified Layout*, are expected to be similar to those based on the *Approved Layout*. The potential impacts of far-field horizontal movements on the natural and built features within the vicinity of the proposed longwalls are not expected to be significant. It is not considered necessary, therefore, that monitoring be established to measure the far-field horizontal movements resulting from the proposed mining.

4.6. Non-Conventional Ground Movements

It is likely non-conventional ground movements will occur within the Study Area, due to near surface geological features and multi-seam mining conditions, which were discussed in Section B.5. These non-conventional movements are often accompanied by elevated tilts, curvatures and strains which are likely to exceed the conventional predictions.

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, including both conventional and non-conventional anomalous strains, which is discussed in Section 4.4.

The magnitudes and likelihoods of non-conventional ground movements, based on the *Modified Layout*, are expected to be similar to those based on the *Approved Layout*. Also, the non-conventional ground movements resulting from the extraction of the proposed WMLW9 and WMLW10 are expected to be similar to those previously observed due to the extraction of the existing longwalls in the Wambo Seam at the NWUM.

4.7. 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 joints in the bedrock, the presence of near surface geological structures and multi-seam mining conditions.

Fractures and joints in bedrock occur naturally during the formation of the strata and from subsequent disturbance, tectonic movements, igneous intrusions, erosion and weathering processes. 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.

As subsidence occurs, surface cracks will generally appear in the tensile zone, i.e. within 0.1 to 0.4 times the depth of cover from the longwall perimeters. Most of the cracks will occur within a radius of approximately 0.1 times the depth of cover from the longwall perimeters. The cracks will generally be parallel to the longitudinal edges or the ends of the longwalls.

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

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

Surface cracking above the previously extracted longwalls at the NWUM have been typically in the order of 25 mm to 50 mm, with surface cracks in some locations greater than 150 mm. Photographs of typical cracking at the mine are provided in Fig. 4.4.

Fig. 4.4 Photographs of Surface Cracking at the NWUM

The surface cracking observed at the NWUM is similar to that observed for multi-seam mining elsewhere in the NSW Coalfields, where the depths of cover, extraction heights and interburden thicknesses were similar. For example, the surface cracking observed during the extraction of BSLW1 at the Blakefield South Mine beneath the previously extracted longwalls in the Whybrow Seam typically varied up to 50 mm, with a maximum observed crack width around 450 mm. Photographs of typical surface cracking observed above BSLW1 are provided in Fig. 4.5.

Fig. 4.5 Photographs of Surface Cracking above BSLW1 at the Blakefield South Mine

Further discussion on surface cracking is provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

4.8. Estimated Height of the Fractured Zone

The extraction of longwalls results in deformation throughout the overburden strata. The terminology used by different authors to describe the strata deformation zones above extracted longwalls varies considerably and caution should be taken when comparing the recommendations from differing authors. Forster (1995) noted that most studies have recognised four separate zones, as shown in Fig. 4.6, with some variations in the definitions of each zone.

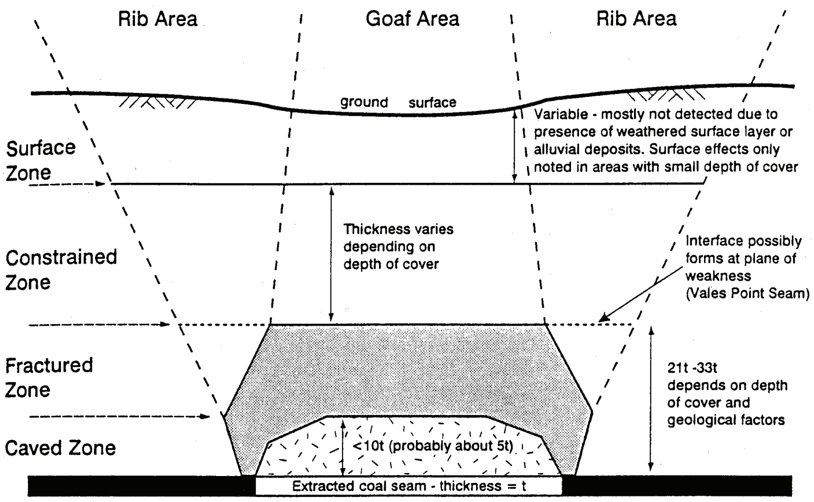

Fig. 4.6 Zones in the Overburden according to Forster (1995)

Peng and Chiang (1984) recognised only three zones as reproduced in Fig. 4.7.

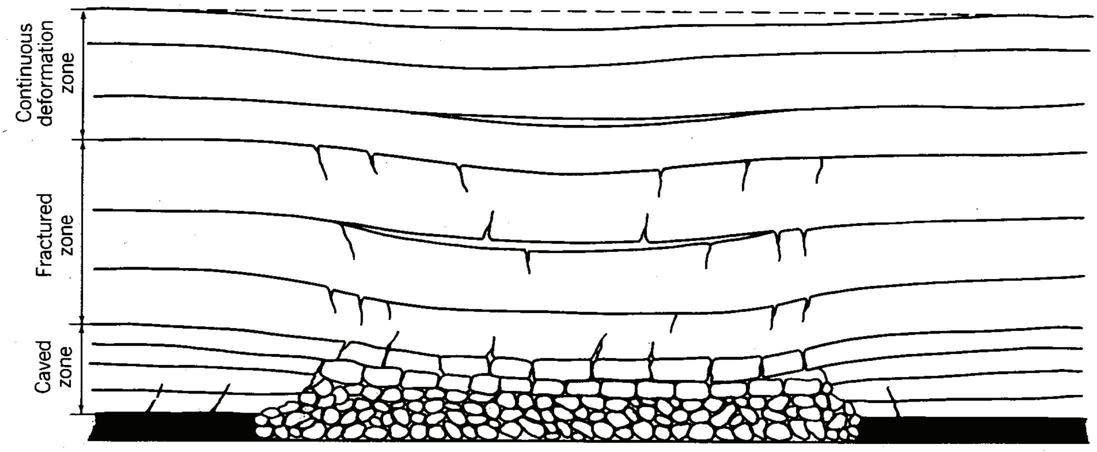

Fig. 4.7 Zones in the Overburden According to Peng and Chiang (1984)

McNally et al (1996) also recognised three zones, which they referred to as the caved zone, the fractured zone and the elastic zone. Kratzsch (1983) identified four zones, but he named them the immediate roof, the main roof, the intermediate zone and the surface zone.

For the purpose of these discussions, the following zones, as described by Singh and Kendorski (1981) and proposed by Forster (1995), as shown in Fig. 4.6, have been adopted:-

- *Caved* or *Collapsed Zone* comprises loose blocks of rock detached from the roof and occupying the cavity formed by mining. This zone can contain large voids. It should be noted, that some authors note primary and secondary caving zones.
- *Disturbed* or *Fractured Zone* comprises in-situ material lying immediately above the caved zone which have sagged downwards and consequently suffered significant bending, fracturing, joint opening and bed separation. It should be noted, that some authors include the secondary caving zone in this zone.
- *Constrained* or *Aquiclude Zone* comprises confined rock strata above the disturbed zone which have sagged slightly but, because they are constrained, have absorbed most of the strain energy without suffering significant fracturing or alteration to the original physical properties. Some bed separation or slippage can be present as well as some discontinuous vertical cracks, usually on the underside of thick strong beds, but not of a degree or nature which would result in connective cracking or significant increases in vertical permeability. Some increases in horizontal permeability can be found. Weak or soft beds in this zone may suffer plastic deformation.
- *Surface Zone* comprises unconfined strata at the ground surface in which mining induced tensile and compressive strains may result in the formation of surface cracking or ground heaving.

Just as the terminology differs between authors, the means of determining the extents of each of these zones also varies. Some of the difficulties in establishing the heights of the various zones of disturbance above extracted longwalls stem from the imprecise definitions of the fractured and constrained zones, the differing zone names, the use of different testing methods and differing interpretations of monitoring data, such as extensometer readings.

Some authors interpret the collapsed and fractured zones to be the zone from which groundwater or water in boreholes would flow freely into the mine and, hence, look for the existence of aquiclude or aquitard layers above this height to confirm whether surface water would or would not be lost into the mine.

The heights of the collapsed and fractured zones above extracted longwalls are affected by a number of factors, which include the:-

- widths of extraction,
- heights of extraction,
- depths of cover,
- types of previous workings, if any, above the current extractions,
- interburden thicknesses to previous workings,

- presence of pre-existing natural joints within each strata layer,
- thickness, geology, geomechanical properties and permeability of each strata layer,
- angle of break of each strata layer,
- spanning capacity of each strata layer, particularly those layers immediately above the collapsed and fractured zones,
- bulking ratios of each strata layer within the collapsed zone, and the
- presence of aquiclude or aquitard zones.

Some authors have suggested simple equations to estimate the heights of the collapsed and fractured zones based solely on the extracted seam height, others have suggested equations based solely on the widths of extraction, whilst others have suggested equations based on the width-to-depth ratios of the extractions. As this is a complex issue, MSEC understand that no simple geometrical equation can properly estimate the heights of the collapsed and fractured zones and a more thorough analysis is required, which should include other properties, such as geology and permeability, of the overburden strata. The following discussions provide background information and an estimation of the height of fracturing based on mining geometry only.

While there are many factors that may influence the height of fracturing and dilation, it is generally considered by various authors, e.g. Gale (2008) and Guo et al (2007), that an increase in panel width will generally result in an increase in the height of fracturing and dilation.

The theoretical height of the fractured zone can be estimated from the mining geometry, as being equal to the panel width (W) minus the span (w) divided by twice the tangent of the angle of break. These are illustrated in Fig. 4.8.

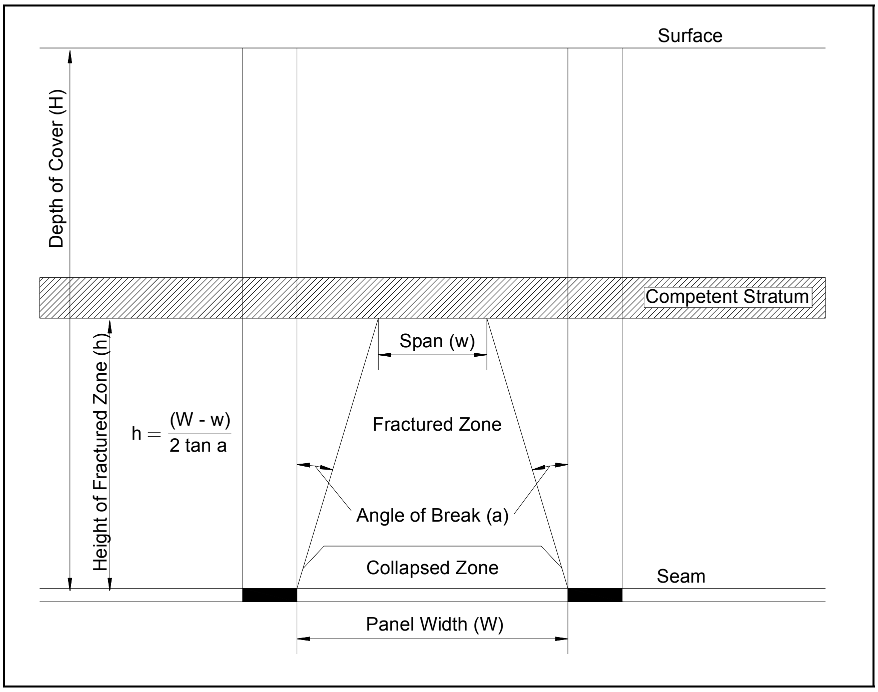

Fig. 4.8 Theoretical Model Illustrating the Development and Limit of the Fractured Zone

MSEC has gathered observed data sourced from a number of literature studies. The data points collected to date are shown in Fig. 4.9. The data points are compared with the results of the theoretical model developed by MSEC, using an angle of break of 20 degrees and spanning width of 30 metres. The results are also compared with lines representing factors of 1.0 times and 1.5 times the panel width, which was suggested by Gale (2008).

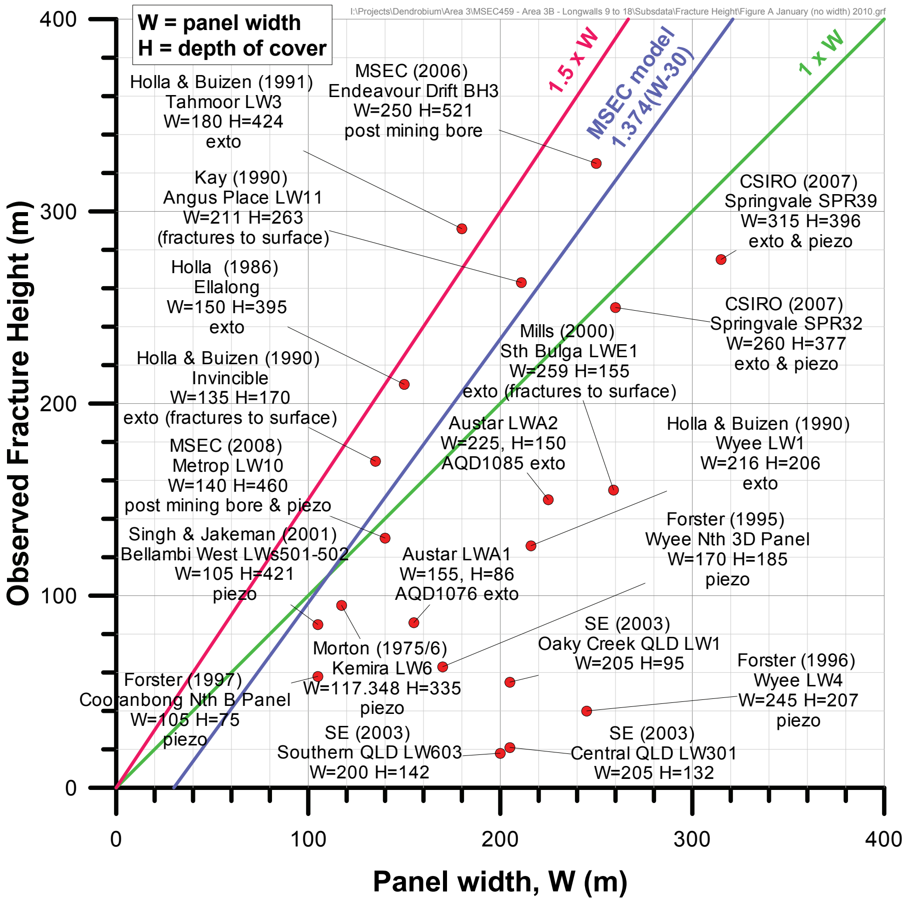

Fig. 4.9 Observed Fracture Heights versus Panel Width

It can seen from Fig. 4.9, that the MSEC model and Gale's suggested factors of 1.0 and 1.5 provide similar estimates for the height of fracturing based on panel width. As described previously, however, it is necessary to undertake a more detailed review of the site specific geology and permeability before determining whether these heights are reasonable for this site.

As described in Section 1.4, the overburden above the Wambo Seam comprises interbedded medium strength sandstones and siltstones. These strata would be expected to be capable of spanning at least 30 metres. If an average angle of break of 20 degrees is assumed, with an extracted panel width of 263 metres, then a height of 320 metres would be required above the seam to reduce the effective span to 30 metres. If an angle of break of 23 degrees is assumed, then a height of 275 metres would be required above the seam to reduce the effective span to 30 metres.

The interburden thickness between the Wambo and Whybrow Seams, directly above the proposed WMLW9 and WMLW10, varies between 55 metres and 95 metres. Also, the depth of cover to the Wambo Seam, directly above the proposed longwalls, varies between a minimum of 120 metres and 230 metres. It is expected, therefore, that the fractured zone resulting from the extraction of the proposed WMLW9 and WMLW10 would extend up to the existing workings in the Whybrow Seam, re-activate the existing goaf, with the fracturing extending up to the surface where the depths of cover are the shallowest.

This does not necessarily imply that there will be hydraulic connectivity between the surface and the seam, as the vertical fractures can be discontinuous near to the surface where the depths of cover are higher. It is not expected that there would be a hydraulic connection between the surface and seam, as none was observed after the extraction of the first four longwalls at the NWUM, which extracted directly beneath North Wambo Creek at a depth of cover of around 100 metres. This was anticipated by Holt (2003), who stated that "*This depth of cover is not expected to cause connection from the surface to the workings as it has not caused connection to single seam workings in the WCPL lease area before*".

Further discussions on the heights of fracturing and specific geology and permeability of the overburden strata are provided in the report by *Heritage Computing* (2012). Further details on sub-surface strata movements are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

5.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE NATURAL FEATURES

The following sections provide the descriptions, predictions and impact assessments for the natural features within the Study Area, as identified in Chapter 2. All significant natural features located outside the Study Area, which may be subjected to valley related or far-field horizontal movements and may be sensitive to these movements, have also been included as part of these assessments.

5.1. Natural Features

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

- drinking water catchment areas or declared special areas,
- known springs or groundwater seeps,
- seas or lakes,
- shorelines,
- natural dams,
- cliffs or pagodas,
- steep slopes,
- escarpments,
- swamps or wetlands,
- lands declared as critical habitat under the *Threatened Species Conservation Act 1995*,
- National Parks,
- State Recreation Areas or State Conservation Areas,
- State Forests,
- 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. Wollombi Brook

5.2.1. Description of the Wollombi Brook

The location of *Wollombi Brook* is shown in Drawing No. MSEC495-11. The brook is situated outside the Study Area, at a distance of 450 metres east of WMLW10, at its closest point to the proposed longwalls. Whilst the brook is located outside the Study Area, it has been included in the impact assessments, as it will experience small far-field movements and could be sensitive to these movements.

Wollombi Brook is a perennial stream associated with a shallow aquifer. The bed of the brook comprises alluvial deposits which are situated approximately 5 metres below the banks on each side of the brook. The natural grade of the brook, in the vicinity of the proposed longwalls, is less than 5 mm/m (i.e. less than 0.5 %), or a grade of less than 1 in 200.

The limit of the alluvium for Wollombi Brook is shown in Drawing No. MSEC495-11, which is based on the geophysical mapping undertaken by Groundwater Imaging (2012). The alluvium associated with the brook is located at a distance of 300 metres from the north-eastern end of WMLW10, at its closest point to the proposed longwalls.

Photographs of Wollombi Brook are provided in Fig. 5.1, which were taken near the confluence with North Wambo Creek. The locations of these photographs are indicated in Drawing No. MSEC495-11.

Fig. 5.1 Photographs of Wollombi Brook

5.2.2. Predictions for the Wollombi Brook

A summary of the maximum predicted additional subsidence, tilts and curvatures for Wollombi Brook, due to the extraction of the proposed WMLW9 and WMLW10, is provided in Table 5.1. The predictions include the affects of the existing workings in the overlying Whybrow Seam.

Table 5.1 Maximum Predicted Additional Subsidence, Tilts and Curvatures for Wollombi Brook due to the Extraction of the Proposed WMLW9 and WMLW10

Location	Longwall	Maximum Predicted Additional Subsidence (mm)	Maximum Predicted Additional Tilt (mm/m)	Maximum Predicted Additional Hogging Curvature (km^{-1})	Maximum Predicted Additional Sagging Curvature (km^{-1})
Wollombi Brook	WMLW9 Only	< 20	< 0.5	< 0.01	< 0.01
	WMLW9 and WMLW10	< 20	< 0.5	< 0.01	< 0.01

The section of Wollombi Brook in the vicinity of the proposed longwalls has a shallow incision into the alluvium. It is unlikely, therefore, that the brook would experience any significant valley related movements resulting from the extraction of the proposed longwalls.

5.2.3. Comparisons of Predictions for the Wollombi Brook

The predicted additional subsidence at Wollombi Brook, due to the extraction of the proposed WMLW9 and WMLW10, is less than 20 mm. The total predicted subsidence parameters for the brook, based on the *Modified Layout*, therefore, are the same as those based on the *Approved Layout*.

5.2.4. Impact Assessments for Wollombi Brook

The Wollombi Brook is located at a distance of 450 metres east of WMLW10, at its closest point to the proposed longwalls. At this distance, the brook is predicted to experience less than 20 mm of vertical subsidence. While it is possible that Wollombi Brook could experience very low levels of subsidence, it would not be expected to experience any measurable tilts, curvatures or ground strains.

The limit of alluvium for Wollombi Brook is shown in Drawing No. MSEC495-11. It can be seen from this drawing, that the alluvium associated with the brook is located outside the Study Area and, therefore, is also located outside the predicted additional 20 mm subsidence contour due to the extraction of the proposed WMLW9 and WMLW10.

It was stated, in the 2003 EIS, that the "*Mining of the longwall panels would be constrained by the subsidence exclusion zone limited to an angle of 26.5 degrees from the vertical to "Protected Land" (i.e. within 40 m of Wollombi Brook in accordance with the Rivers and Foreshore Improvement Act, 1948)*". The proposed WMLW9 and WMLW10 are located outside this subsidence exclusion zone.

It is unlikely, therefore, that Wollombi Brook or the associated alluvium would be adversely impacted as a result of the extraction of the proposed WMLW9 and WMLW10. That is, the potential subsidence impacts on the Wollombi Brook, due to the extraction of the proposed longwalls, are expected to be negligible. Further discussions on the potential impacts on the alluvial aquifer associated with Wollombi Brook are provided in the report by *Heritage Computing* (2012).

5.2.5. Impact Assessments for Wollombi Brook Based on Increased Predictions

If the actual subsidence exceeded that predicted by a factor of 2 times, it would still be expected that there would not be any measurable tilts, curvatures and strains at Wollombi Brook. In this case, it would still be unlikely that the brook would experience any adverse impacts as a result of the extraction of the proposed WMLW9 and WMLW10. That is, the potential subsidence impacts on the Wollombi Brook, due to the extraction of the proposed longwalls, would still be expected to be negligible.

5.2.6. Recommendations for Wollombi Brook

It is recommended that management strategies be developed which could include the installation of additional piezometers to measure the groundwater levels, and the establishment of ground monitoring lines to measure the actual limit of vertical subsidence, where the proposed longwalls are closest to the brook. The appropriate management strategies and monitoring for Wollombi Brook will be developed during the Extraction Plan stage for the proposed longwalls.

5.3. North Wambo, Wambo and Stony Creeks

5.3.1. Description of the Creeks

The North Wambo, Wambo and Stony Creeks are located in the vicinity to, but, outside the extents of the proposed WMLW9 and WMLW10. The locations of these creeks are shown in Drawing No. MSEC495-11. A summary of the minimum distances between these creeks and the proposed longwalls is provided in Table 5.2.

Table 5.2 Minimum Distances of the Creeks from the Proposed WMLW9 and WMLW10

Creek	Minimum Distance from the Proposed Longwalls (m)
North Wambo Creek	190 metres north of WMLW9
Wambo Creek	190 metres south-east of WMLW10
Stony Creek	Adjacent to the southern corner of WMLW10

The creeks commence in the Wollemi Escarpment and flow eastwards to where they join the Wollombi Brook. The natural grades of the creeks in the vicinity of the proposed longwalls are generally less than 10 mm/m (i.e. 1 %, or 1 in 100).

The creeks have shallow incisions into the natural surface soils which are derived from the Jerrys Plains Subgroup of the Wittingham Coal Measures. The lower reaches of the creeks, near the confluence of the Wollombi Brook, have exposed bedrock and there are also isolated outcropping further upstream. The creeks are ephemeral, but there are some standing pools in sections with exposed bedrock and, to a lesser extent, in the sections with natural surface soil beds. There are also significant debris accumulations which includes boulders and tree branches.

Photographs of North Wambo, Wambo and Stony Creeks are provided in Fig. 5.2, Fig. 5.3 and Fig. 5.4, respectively. The locations of these photographs are indicated in Drawing No. MSEC495-11.

Fig. 5.2 Photographs of North Wambo Creek

Fig. 5.3 Photographs of Wambo Creek

Fig. 5.4 Photographs of Stony Creek

5.3.2. Predictions for the Creeks

A summary of the maximum predicted additional subsidence, tilts and curvatures for the creeks, due to the extraction of the proposed WMLW9 and WMLW10, is provided in Table 5.3. The predictions include the affects of the existing workings in the overlying Whybrow Seam.

Table 5.3 Maximum Predicted Additional Subsidence, Tilts and Curvatures for the Creeks due to the Extraction of the Proposed WMLW9 and WMLW10

Location	Longwall	Maximum Predicted Additional Subsidence (mm)	Maximum Predicted Additional Tilt (mm/m)	Maximum Predicted Additional Hogging Curvature (km^{-1})	Maximum Predicted Additional Sagging Curvature (km^{-1})
North Wambo Creek	WMLW9 Only	< 20	< 0.5	< 0.01	< 0.01
	WMLW9 and WMLW10	< 20	< 0.5	< 0.01	< 0.01
Wambo Creek	WMLW9 Only	< 20	< 0.5	< 0.01	< 0.01
	WMLW9 and WMLW10	< 20	< 0.5	< 0.01	< 0.01
Stony Creek	WMLW9 Only	< 20	< 0.5	< 0.01	< 0.01
	WMLW9 and WMLW10	50	1	0.01	< 0.01

The creeks have shallow incisions into the natural surface soils and, therefore, are unlikely to experience any significant valley related movements resulting from the extraction of the proposed longwalls.

North Wambo and Wambo Creeks are located at distances of 190 metres from WMLW9 and WMLW10, respectively, at their closest points to the proposed longwalls. It is unlikely, therefore, that these creeks would experience any measurable tilts, curvatures or strains resulting from the extraction of these proposed longwalls.

Whilst Stony Creek is not located directly above the proposed longwalls, it is located immediately adjacent to the southern corner of the proposed WMLW10. The predicted strains in this section of creek have been determined by analysing the strains measured at similar distances from previously extracted longwalls in the Hunter and Newcastle Coalfields.

The distributions of observed strain for monitoring lines in the Hunter and Newcastle Coalfields for depths of cover between than 100 metres and 250 metres, measured at distances between 25 metres and 100 metres from edges of longwalls, are provided in Fig. 5.5. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

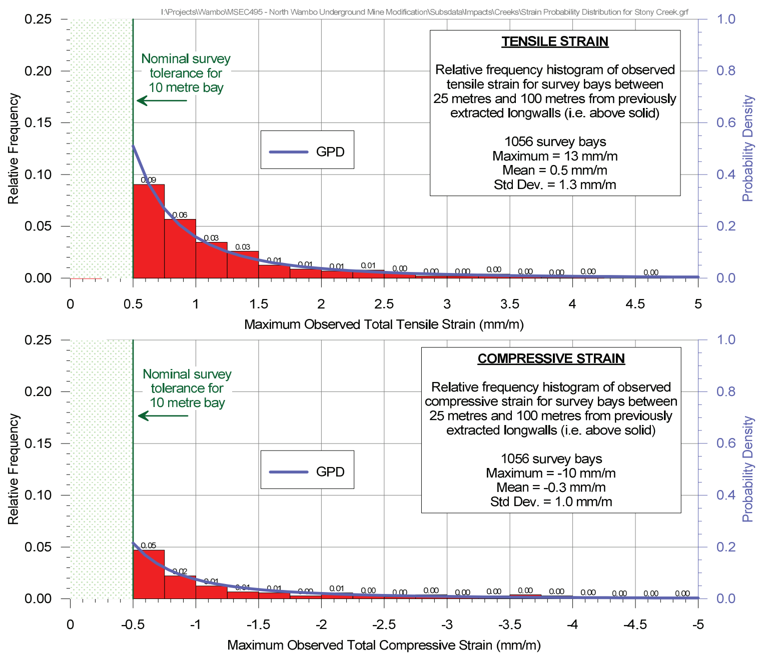

Fig. 5.5 Distribution of Observed Strains between 25 metres and 100 metres from Edges of Previously Extracted Longwalls in the Hunter and Newcastle Coalfields

Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during the longwall extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay).

The 95 % confidence levels for the maximum strains that the individual survey bays experienced at any time during mining were 2 mm/m tensile and compressive. The 99 % confidence levels for the maximum strains that the individual survey bays experienced at any time during mining were 6 mm/m tensile and compressive.

5.3.3. Comparisons of Predictions for the Creeks

The predicted additional subsidence at North Wambo and Wambo Creeks, due to the extraction of the proposed WMLW9 and WMLW10, are less than 20 mm. The total predicted subsidence parameters for these creeks, based on the *Modified Layout*, therefore, are the same as those based on the *Approved Layout*.

The predicted additional subsidence at Stony Creek, due to the extraction of the proposed WMLW9 and WMLW10, is 50 mm. Whilst this creek could experience small additional subsidence in the vicinity of the proposed longwalls, this is negligible when compared with the total subsidence where the creek is located directly above the longwalls in the Wambo, Arrowfield and Bowfield Seams further upstream.

5.3.4. Impact Assessments for the Creeks

North Wambo and Wambo Creeks are located 190 metres from WMLW9 and WMLW10, respectively, at their closest points to the proposed longwalls. At this distance, these creeks are predicted to experience less than 20 mm of vertical subsidence. While it is possible that the North Wambo and Wambo Creeks could experience very low levels of subsidence, they would not be expected to experience any significant tilts, curvatures or ground strains.

Stony Creek could experience low level subsidence movements where it is located closest to the proposed WMLW10. The ground strains could be sufficient to result in fracturing in the uppermost bedrock beneath the natural surface soils. Surface cracking in the bed of the creek could be visible if the depth to bedrock is relatively shallow.

The creek is ephemeral and, therefore, water only flows during and for a short period of time after each rain event. Any fracturing in the underlying bedrock is expected to be filled with the soil and alluvial deposits during subsequent flow events.

As described in Section 4.8, it is expected that the fractured zone above the proposed WMLW9 and WMLW10 would extend up to the existing workings in the overlying Whybrow Seam. It is not expected, however, that there would be a hydraulic connection between the surface and seam, as none was observed after the extraction of the first four longwalls at the NWUM, which extracted directly beneath North Wambo Creek at a depth of cover of around 100 metres. This was anticipated by Holt (2003), who stated that "*This depth of cover is not expected to cause connection from the surface to the workings as it has not caused connection to single seam workings in the WCPL lease area before*".

The potential impacts on North Wambo, Wambo and Stony Creeks, based on the *Modified Layout*, are the same as those assessed based on the *Approved Layout*.

5.3.5. Impact Assessments for the Creeks Based on Increased Predictions

If the actual subsidence exceeded that predicted by a factor of 2 times, it would still be expected that there would not be any measurable tilts, curvatures and strains at North Wambo and Wambo Creeks. In this case, it would still be unlikely that these creeks would experience any adverse impacts as a result of the extraction of the proposed WMLW9 and WMLW10.

Whilst Stony Creek could experience additional subsidence up to 100 mm, in the vicinity of the proposed longwalls, this is negligible when compared with the total subsidence where the creek is located directly above the longwalls in the Wambo, Arrowfield and Bowfield Seams further upstream.

In this case, the potential impacts on North Wambo, Wambo and Stony Creeks, based on the *Modified Layout*, would still be similar to those assessed based on the *Approved Layout*.

5.3.6. Recommendations for the Creeks

Management strategies have previously been developed for the sections of the creeks which have already been directly mined beneath at the NWUM. It is recommended that the existing management strategies for the creeks be reviewed and, where required, are revised to include the affects of the proposed longwalls.

5.4. Aquifers and Known Ground Water Resources

The descriptions, predictions and the assessment of potential impacts on the aquifers and groundwater resources within the Study Area are provided in the Groundwater Assessment report prepared by *Heritage Computing* (2012).

There are no *Ground Water Management Areas*, as defined by the Department of Environment, Climate Change and Water, within the Study Area. There are, however, registered groundwater bores in the vicinity of the Study Area, which as discussed in Section 6.10.

5.5. Steep Slopes

For the purposes of discussion in this report, a steep slope has been defined as an area of land having a natural gradient greater than 1 in 3 (i.e. a grade of 33 %, or an angle to the horizontal of 18°). The locations of any steep slopes were identified from the 1 metre surface level contours which were generated from the Lidar survey of the area.

There were no natural steep slopes identified within the Study Area, that is, the natural grades were less than 1 in 3. The surface grades are locally greater than 1 in 3, in some locations, such as the banks of the creeks and the walls of the farm dams and water storage dam.

5.6. Escarpments

There are no escarpments or cliffs located within the Study Area. The *Wollemi Escarpment* is located west of the Study Area and is at a distance greater than 1 kilometre west of the proposed longwalls, at its closest point. There were also no large rock platforms identified within the Study Area. There is some minor and isolated rock outcropping within the Study Area, primarily along the alignments of the drainage lines.

5.7. Land Prone to Flooding or Inundation

The land within the Study Area adjacent to the creeks could be susceptible to inundation, during major rainfall events, as the result of the surface water flows originating the steep slopes to the west of the Study Area.

5.8. Water Related Ecosystems

There are water related ecosystems associated with the drainage within the Study Area, which are described and assessed in the report prepared by *Niche Environmental and Heritage* (2012).

5.9. Threatened or Protected Species

An investigation of the flora and fauna within the Study Area has been undertaken, which is described and assessed in the reports prepared by *FloraSearch* (2012) and *Niche Environmental and Heritage* (2012).

5.10. National Parks or Wilderness Areas

The *Wollemi National Park* is located west of the proposed longwalls, outside the Study Area, at a distance more than 1 kilometre from the proposed longwalls.

5.11. Natural Vegetation

The land has been partially cleared in the south-western and north-eastern parts of the Study Area. There is natural vegetation adjacent to the water storage dam, near the middle of the Study Area, which can be seen from the aerial photograph in Fig. 1.1. There are also tree lines along the alignments of the creeks. A detailed survey of the natural vegetation has been undertaken and is described and assessed in the report prepared by *FloraSearch* (2012).

6.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE BUILT FEATURES

The following sections provide the descriptions, predictions and impact assessments for the built features within the Study Area, as identified in Chapter 2. All significant built features located outside the Study Area, which may be subjected to valley related or far-field horizontal movements and may be sensitive to these movements, have also been included as part of these assessments.

6.1. Public Utilities

As listed in Table 2.1, there were no Public Utilities identified within the Study Area, apart from the 11 kilovolt (kV) powerlines. There are unsealed roads, drainage culverts and water pipelines, which are owned and maintained by WCPL, which are also located within the Study Area. The descriptions, predictions and impact assessments for these built features are provided in the following sections.

6.2. Unsealed Roads

6.2.1. Descriptions of the Unsealed Roads

There are unsealed roads within the Study Area which are used for the mining operations, the locations of which are shown in Drawing No. MSEC495-12. Whilst there are no public roads within the Study Area, the road above WMLW10 is a right of way in favour of two private properties, the route of which may be varied on reasonable notice.

A photograph of a typical road within the Study Area is provided in Fig. 6.1. The location of this photograph is indicated in Drawing No. MSEC495-12.

Fig. 6.1 Photograph of an Unsealed Road

There are circular concrete drainage culverts within the Study Area where the unsealed roads cross the drainage lines.

6.2.2. Predictions for the Unsealed Roads

The unsealed roads are located across the Study Area and, therefore, could experience the full range of predicted subsidence movements. A summary of the maximum predicted mine subsidence parameters within the Study Area was provided in Chapter 4.

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

6.2.3. Comparisons of Predictions for the Unsealed Roads

Specific subsidence predictions for the unsealed roads were not provided in the subsidence report by Holt (2005) which supported the 2005 SEE. For this reason, comparisons have been made based on the predictions obtained from the calibrated Incremental Profile Method for both the *Approved Layout* and *Modified Layout*.

The comparison of the maximum predicted conventional subsidence parameters for the unsealed roads within the Study Area, based on the *Approved Layout* and the *Modified Layout*, is provided in Table 6.1.

Table 6.1 Comparison of the Maximum Predicted Subsidence Parameters for the Unsealed Roads due to Mining in the Wambo, Arrowfield and Bowfield Seams

Layout	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt Along Alignment (mm/m)	Maximum Predicted Total Conventional Tilt Across Alignment (mm/m)
Approved Layout	7600	90	3.0
Modified Layout	7900	90	3.0

It can be seen from the above Table 6.1, that the maximum predicted vertical subsidence for the unsealed roads within the Study Area, based on the *Modified Layout*, is similar to but slightly greater (i.e. 4 %) than that predicted based on the *Approved Layout*.

The maximum predicted tilts and curvatures for the unsealed roads, based on the *Modified Layout*, are similar to the maxima predicted based on the *Approved Layout*. It is noted that, whilst the predicted maxima for the roads do not change, as a result of the proposed modification, the predicted tilts increase in some locations and decrease in other locations away from the maxima.

It is also noted, that the predicted subsidence parameters for the unsealed roads, based on the *Approved Layout*, have been obtained using the calibrated Incremental Profile Method, as described in Section 3.3.2, which provides greater predictions than those previously provided in the report by Holt (2005) which supported the 2005 SEE. For this reason, the impact assessments for the unsealed roads have been provided in the following sections based on the predictions obtained from the calibrated Incremental Profile Method for the *Modified Layout*.

6.2.4. Impact Assessments for the Unsealed Roads

It is expected, at these magnitudes of predicted curvatures and strains, that cracking and heaving of the unsealed road surfaces would occur as each of the proposed and future longwalls mine beneath them. It is expected, however, that the unsealed roads could be maintained in safe and serviceable condition throughout the mining period using normal road maintenance techniques.

The drainage culverts could experience the full range of predicted subsidence movements. The predicted tilts could result in a reduction or, in some cases, a reversal of grade of the drainage culverts. In these cases, the culverts would need to be re-established to provide the minimum required grades. The predicted curvatures and ground strains could result in cracking of the concrete culverts. It may be necessary to repair, or in some cases, replace the affected culverts.

6.2.5. Impact Assessments for the Unsealed Roads Based on Increased Predictions

If the actual curvatures and strains exceeded those predicted by a factor of 2 times, the incidence of cracking, stepping and heaving of the unsealed surfaces would increase directly above the proposed longwalls and future longwalls. It would be expected, however, that any impacts could still be repaired using normal road maintenance techniques.

6.2.6. Recommendations for the Unsealed Roads

It is recommended that management strategies are developed for the unsealed roads, which could the establishment of methods to remediate the unsealed road surfaces which are adversely impacted by mining, if required. The roads should also be visually monitored during active subsidence. The appropriate management strategies and monitoring for the roads will be developed during the Extraction Plan stage for the proposed longwalls.

6.3. Water Pipelines

6.3.1. Description of the Water Pipelines

There are a number of water pipelines located within the Study Area which supply water for mining activities. The locations of these pipelines are shown in Drawing No. MSEC495-12. The polyethylene pipelines are shallow buried or resting on the natural ground. Photographs of the typical water pipelines within the Study Area are provided in Fig. 6.2. The locations of these photographs are indicated in Drawing No. MSEC495-12.

Fig. 6.2 Photographs of the Water Pipelines

The pipelines are owned and maintained by WCPL.

6.3.2. Predictions for the Water Pipelines

The water pipelines are located across the Study Area and, therefore, could experience the full range of predicted subsidence movements. A summary of the maximum predicted mine subsidence parameters within the Study Area was provided in Chapter 4.

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

6.3.3. Comparisons of Predictions for the Water Pipelines

Specific subsidence predictions for the water pipelines were not provided in the subsidence report by Holt (2005) which supported the 2005 SEE. For this reason, comparisons have been made based on the predictions obtained from the calibrated Incremental Profile Method for both the *Approved Layout* and *Modified Layout*.

The comparison of the maximum predicted conventional subsidence parameters for the water pipelines within the Study Area, based on the *Approved Layout* and the *Modified Layout*, is provided in Table 6.2.

Table 6.2 Comparison of the Maximum Predicted Subsidence Parameters for the Water Pipelines due to Mining in the Wambo, Arrowfield and Bowfield Seams

Layout	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt Along Alignment (mm/m)	Maximum Predicted Total Conventional Tilt Across Alignment (mm/m)
Approved Layout	7600	90	3.0
Modified Layout	7900	90	3.0

It can be seen from the above Table 6.2, that the maximum predicted vertical subsidence for the water pipelines within the Study Area, based on the *Modified Layout*, is similar to but slightly greater (i.e. 4 %) than that predicted based on the *Approved Layout*.

The maximum predicted tilts and curvatures for the water pipelines, based on the *Modified Layout*, are similar to the maxima predicted based on the *Approved Layout*. It is noted that, whilst the predicted maxima for the pipelines do not change, as a result of the proposed modification, the predicted tilts increase in some locations and decrease in other locations away from the maxima.

It is also noted, that the predicted subsidence parameters for the water pipelines, based on the *Approved Layout*, have been obtained using the calibrated Incremental Profile Method, as described in Section 3.3.2, which provides greater predictions than those previously provided in the report by Holt (2005) which supported the 2005 SEE. For this reason, the impact assessments for the water pipelines have been provided in the following sections based on the predictions obtained from the calibrated Incremental Profile Method for the *Modified Layout*.

6.3.4. Impact Assessments for the Water Pipelines

The water pipelines are pressure mains and are unlikely, therefore, to be affected to any great extent by changes in gradient due to vertical subsidence or tilt. The pipelines are shallow buried or resting on the natural ground and, therefore, it is unlikely that the localised curvatures or ground strains would be fully transferred into them.

Polyethylene pipelines are flexible and would be expected to tolerate the predicted curvatures and strains without adverse impact. It is possible, although unlikely, that minor impacts could occur, if they are anchored to the ground and the strains are fully transferred into the pipeline. Any impacts are expected to be of a minor nature which could be readily remediated.

Extensive experience of mining beneath polyethylene pipelines in the NSW Coalfields, where the mine subsidence movements were similar to those predicted for the proposed and future longwalls, indicates that incidences of impacts are low and generally of a minor nature.

6.3.5. Impact Assessments for the Water Pipelines Based on Increased Predictions

If the actual subsidence or tilts at the water pipelines exceeded those predicted by a factor of 2 times, it would still be unlikely that they would experience any adverse impacts as they are pressure mains. If the actual curvatures or strains exceeded those predicted by a factor of 2 times, it would still be unlikely that the water pipelines would experience any adverse impacts as they are shallow buried or resting on the natural ground.

6.3.6. Recommendations for the Water Pipelines

It is recommended that management strategies are developed for the water pipelines, which could include the establishment of methods to remediate the pipelines which are adversely impacted by mining, if required. The pipelines should also be visually monitored during active subsidence. The appropriate management strategies and monitoring for the pipelines will be developed during the Extraction Plan stage for the proposed longwalls.

6.4. Electrical Infrastructure

6.4.1. Description of the Electrical Infrastructure

There are two 11 kilovolt (kV) powerlines which cross directly above the proposed WMLW9 and WMLW10. These powerlines have been indicated as Branches 1 and 2 as shown in Drawing No. MSEC495-12. The powerlines comprise aerial cables supported by timber poles. Photographs of the 11 kV powerlines are provided in Fig. 6.3. The locations of these photographs are indicated in Drawing No. MSEC495-12.

Fig. 6.3 Photographs of the 11 kV Powerlines

The 11 kV powerline Branch 1 is owned by Ausgrid and the 11 kV powerline Branch 2 is owned by WCPL.

6.4.2. Predictions for the Electrical Infrastructure

The predicted profiles of conventional subsidence, tilt and curvature along the 11 kV Powerline Branches 1 and 2, based on the *Approved Layout* and *Modified Layout*, are illustrated in Fig. E.03 and E.04, respectively, in Appendix E. It is noted, that specific subsidence predictions for the powerlines were not provided in the subsidence report by Holt (2005) which supported the 2005 SEE. For this reason, the predicted subsidence parameters for the powerlines based on the *Approved Layout* have been determined using the calibrated Incremental Profile Method, as described in Section 3.3.

The predicted profiles resulting from the extraction of the approved WMLW1 to WMLW8 are shown as the solid cyan lines in these figures. The predicted profiles after the completion of the proposed WMLW9 and WMLW10 are shown as the solid blue lines.

The predicted profiles after the completion of the future longwalls in the Arrowfield Seam are shown as the dashed green lines (*Approved Layout*) and solid green lines (*Modified Layout*) in these figures. The predicted profiles after the completion of the future longwalls in the Bowfield Seam are shown as the dashed red lines (*Approved Layout*) and solid red lines (*Modified Layout*) in these figures.

Summaries of the maximum predicted total conventional subsidence parameters for the 11 kV powerlines within the Study Area due to mining in the Wambo, Arrowfield and Bowfield Seams, based on the *Approved Layout* and the *Modified Layout*, are provided in Table 6.3 and Table 6.4, respectively.

Table 6.3 Maximum Predicted Total Conventional Subsidence and Tilt for the 11 kV Powerlines due to Mining in the Wambo, Arrowfield and Bowfield Seams based on the Approved Layout

Seam	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt Along Alignment (mm/m)	Maximum Predicted Total Conventional Tilt Across Alignment (mm/m)
Wambo	1750	40	70
Wambo and Arrowfield Seams	3800	60	65
Wambo, Arrowfield and Bowfield Seams	6500	80	60

Table 6.4 Maximum Predicted Total Conventional Subsidence and Tilt for the 11 kV Powerlines due to Mining in the Wambo, Arrowfield and Bowfield Seams based on the Modified Layout

Seam	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt Along Alignment (mm/m)	Maximum Predicted Total Conventional Tilt Across Alignment (mm/m)
Wambo	2300	60	70
Wambo and Arrowfield Seams	4800	60	65
Wambo, Arrowfield and Bowfield Seams	7600	80	60

The cables are supported by timber poles above the ground and, therefore, they are not adversely impacted by ground strain.

6.4.3. Comparisons of Predictions for the Electrical Infrastructure

The comparison of the maximum predicted conventional subsidence parameters for the 11 kV powerlines within the Study Area, based on the *Approved Layout* and the *Modified Layout*, is provided in Table 6.5.

Table 6.5 Comparison of the Maximum Predicted Subsidence Parameters for the 11 kV Powerlines due to Mining in the Wambo, Arrowfield and Bowfield Seams

Layout	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt Along Alignment (mm/m)	Maximum Predicted Total Conventional Tilt Across Alignment (mm/m)
Approved Layout	6500	80	70
Modified Layout	7600	80	70

It can be seen from the above table, that the maximum predicted vertical subsidence for the 11 kV powerlines within the Study Area, based on the *Modified Layout*, is around 17 % greater than that predicted based on the *Approved Layout*.

The maximum predicted tilts for the powerlines, based on the *Modified Layout*, are similar to the maxima predicted based on the *Approved Layout*. It is noted that, whilst the predicted maxima for the powerlines do not change, as a result of the proposed modification, the predicted tilts increase in some locations and decrease in other locations away from the maxima.

It is also noted, that the predicted subsidence parameters for the 11 kV powerlines, based on the *Approved Layout*, have been obtained using the calibrated Incremental Profile Method, as described in Section 3.3.2, which provides greater predictions than those previously provided in the report by Holt (2005) which supported the 2005 SEE. For this reason, the impact assessments for the powerlines have been provided in the following sections based on the predictions obtained from the calibrated Incremental Profile Method for the *Modified Layout*.

6.4.4. Impact Assessments for the Electrical Infrastructure

The maximum predicted total tilts for the 11 kV powerlines due to mining in the Wambo, Arrowfield and Bowfield Seams, based on the *Modified Layout*, are 80 mm/m (i.e. 8 %) along the alignments and 70 mm/m (i.e. 7 %) across the alignments.

A rule of thumb used by some electrical engineers is that the tops of the poles may displace up to 2 pole diameters horizontally before remediation works are considered necessary. Based on pole heights of 15 metres and pole diameters of 250 mm, the maximum tolerable tilt at the pole locations is in the order of 33 mm/m.

It is likely, therefore, that the some preventive measures will be required for the 11 kV powerlines prior to the proposed and future longwalls mining directly beneath them. It may be necessary that preventive measures are implemented, which could include the installation of cable rollers, guy wires or additional poles, or the adjustment of cable catenaries.

Extensive experience of mining beneath powerlines in the NSW Coalfields, where the mine subsidence movements were similar to those predicted for the proposed and future longwalls, indicates that incidences of impacts are manageable with the implementation of the necessary strategies.

6.4.5. Impact Assessments for the Electrical Infrastructure Based on Increased Predictions

If the actual tilts at the 11 kV powerlines exceeded those predicted by a factor of 2 times, the likelihoods of impacts would also increase. It would be expected, however, that the types of preventive measures would not change, although these would be more extensive.

6.4.6. Recommendations for the Electrical Infrastructure

It is recommended that management strategies are developed for the 11 kV powerlines, which could include visual pre-mining inspections, so that the appropriate preventive measures can be established. The powerlines should also be visually monitored during active subsidence, so that they can be maintained in safe and serviceable conditions at all times. The appropriate management strategies and monitoring for the powerlines will be developed during the Extraction Plan stage for the proposed longwalls.

6.5. Public Amenities

As listed in Table 2.1, there were no Public Amenities identified within the Study Area.

6.6. Farm Land or Facilities

As listed in Table 2.1, the following Farm Land or Facilities were not identified within the Study Area nor the immediate surrounds:-

- Farm buildings or sheds,
- Tanks, gas or fuel storages,
- poultry sheds or glass houses,
- hydroponic systems or irrigation systems, and
- other significant farm features.

The following sections describe the farm land and facilities which have been identified within and in the vicinity of the Study Area.

6.7. Agriculture Utilisation and Agriculture Improvements

The land in the south-western and north-eastern parts of the Study Area has been partially cleared and is used for light grazing. There are also some farm features within the Study Area, which are described in the following sections.

6.8. Fences

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

Wire 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. These types of fences are generally flexible in construction and can usually tolerate tilts of up to 10 mm/m and strains of up to 5 mm/m without significant impacts.

It is likely, therefore, that some of the wire fences within the Study Area would be impacted as the result of the extraction of the longwalls in the Wambo, Arrowfield and Bowfield Seams. Any impacts on the wire fences could be remediated by re-tensioning the fencing wire, straightening the fence posts, and if necessary, replacing some sections of fencing.

The management of potential subsidence impacts on fences would be detailed in the relevant Extraction Plan for consideration and approval by the relevant authorities, and would be consistent with the requirements of the Wambo Development Consent.

6.9. Farm Dams

6.9.1. Descriptions of the Farm Dams

There are five farm dams which have been identified within the Study Area, the locations of which are shown in Drawing No. MSEC462-12. The farm dams are typically of earthen construction and have been established by localised cut and fill operations within the natural drainage lines. A photograph of a typical farm dam is provided in Fig. 6.4 below. The location of this photograph is indicated in Drawing No. MSEC495-12.

Fig. 6.4 Photograph of a Typical Farm Dam

The farm dams have surface areas varying between 90 m^2 and 3,200 m^2 and have maximum lengths varying between 10 metres and 85 metres. The farm dams are owned by WCPL.

6.9.2. Predictions for the Farm Dams

Summaries of the maximum predicted total conventional subsidence parameters for the farm dams due to mining in the Wambo, Arrowfield and Bowfield Seams, based on the *Approved Layout* and the *Modified Layout*, are provided in Table 6.6 and Table 6.7, respectively. It is noted, that specific subsidence predictions for the farm dams were not provided in the subsidence report by Holt (2005) which supported the 2005 SEE. For this reason, the predicted subsidence parameters for the farm dams based on the *Approved Layout* have been determined using the calibrated Incremental Profile Method, as described in Section 3.3

Table 6.6 Maximum Predicted Total Conventional Subsidence Parameters for the Farm Dams due to Mining in the Wambo, Arrowfield and Bowfield Seams Based on the Approved Layout

Seam	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})
Wambo Seam	350	10	0.20	0.10
Wambo and Arrowfield Seams	1900	15	0.35	0.20
Wambo, Arrowfield and Bowfield Seams	4050	25	0.50	0.30

Table 6.7 Maximum Predicted Total Conventional Subsidence Parameters for the Farm Dams due to Mining in the Wambo, Arrowfield and Bowfield Seams Based on the Modified Layout

Seam	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})
Wambo Seam	2300	30	0.90	0.90
Wambo and Arrowfield Seams	4150	40	0.90	0.90
Wambo, Arrowfield and Bowfield Seams	6300	50	0.90	0.90

The farm dams are located across the Study Area and, therefore, could experience the full range of predicted strains. The analysis of strains measured in the Hunter Coalfield, for previously extracted longwalls having similar width-to-depth ratios as the proposed longwalls, is provided in Section 4.4.

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

6.9.3. Comparisons of the Predictions for the Farm Dams

The comparison of the maximum predicted conventional subsidence parameters for the farm dams, based on the *Approved Layout* and the *Modified Layout*, is provided in Table 6.8.

Table 6.8 Comparison of the Maximum Predicted Subsidence Parameters for the Farm Dams due to Mining in the Wambo, Arrowfield and Bowfield Seams

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})
Approved Layout	4050	25	0.50	0.30
Modified Layout	6300	50	0.90	0.90

It can be seen from the above Table 6.8, that the maximum predicted vertical subsidence, tilt and curvatures for the farm dams, based on the *Modified Layout*, are around 55 % to 100 % greater than those predicted based on the *Approved Layout*. For this reason, the impact assessments for the farm dams have been provided in the following section based on the predictions obtained using the calibrated Incremental Profile Method for the *Modified Layout*.

6.9.4. Impact Assessments for the Farm Dams

The maximum predicted tilt for the farm dams due to mining in the Wambo, Arrowfield and Bowfield Seams, based on the *Modified Layout*, is 50 mm/m (i.e. 5.0 %), which represents a change in grade of 1 in 20. Mining induced tilts can affect the water levels around the perimeters of farm dams, with the freeboard increasing on one side and decreasing on the other.

The predicted changes in freeboard for the farm dams within the Study Area vary between 50 mm and 900 mm. The maximum predicted change in freeboard occurs at the largest farm dam located above the tailgate of the proposed WMLW9.

Changes in freeboard can potentially reduce the storage capacity of farm dams by causing them to overflow. If the storage capacity of any farm dams were adversely affected as a result of mining, these could be re-instated by raising the earthen walls of the affected dams.

It is expected, at the magnitudes of predicted curvatures and strains, that fracturing and buckling would occur in the uppermost bedrock beneath the natural surface soils. Surface cracking in the bases of the farm dams would be visible, especially where the depths of bedrock are relatively shallow. It may be necessary to remediate some of the farm dams, at the completion of mining, by excavating and re-establishing cohesive material in the beds of the farm dams to reduce permeability.

6.9.5. Impact Assessments for the Farm Dams Based on Increased Predictions

If the actual mine subsidence movements exceeded those predicted by a factor of 2 times, the extent of impacts to farm dams would also increase. It would still be expected, that the potential impacts could be remediated by excavating and re-establishing cohesive material in the beds of the farm dams to reduce permeability.

6.9.6. Recommendations for the Farm Dams

It is recommended that management strategies are developed for the farm dams, which could include the establishment of methods to remediate the dam bases and walls which are adversely impacted by mining, if required. The dams should also be visually monitored during active subsidence. The appropriate management strategies and monitoring for the farm dams will be developed during the Extraction Plan stage for the proposed longwalls.

6.10. Registered Ground Water Bores

The locations of the registered groundwater bores in the vicinity of the Study Area are shown in Drawing No. MSEC495-12. The locations and details of these were obtained from the Department of Natural Resources using the *Natural Resource Atlas* website (NRAtlas, 2012).

There were no registered groundwater bores identified within the Study Area. There were a number of bores identified in the vicinity of the Study Area, primarily to the north and east of the proposed longwalls, adjacent to Wollombi Brook. These groundwater bores are owned by WCPL and their intended use are for stock, irrigation, exploration, mining and monitoring. It appears from the information obtained from NRAtlas, that none of the bores in the immediate vicinity of the proposed longwalls are used for potable water.

It is likely that the groundwater bores will experience some impacts as the result of the proposed mining, particularly those located directly above the future longwalls in the Arrowfield and Bowfield Seams. Impacts may include temporary lowering of the piezometric surfaces, blockage of the bores due to differential horizontal displacements at different horizons within the strata and changes to groundwater quality. Such impacts on the groundwater bores can be readily managed.

Further discussions on the potential impacts on the groundwater are provided by the specialised groundwater consultant in the report by *Heritage Computing* (2012).

6.11. Industrial, Commercial or Business Establishments

As listed in Table 2.1, there were no Industrial, Commercial or Business Establishments identified within the Study Area, apart from Wambo and other mine related infrastructure, such as the water storage dam and exploration bores, which are described below.

6.12. Water Storage Dam

6.12.1. Description of the South Wambo Dam

The *South Wambo Dam* is located directly above the proposed WMLW9 and WMLW10. The dam is owned by WCPL and supplies water for mining activities.

The location of the South Wambo Dam is shown in Drawing No. MSEC495-12. The dam has a planar area of around 270,000 m^2 and a maximum planar dimension of around 700 metres. The dam wall follows the southern and eastern perimeters of the dam and is up to around 5 metres high.

Photographs of the South Wambo Dam are provided in Fig. 6.5. The locations of these photographs are indicated in Drawing No. MSEC495-12.

Fig. 6.5 Photographs of the South Wambo Dam

The South Wambo Dam has been approved by the NSW Dams Safety Committee.

6.12.2. Predictions for the South Wambo Dam

Summaries of the maximum predicted total conventional subsidence parameters for the South Wambo Dam due to mining in the Wambo, Arrowfield and Bowfield Seams, based on the *Approved Layout* and the *Modified Layout*, are provided in Table 6.9 and Table 6.10, respectively.

It is noted, that the South Wambo Dam was constructed after the 2005 SEE and, therefore, specific subsidence predictions for this dam were not provided in the subsidence report by Holt (2005). For this reason, comparisons have been made based on the predictions obtained from the calibrated Incremental Profile Method for both the *Approved Layout* and *Modified Layout*.

Table 6.9 Maximum Predicted Total Conventional Subsidence Parameters for the South Wambo Dam due to Mining in the Wambo, Arrowfield and Bowfield Seams Based on the Approved Layout

Seam	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})
Wambo Seam	1900	40	1.0	1.0
Wambo and Arrowfield Seams	2700	40	1.5	1.5
Wambo, Arrowfield and Bowfield Seams	5400	40	1.5	1.5

Table 6.10 Maximum Predicted Total Conventional Subsidence Parameters for the South Wambo Dam due to Mining in the Wambo, Arrowfield and Bowfield Seams Based on the Modified Layout

Seam	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})
Wambo Seam	2400	40	1.5	1.5
Wambo and Arrowfield Seams	5000	55	1.5	1.5
Wambo, Arrowfield and Bowfield Seams	7800	75	1.5	1.5

The South Wambo Dam is located directly above the proposed longwalls and, therefore, could experience the full range of predicted strains. The analysis of strains measured in the Hunter Coalfield, for previously extracted longwalls having similar width-to-depth ratios as the proposed longwalls, is provided in Section 4.4.

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

6.12.3. Comparisons of Predictions for the South Wambo Dam

The comparison of the maximum predicted conventional subsidence parameters for the South Wambo Dam, based on the *Approved Layout* and the *Modified Layout*, is provided in Table 6.11.

Table 6.11 Comparison of the Maximum Predicted Subsidence Parameters for the South Wambo Dam due to Mining in the Wambo, Arrowfield and Bowfield Seams

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})
Approved Layout	5400	40	1.5	1.5
Modified Layout	7800	75	1.5	1.5

It can be seen from the above Table 6.11, that the maximum predicted vertical subsidence and tilt for the South Wambo Dam, based on the *Modified Layout*, are around 44 % and 88 %, respectively, greater than those predicted based on the *Approved Layout*. It is noted, however, that vertical subsidence and tilt do not result in adverse impacts on the integrity of the dam.

The maximum predicted curvatures for the South Wambo Dam, based on the *Modified Layout*, are similar to those predicted based on the *Approved Layout*. Whilst the predicted maxima are similar for the dam, the local predicted curvatures increase, away from the maximum, as a result of the proposed modification.

For this reason, the impact assessment for the South Wambo Dam has been provided in the following section based on the predictions obtained using the calibrated Incremental Profile Method for the *Modified Layout*.

6.12.4. Impact Assessments for the South Wambo Dam

The predicted subsidence around the perimeter of the South Wambo Dam due to mining in the Wambo, Arrowfield and Bowfield Seams, based on the *Modified Layout*, varies between a minimum of 3,500 mm and a maximum of 7,900 mm. The predicted change in freeboard for the dam is greater than 2 metres and, therefore, could be sufficient for the stored water to top the dam wall.

It is expected, at the magnitudes of predicted curvatures and strains, that fracturing and buckling would occur in the uppermost bedrock beneath the South Wambo Dam. Cracking in the base of the dam or in the dam wall could result in the loss of stored water from the dam.

The South Wambo Dam is owned by WCPL and, therefore, it will be necessary for the mine to develop management strategies for the dam, which could include lowering the water level or completely draining the dam prior to directly mining beneath it. The management strategies for the South Wambo Dam will be developed as part of the Extraction Plan process.

6.12.5. Impact Assessments for the South Wambo Dam Based on Increased Predictions

If the actual mine subsidence movements exceeded those predicted by a factor of 2 times, the likelihood of impact on the South Wambo Dam would also increase. It would be expected, however, that the management strategies would not change, but the extents of impacts and, hence, remediation would increase.

6.12.6. Recommendations for the South Wambo Dam

It is recommended that management strategies are developed for the South Wambo Dam, which could include the establishment of methods to remediate the dam base and wall, if required. It is also recommended that a ground monitoring line be established, following the base of the dam wall, to measure the actual subsidence movements and to detect any localised or irregular ground movements. The appropriate management strategies and monitoring for the South Wambo Dam will be developed during the Extraction Plan stage for the proposed longwalls.

6.13. Exploration Bores

The locations of the exploration bores in the vicinity of the proposed longwalls are shown in Drawing No. MSEC495-12. The exploration bores are located directly above the proposed longwalls and, therefore, could experience the full range of predicted subsidence movements, which were described in Chapter 4. It is likely, therefore, that fracturing and shearing would occur in the boreholes as the result of mining. It is recommended that the exploration bores are capped prior to being directly mined beneath.

6.14. Archaeological Sites

6.14.1. Descriptions of the Archaeological Sites

There are no lands within the Study Area declared as an Aboriginal Place under the *National Parks and Wildlife Act 1974*. There are a number of archaeological sites which have been identified within the Study Area which are shown in Drawing No. MSEC495-12. A summary of these archaeological sites is provided in Table 6.12 below.

Table 6.12 Archaeological Sites within the Study Area

Site Name	Location	Description
Wambo Site 45	South-west of proposed WMLW10	Isolated find
Wambo Site 46	Directly above proposed WMLW10	Artefact scatter
Wambo Site 47	South-west of proposed WMLW 9	Isolated find
Wambo Site 48	Directly above proposed WMLW9	Isolated find
Wambo Site 55	Directly above approved WMLW8	Artefact scatter
Wambo Site 56	Directly above approved WMLW8	Isolated find
Wambo Site 57	Above proposed WMLW9 chain pillar	Artefact scatter
Wambo Site 58	Directly above proposed WMLW9	Isolated find
Wambo Site 59	Directly above proposed WMLW9	Isolated find
Wambo Site 60	Directly above proposed WMLW9	Artefact scatter
Wambo Site 61	Directly above approved WMLW8	Artefact scatter
Wambo Site 98b	Above north-eastern end of WMLW9	Artefact scatter
Wambo Site 333	Directly above proposed WMLW9	Artefact scatter
Wambo Site 338	Directly above proposed WMLW9	Artefact scatter
Wambo Site 348	Directly above approved WMLW8	Artefact scatter
Wambo Site 351	Directly above approved WMLW8	Artefact scatter
Wambo Site 352	Directly above proposed WMLW9	Artefact scatter
Wambo Site 353	Above proposed WMLW9 chain pillar	Artefact scatter
Wambo Site 354	South-west of proposed WMLW9	Artefact scatter
Wambo Site 356	Directly above proposed WMLW9	Artefact scatter
Wambo Site 357	Directly above proposed WMLW9	Artefact scatter
Wambo Site 358	Directly above proposed WMLW10	Isolated find
Wambo Site 360	Above proposed WMLW9 chain pillar	Scar tree
Wambo Site 361	Directly above proposed WMLW9	Isolated find
Wambo Site 362	Directly above proposed WMLW9	Artefact scatter
Wambo Site 363	South of proposed WMLW10	Artefact scatter

The archaeological sites comprise artefact scatters, isolated finds, and a scarred tree. Detailed descriptions of the archaeological sites within the Study Area are provided by *RPS* (2012).

6.14.2. Predictions for the Archaeological Sites

The predicted total conventional subsidence, tilts and curvatures for the archaeological sites within the Study Area, based on the *Approved Layout* and the *Modified Layout*, are provided in Table D.01, in Appendix D. The predicted tilts are the maxima after the completion the longwalls in the Wambo, Arrowfield and Bowfield Seams. The predicted curvatures are the maxima at any time during or after the extraction of the longwalls.

It is noted, that specific subsidence predictions for the archaeological sites were not provided in the subsidence report by Holt (2005) which supported the 2005 SEE. For this reason, the predicted subsidence parameters for these sites based on the *Approved Layout* have been determined using the calibrated Incremental Profile Method, as described in Section 3.3.

Summaries of the maximum predicted total conventional subsidence parameters for the archaeological sites within the Study Area due to mining in the Wambo, Arrowfield and Bowfield Seams, based on the *Approved Layout* and the *Modified Layout*, are provided in Table 6.13 and Table 6.14, respectively.

Table 6.13 Maximum Predicted Total Conventional Subsidence Parameters for the Archaeological Sites due to Mining in the Wambo, Arrowfield and Bowfield Seams Based on the Approved Layout

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})
Artefact Scatters	5300	40	0.7	1.0
Isolated Finds	4300	25	0.5	0.4
Scarred Tree	3000	15	0.5	0.1

Table 6.14 Maximum Predicted Total Conventional Subsidence Parameters for the Archaeological Sites due to Mining in the Wambo, Arrowfield and Bowfield Seams Based on the Modified Layout

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})
Artefact Scatters	6200	50	1.0	1.0
Isolated Finds	6400	50	2.0	2.0
Scarred Tree	3300	25	0.6	0.1

The archaeological sites are located across the Study Area and, therefore, could experience the full range of predicted strains. The analysis of strains measured in the Hunter Coalfield, for previously extracted longwalls having similar width-to-depth ratios as the proposed longwalls, is provided in Section 4.4.

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

6.14.3. Comparisons of Predictions for the Archaeological Sites

The comparisons of the maximum predicted total conventional subsidence parameters for the archaeological sites within the Study Area, based on the *Approved Layout* and the *Modified Layout*, are provided in Table 6.15, Table 6.16 and Table 6.17.

Table 6.15 Comparison of the Maximum Predicted Subsidence Parameters for the Artefact Scatters due to Mining in Wambo, Arrowfield and Bowfield Seams

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})
Approved Layout	5300	40	0.7	1.0
Modified Layout	6200	50	1.0	1.0

Table 6.16 Comparison of the Maximum Predicted Subsidence Parameters for the Isolated Finds due to Mining in Wambo, Arrowfield and Bowfield Seams

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})
Approved Layout	4300	25	0.5	0.4
Modified Layout	6400	50	2.0	2.0

Table 6.17 Comparison of the Maximum Predicted Subsidence Parameters for the Scarred Tree due to Mining in Wambo, Arrowfield and Bowfield Seams

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})
Approved Layout	3000	15	0.5	0.1
Modified Layout	3300	25	0.6	0.1

It can be seen from the above tables, that the maximum predicted vertical subsidence for the archaeological sites within the Study Area, based on the *Modified Layout*, are between 10 % and 50 % greater than those predicted based on the *Approved Layout*. Also, the maximum predicted tilts for these sites, based on the *Modified Layout*, are between 25 % and 100 % greater than those predicted based on the *Approved Layout*. It is noted, however, that vertical subsidence and tilt do not result in adverse impacts on these types of archaeological sites.

The maximum predicted curvatures for the artefact scatters and the scarred tree, based on the *Modified Layout*, are similar to those predicted based on the *Approved Layout*. Whilst the predicted maxima are similar for these sites, the predicted curvatures at individual sites increase as a result of the proposed modification. Also, the maximum predicted curvatures for the isolated finds, based on the *Modified Layout*, are greater than those predicted based on the *Approved Layout*.

It is also noted, that the predicted subsidence parameters for the archaeological sites, based on the *Approved Layout*, have been obtained using the calibrated Incremental Profile Method, as described in Section 3.3, which provides greater predictions than those previously provided in the report by Holt (2005) which supported the 2005 SEE. For this reason, the impact assessments for the archaeological sites have been provided in the following sections based on the predictions obtained using the calibrated Incremental Profile Method for the *Modified Layout*.

6.14.4. Impact Assessments for the Artefact Scatters and Isolated Finds

There are 17 sites comprising artefact scatters within the Study Area, being Wambo Sites 46, 55, 57, 60, 61, 98b, 333, 338, 348, 351, 352, 353, 354, 356, 357, 362 and 363. There are eight sites comprising isolated finds within the Study Area, being Wambo Sites 45, 47, 48, 56, 58, 59, 358 and 361.

The maximum predicted total tilt due to mining in the Wambo, Arrowfield and Bowfield Seams, based on the *Modified Layout*, is 50 mm/m (i.e. 5 %), which represents a change in grade of 1 in 20. The maximum predicted additional tilt for these sites, due to the proposed modification, is 10 mm/m (i.e. 1 %), which represents a change in grade of 1 in 100. It is unlikely that these sites would experience any adverse impacts resulting from the mining induced tilts.

The maximum predicted total curvature for the artefact scatters and isolated finds due to mining in the Wambo, Arrowfield and Bowfield Seams, based on the *Modified Layout*, is 2.0 km^{-1} hogging and sagging, which represents a minimum radius of curvature of 0.5 kilometres. The maximum predicted additional curvature for these sites, due to the proposed modification, are 1.5 km^{-1} hogging and 1.9 km^{-1} sagging, which represent minimum radii of curvature of 0.7 kilometre and 0.5 kilometres, respectively.

These sites can potentially be affected by cracking of the surface soils as a result of mine subsidence movements. It is unlikely, however, that the scattered artefacts or isolated finds themselves would be impacted by surface cracking. It is possible, however, that if remediation of the surface was required after mining, that these works could potentially impact these sites.

It is recommended that WCPL seek the required approvals from the appropriate authorities, in the event that remediation of the surface is required in the locations of the artefact scatters and isolated finds.

Further assessments of the potential impacts on the open sites are provided in a report by *RPS* (2012).

6.14.5. Impact Assessments for the Scarred Tree

There is one scarred tree within the Study Area, being Wambo Site 360, which is located above the chain pillar between the approved WMLW8 and the proposed WMLW9 in the Wambo Seam.

It has been found, from past longwall mining experience, that the incidence of impacts on trees is extremely rare. Impacts on trees have only been previously observed where the depths of cover were extremely shallow, in the order of 50 metres or less, or on very steeply sloping terrain, in the order of 1 in 1 or greater.

In the location of the scarred tree, the depths of cover are 125 metres to the existing workings in the Whybrow Seam, 210 metres to the proposed longwalls in the Wambo Seam, 380 metres to the future longwalls in the Arrowfield Seam, and 410 metres to the future longwalls in the Bowfield Seam. The natural surface in this location is relatively flat, with the natural gradient being less than 1 in 3. It is unlikely, therefore, that the scarred tree would be adversely impacted as a result of the extraction of the proposed and future longwalls.

Large surface cracking or ground heaving could occur as a result of the multi-seam mining, which is described in Section 4.7. The incidence of the larger surface deformations being coincident with the scarred tree is considered low.

Further assessments of the potential impacts on the scarred tree are provided in a report by *RPS* (2012).

6.14.6. Impact Assessments for the Archaeological Sites Based on Increased Predictions

If the actual mine subsidence at the archaeological sites exceeded those predicted by a factor of 2 times, the likelihoods and extents of cracking in the surface soils would also increase. It would still be unlikely that the artefacts scatters or isolated finds themselves would be impacted by the surface cracking and the methods of remediation, if required, would not be expected to change. It would also be unlikely that the scarred tree would be impacted by the surface cracking, as mining induced impacts have not been observed on trees in the NSW Coalfields where the depths of cover have been greater than 50 metres, such as the case within the Study Area.

6.15. State Survey Control Marks

The locations and details of the state survey control marks were obtained from the *Land and Property Management Authority* using the *Six Viewer* (2012). There were no state survey control marks identified within or in the immediate vicinity of the Study Area. There were state survey control marks identified further afield, outside the extents of Drawing No. MSEC495-12, which are located at distances greater than 1.5 kilometres from the proposed longwalls.

The survey control marks located in the area could be affected by far-field horizontal movements, up to 3 kilometres outside the extents of the proposed longwalls. Far-field horizontal movements and the methods used to predict such movements are described further in Sections 4.5 and B.4.

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

APPENDIX A. REFERENCES

References

DMR (1998). *Geological Series Sheet 9032-I-N (Edition 1)*. Department of Mineral Resources, 1988.

DMR (1993). *Hunter Coalfield Regional Geology 1:100 000 Geology Map, 2nd Edition*. Geological Survey of New South Wales, Sydney. Department of Mineral Resources, 1993.

DMR (2003). *Guidelines for Applications for Subsidence Management Approvals*. NSW Department of Mineral Resources, December 2003.

Earth Data (2011). *DDH WA91 Geological Log*. Earth Data Pty Ltd. September 2011.

FloraSearch (2012). *North Wambo Underground Mine Modification Flora Assessment*.

Forster (1995). *Impact of Underground Mining on the Hydrogeological Regime, Central Coast NSW*. Engineering Geology of the Newcastle-Gosford Region. Australian Geomechanics Society. Newcastle, February 1995.

Gale (2008). *Aquifer Inflow Prediction above Longwall Panels*. Winton, G. SCT Operations. ACARP Research Project No. C13013, September 2008.

Groundwater Imaging (2012). *A Transient Electromagnetic Investigation of the Extent of the Wollombi Brook Alluvium at the Wambo Coal Mine Site*. Groundwater Imaging Pty Ltd, July 2012.

Guo et al (2007). *Hydrogeological Response to Longwall Mining*. Guo, H., Adhikary, D.P., Gaveva, D. CSIRO Exploration and Mining. ACARP Research Project No. C14033, October 2007.

Heritage Computing (2012). *North Wambo Underground Mine Modification Groundwater Review*.

Holla, L. and Armstrong, M., (1986). *Measurement of Sub-Surface Strata Movement by Multi-wire Borehole Instrumentation*. Proc. Australian Institute of Mining and Metallurgy, 291, pp. 65-72.

Holla, L., (1987). *Mining Subsidence in New South Wales - 1. Surface Subsidence Prediction in the Newcastle Coalfield.* Department of Mineral Resources.

Holt (2003). *Wambo Development Project Subsidence Assessment*. G. E. Holt and Associates Pty Ltd. Document No. SUBREP-06, April 2003.

Holt (2005). *Review of Subsidence Assessment for Re-Orientation of Wambo Seam Longwall Panels for the Wambo Development Project*. G. E. Holt and Associates Pty Ltd. 18th January 2005.

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

Li et al (2007). *A Case Study on Multi-seam Subsidence with Specific Reference to Longwall Mining under Existing Longwall Goaf*. Li, G., Steuart, P., and Pâquet, R. Mine Subsidence Technological Society Seventh Triennial Conference. The University of Wollongong, November 2007. pp111 ~ 125.

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

Niche Environmental and Heritage (2012). *North Wambo Underground Mine Modification Terrestrial Fauna Assessment*.

NRAtlas, (2012). *Natural Resource Atlas* website, viewed on the 30th August 2012. The Department of Natural Resources. http://nratlas.nsw.gov.au/

Patton and Hendron (1972). *General Report on Mass Movements*. Patton, F.D., and Hendron, A.J. Proc. 2nd Intl. Congress of International Association of Engineering Geology, V-GR1-V-GR57.

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

RPS (2012). *North Wambo Underground Mine Modification Aboriginal Cultural Heritage Assessment*.

SEE (2005). *Wambo Development Project - Wambo Seam Underground Mine Modification – Statement of Environmental Effects*. Resource Strategies Pty Ltd. Project No. WAM-04-08. Document No. SEE-01-I. January 2005.

Singh and Kendorski (1981). *Strata Disturbance Prediction for Mining Beneath Surface Water and Waste Impoundments*. Singh, M.M., and Kendorski, F.D. Proc. First Conference on Ground Control in Mining, West Virginia University, PP 76-89.

Six Viewer (2012). Spatial Information Exchange, accessed on the 30th August 2012. Land and Property Information. https://www.six.nsw.gov.au/wps/portal/

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

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

APPENDIX B. OVERVIEW OF LONGWALL MINING, DEVELOPMENT OF SUBSIDENCE AND MINE SUBSIDENCE PARAMETERS

APPENDIX B OVERVIEW OF LONGWALL MINING, DEVELOPMENT OF SUBSIDENCE AND MINE SUBSIDENCE PARAMETERS

B.1. Introduction

This appendix provides a brief overview of longwall mining, the development of mine subsidence and the parameters which are typically used to quantify mine subsidence movements. Further details 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*.

B.2. Overview of Longwall Mining

WCPL has approved to extract longwalls in the Wambo Seam, Arrowfield and Bowfield Seams at the NWUM. A generic cross section through the immediate roof strata and along the length of a typical longwall, at the coal face, is shown in Fig. B. 1.

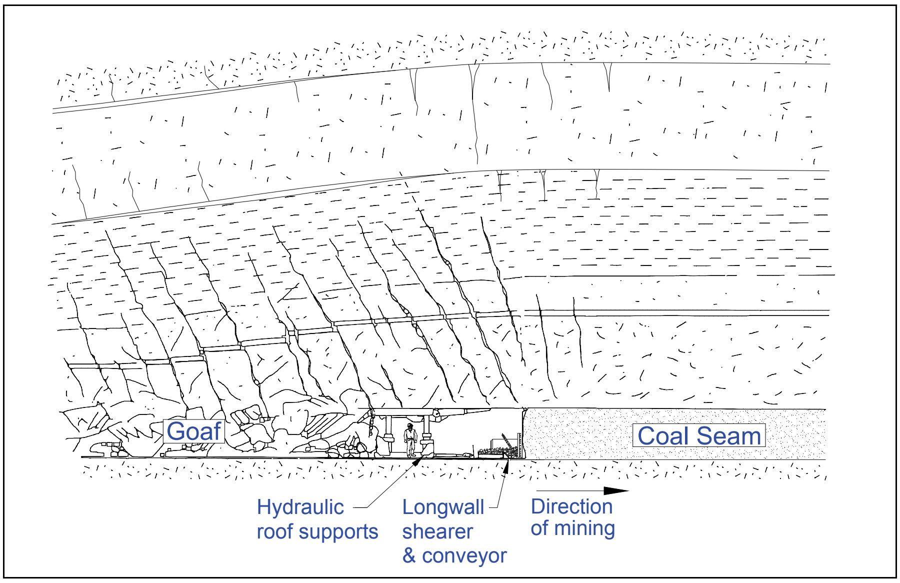

Fig. B. 1 Cross-section along the Length of a Typical Longwall at the Coal Face

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

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

At the surface, the ground subsides vertically as well as moves horizontally towards the centre of the mined goaf area. The maximum subsidence at the surface varies, depending on a number of factors including longwall geometry, depth of cover, extracted seam thickness, overburden geology and previous workings. The maximum achievable subsidence in the Hunter Coalfield, for a critical width of extraction and single-seam mining conditions, is generally 60 % to 65 % of the extracted seam thickness.

The longwalls in Wambo Seam are located beneath the existing Homestead/Wollemi workings in the overlying Whybrow Seam. Also, the future longwalls in the Arrowfield and Bowfield Seams are located beneath the workings in the Whybrow and Wambo Seams. The maximum achievable subsidence for multi-seam conditions is greater than that for single-seam conditions, as a result of the re-activation of the overlying goaf and pillars. Further discussions on multi-seam subsidence are provided in Section 3.3.2 of this report.

B.3. Overview of Conventional Subsidence Parameters

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

- **Subsidence** usually refers to vertical displacement of a point, but subsidence of the ground actually includes both vertical and horizontal displacements. These horizontal displacements in some cases, where the subsidence is small beyond the longwall goaf edges, can be greater than the vertical subsidence. Subsidence is usually expressed in units of *millimetres (mm)*.

- **Tilt** is the change in the slope of the ground as a result of differential subsidence, and is calculated as the change in subsidence between two points divided by the distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. Tilt is usually expressed in units of *millimetres per metre (mm/m)*. A tilt of 1 mm/m is equivalent to a change in grade of 0.1 %, or 1 in 1000.

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

- **Strain** is the relative differential horizontal movements of the ground. **Normal strain** is calculated as the change in horizontal distance between two points on the ground, divided by the original horizontal distance between them. Strain is typically expressed in units of *millimetres per metre (mm/m)*. **Tensile Strains** occur where the distances between two points increase and **Compressive Strains** occur when the distances between two points decrease. So that ground strains can be compared between different locations, they are typically measured over bay lengths that are equal to the depth of cover between the surface and seam divided by 20.

  Whilst mining induced normal strains are measured along monitoring lines, ground shearing can also occur both vertically and horizontally across the directions of monitoring lines. Most of the published mine subsidence literature discusses the differential ground movements that are measured along subsidence monitoring lines, however, differential ground movements can also be measured across monitoring lines using 3D survey monitoring techniques.

- **Horizontal shear deformation** across monitoring lines can be described by various parameters including horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index. It is not possible, however, to determine the horizontal shear strain across a monitoring line using 2D or 3D monitoring techniques. High deformations along monitoring lines (i.e. normal strains) are generally measured where high deformations have been measured across the monitoring line (i.e. shear deformations), and vice versa.

The **additional** subsidence, tilts, curvatures and strains are those which result from the extraction of the proposed WMLW9 and WMLW10 only, including the affects due to the re-activation of the existing workings in the overlying Whybrow Seam. The **total** subsidence, tilts, curvatures and strains are the accumulated parameters after the completion of the longwalls in either the Wambo, Arrowfield, or Bowfield Seams, including the affects due to the re-activation of the existing workings in the Whybrow Seam. The **travelling** tilts, curvatures and strains are the transient movements as the longwall extraction face mines directly beneath a given point.

B.4. 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

B.5. 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 and the compression of the pillars and the strata above the pillars. 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. Irregular subsidence movements are generally associated with:-

- shallow depths of cover,
- sudden or abrupt changes in geological conditions,
- steep topography, and
- valley related mechanisms.

Non-conventional movements due to abovementioned conditions are discussed in the following sections.

B.5.1 Non-Conventional Subsidence Movements due to Shallow Depth of Cover

Irregular ground movements are commonly observed in shallow mining situations, where the collapsed zone, which develops above the extracted longwalls, extends near to the surface. This type of irregularity is generally only seen where panel widths are supercritical and where the depths of cover are less than 100 metres, which does not occur above the proposed WMLW9 and WMLW10. These irregular movements appear as localised bumps and steps in the observed subsidence profiles, which are accompanied by elevated tilts, curvatures and ground strains.

The levels of irregular subsidence movement at varying depths of cover can be seen in the observed subsidence profiles over the previously extracted Whybrow Seam longwalls at South Bulga Colliery, which are shown in Fig. B. 2.

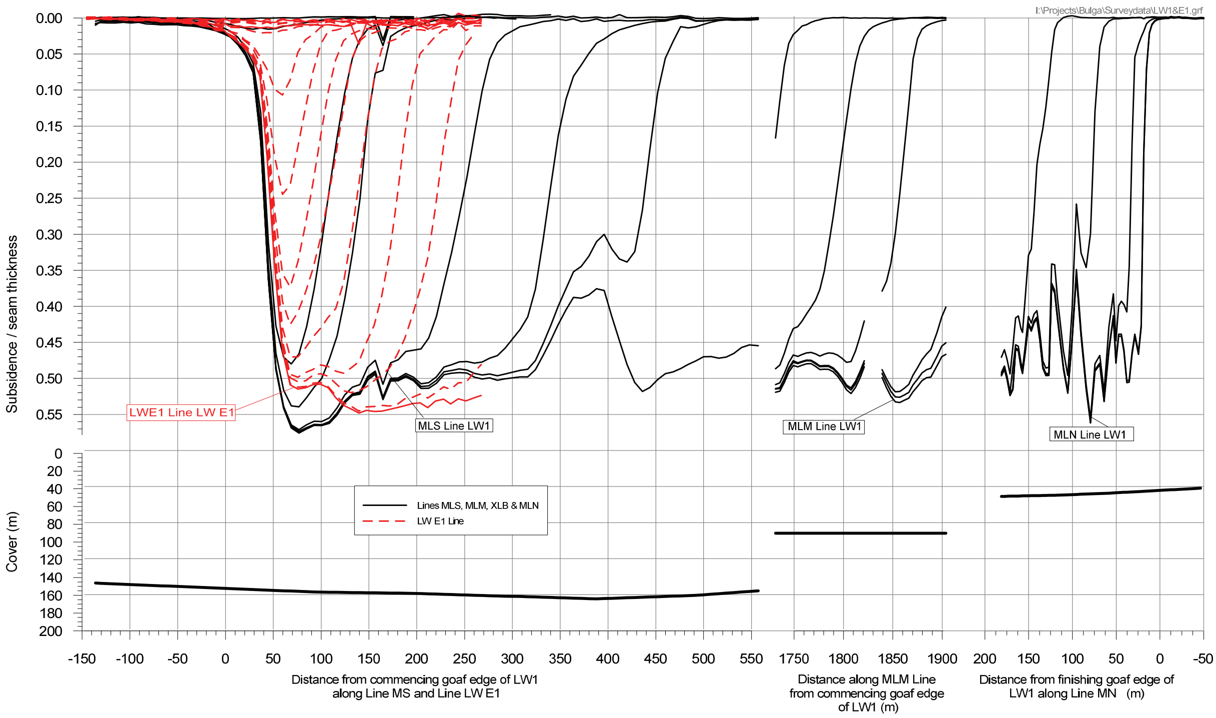

Fig. B. 2 Observed Subsidence Profiles at South Bulga Colliery

The observed subsidence profiles along the MLS and LWE1 monitoring lines above the southern ends of Whybrow Seam Longwalls 1 and E1, respectively, having average depths of cover of 160 metres, are shown in the left of this figure. The observed subsidence profile along the MLM monitoring line above the northern end of Longwall 1, having an average depth of cover of 90 metres, is shown near the middle of the figure. The observed subsidence profile along the MLN monitoring line above the northern end of Longwall 1, having an average depth of cover of 45 metres, is shown in the right of this figure.

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

B.5.2 Non-conventional Subsidence Movements due to Changes in Geological Conditions

It is believed that most non-conventional ground movements are a result of the reaction of near surface strata to increased horizontal compressive stresses due to mining operations. Some of the geological conditions that are believed to influence these irregular subsidence movements are the blocky nature of near surface sedimentary strata layers and the possible presence of unknown faults, dykes or other geological structures, cross bedded strata, thin and brittle near surface strata layers and pre-existing natural joints. The presence of these geological features near the surface can result in a bump in an otherwise smooth subsidence profile and these bumps are usually accompanied by locally increased tilts 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 and 6, include historical impacts resulting from previous longwall mining which have occurred as the result of both conventional and non-conventional subsidence movements.

B.5.3 Non-conventional Subsidence Movements due to Steep Topography

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

Further discussions on the potential for downslope movements for the steep slopes within the Study Area are provided in Section 5.5.

B.5.4 Valley Related Movements

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

Valley bulging movements are a natural phenomenon, resulting from the formation and ongoing development of the valley, as illustrated in Fig. B. 3. The potential for these natural movements are influenced by the geomorphology of the valley.

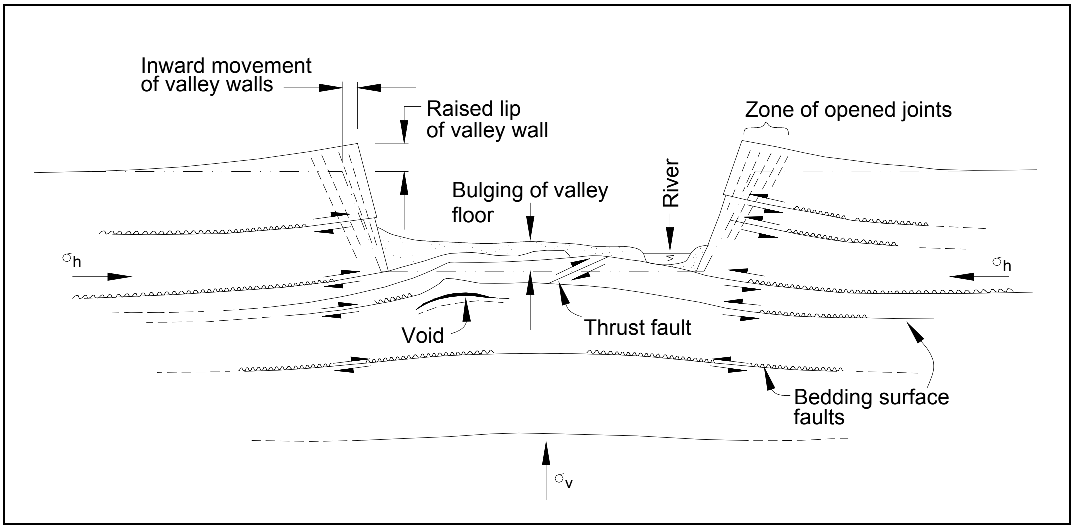

Fig. B. 3 Valley Formation in Flat-Lying Sedimentary Rocks (after Patton and Hendren 1972)

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*.

APPENDIX C. COMPARISONS BETWEEN OBSERVED AND PREDICTED PROFILES OF SUBSIDENCE, TILT AND CURVATURE

Profiles of Observed and Back-Predicted Subsidence, Tilt and Curvature along the XL1-Line at the North Wambo Underground Mine

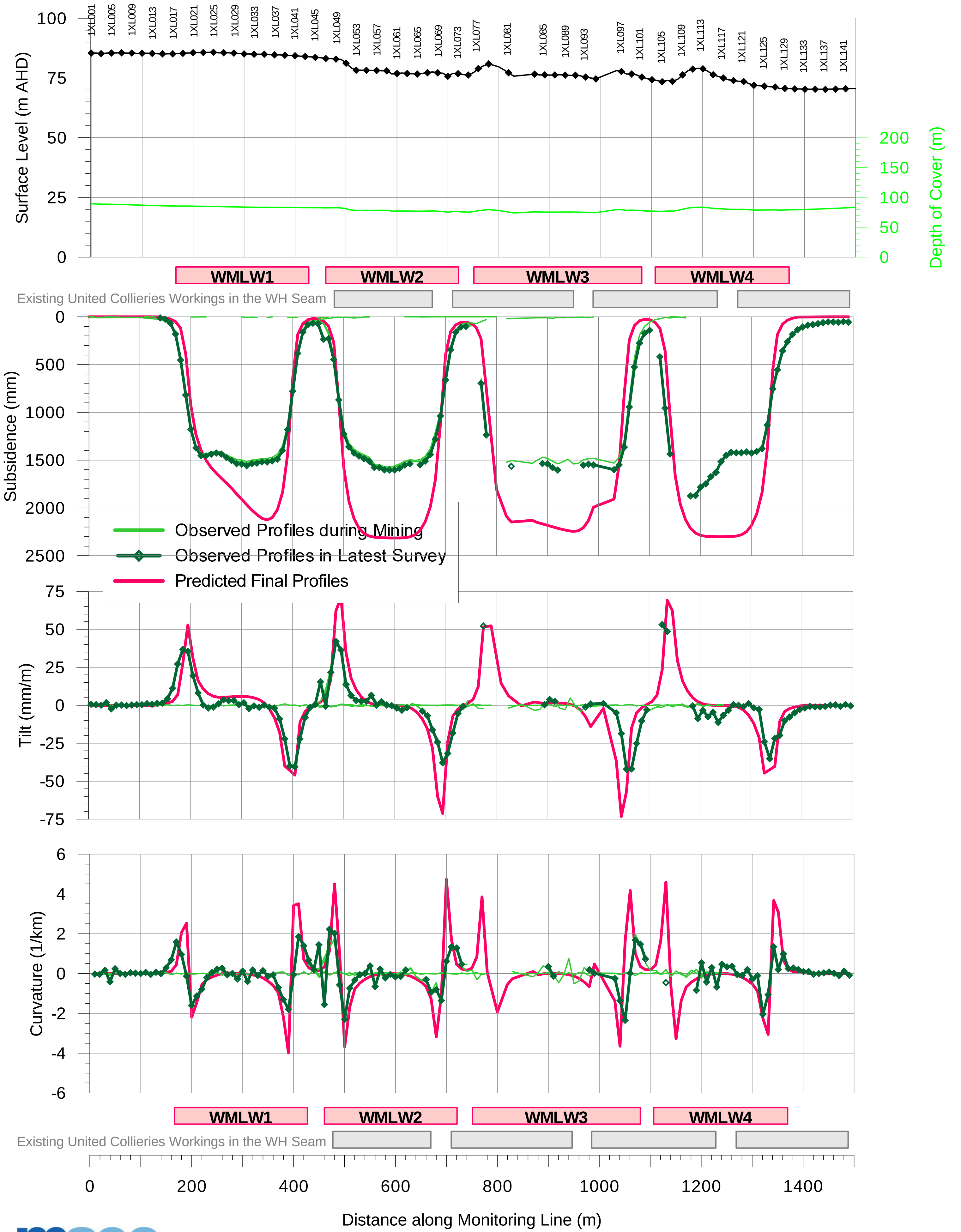

Fig. C.01

Profiles of Observed and Back-Predicted Subsidence, Tilt and Curvature along the XL2-Line at the North Wambo Underground Mine

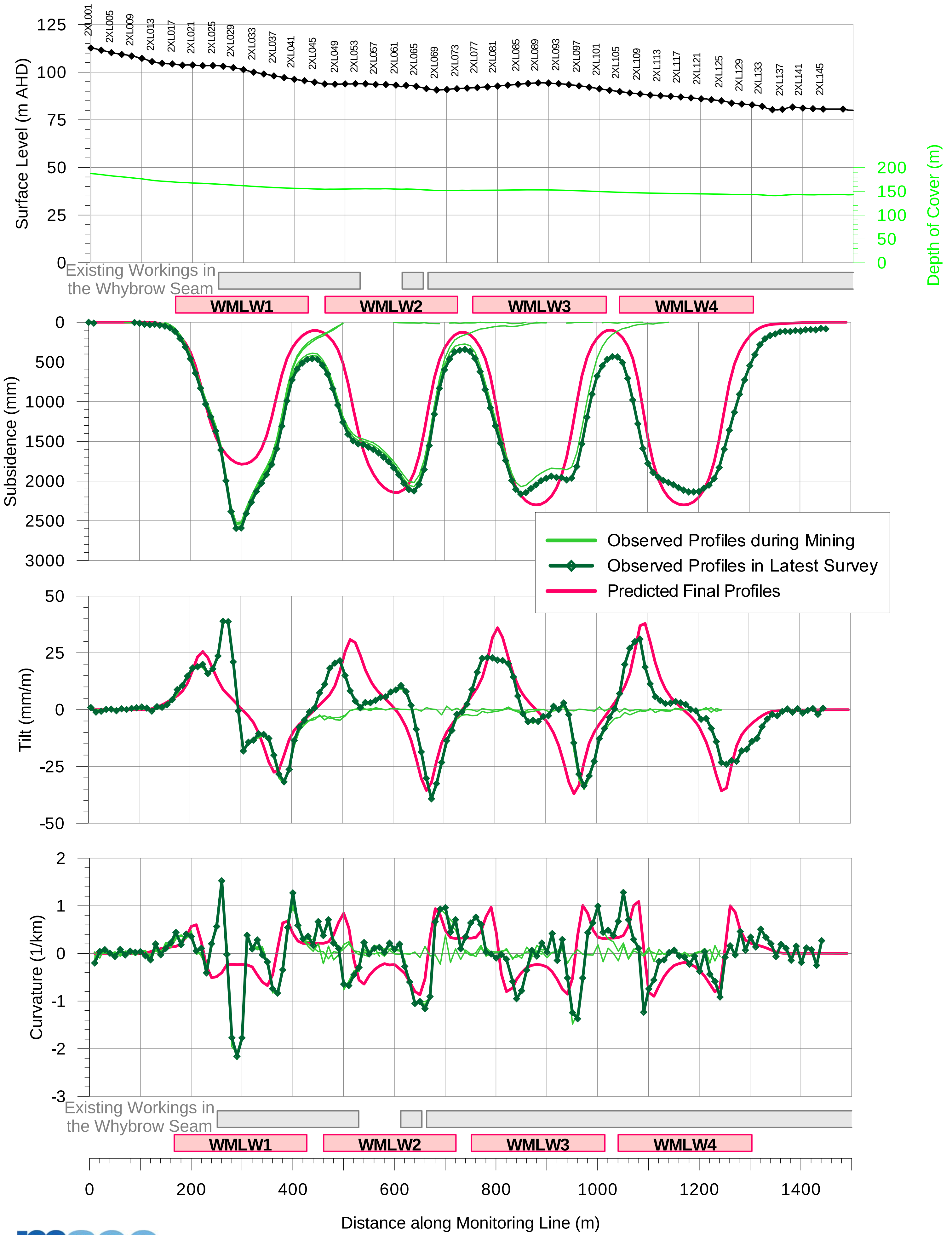

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Fig. C.02

Profiles of Observed and Back-Predicted Subsidence, Tilt and Curvature along the XL3-Line at the North Wambo Underground Mine

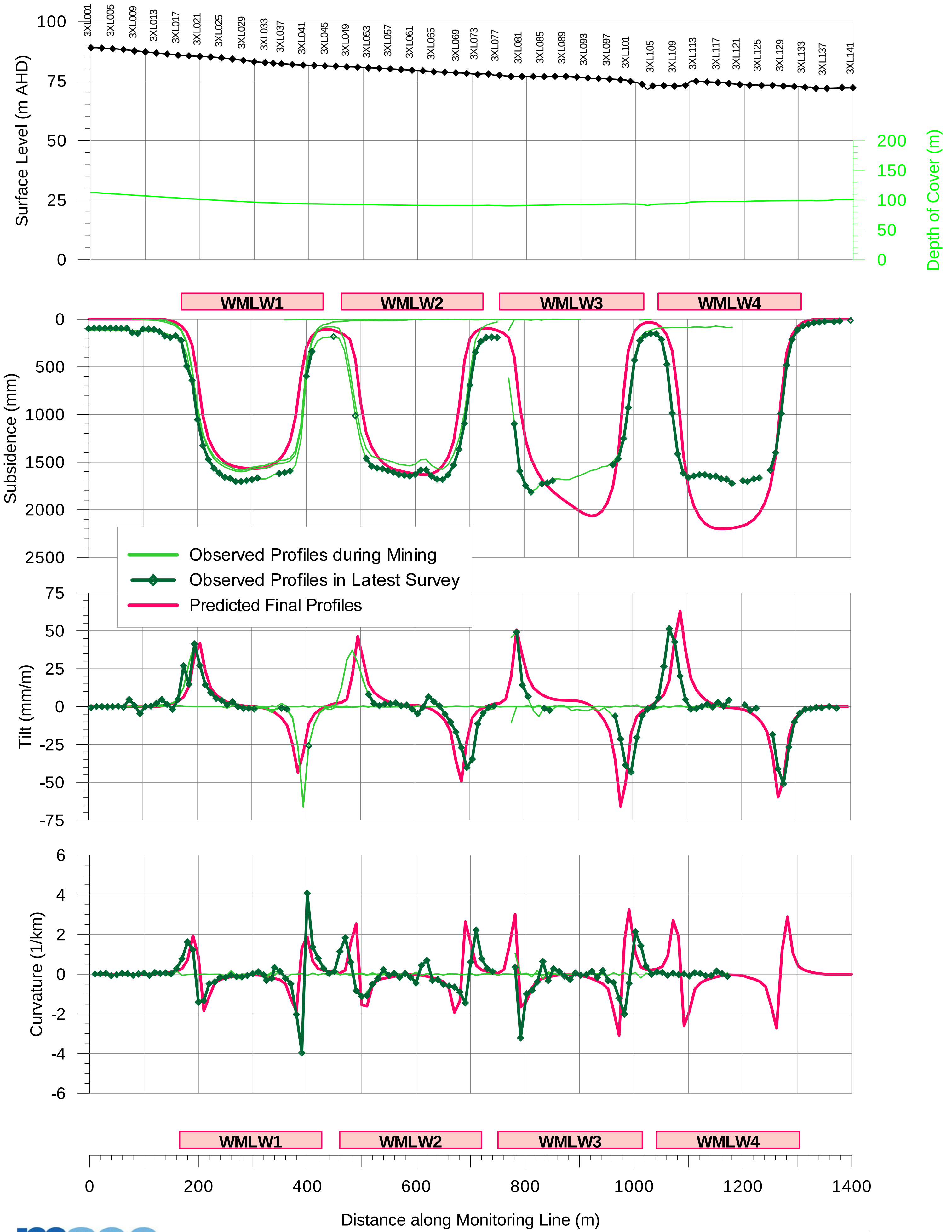

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Fig. C.03

Profiles of Observed and Back-Predicted Subsidence, Tilt and Curvature along the SC1-Line at the North Wambo Underground Mine

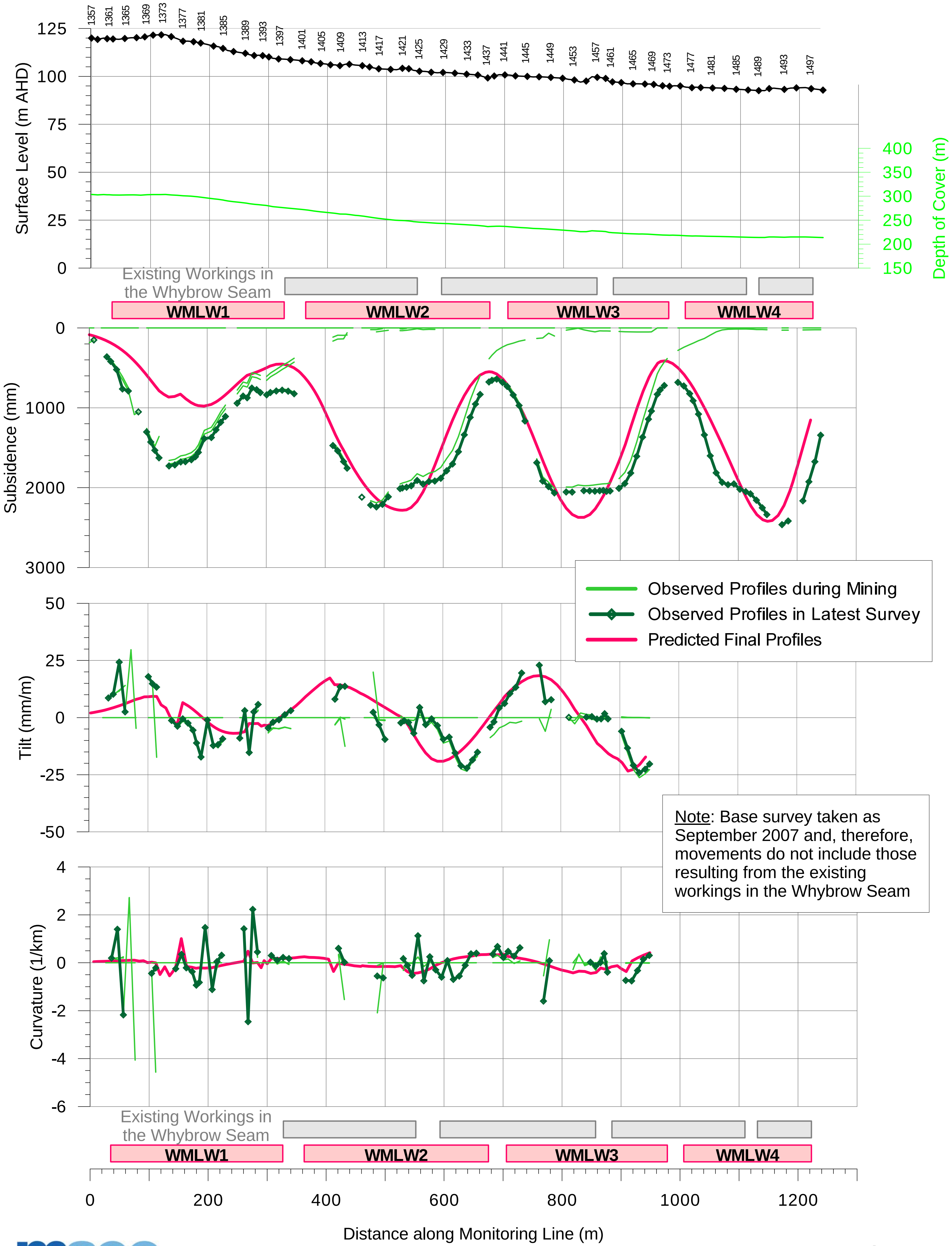

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Fig. C.04

Profiles of Observed and Back Predicted Subsidence, Tilt and Curvature along a Monitoring Line in the Hunter Coalfield with a W/H Ratio of 2.0

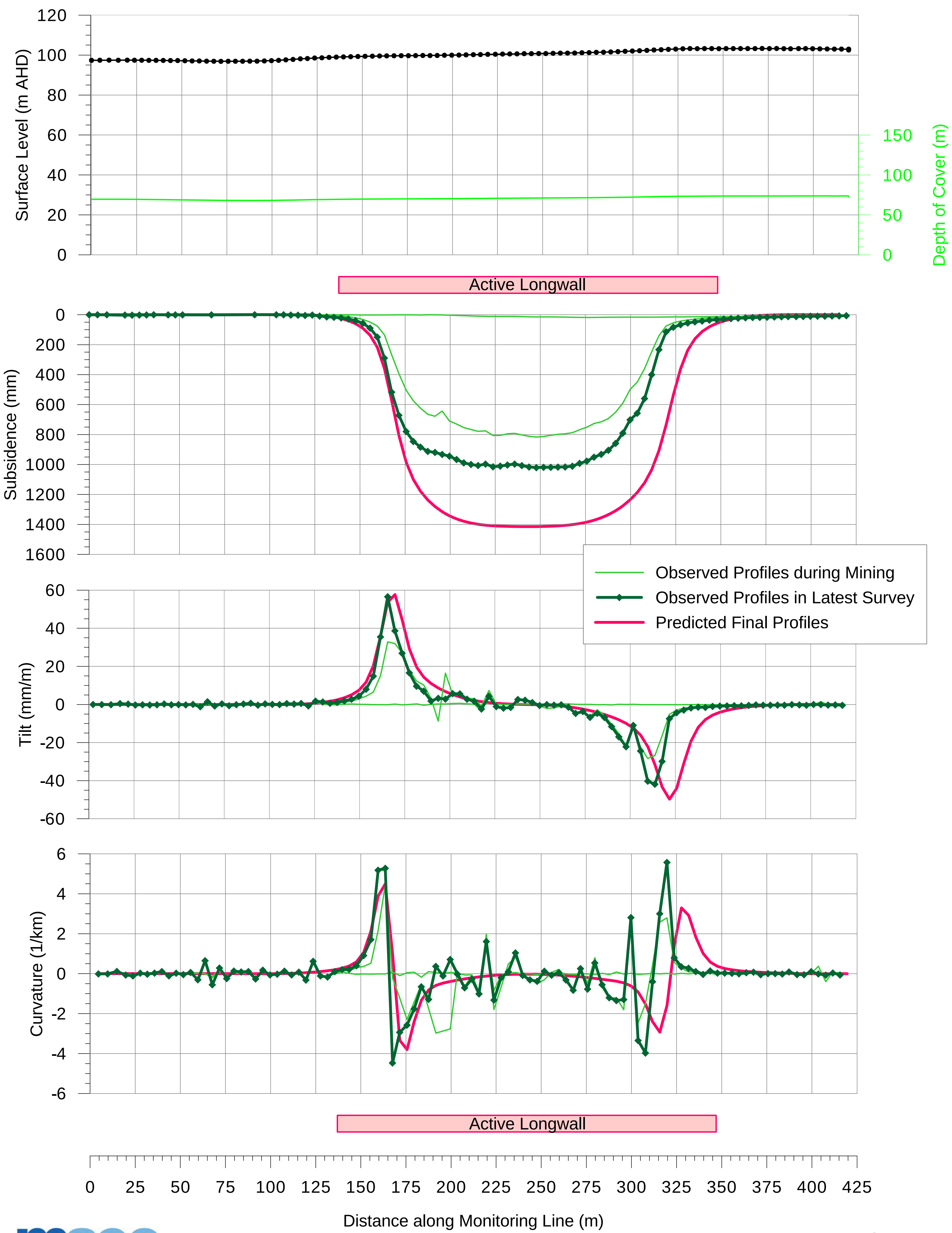

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Fig. C.05

Profiles of Observed and Back Predicted Subsidence, Tilt and Curvature along a Monitoring Line in the Hunter Coalfield with a W/H Ratio of 3.0

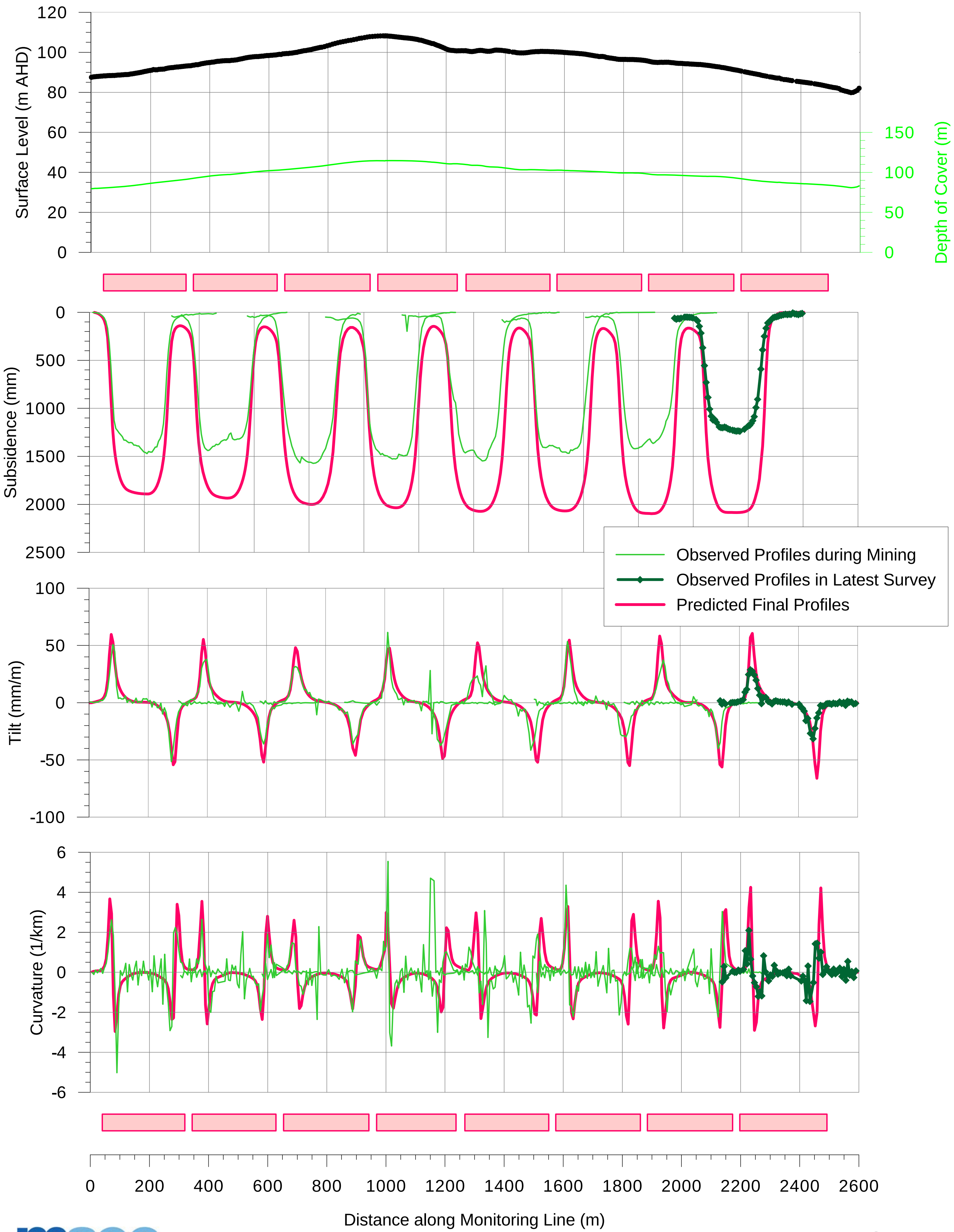

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Fig. C.06

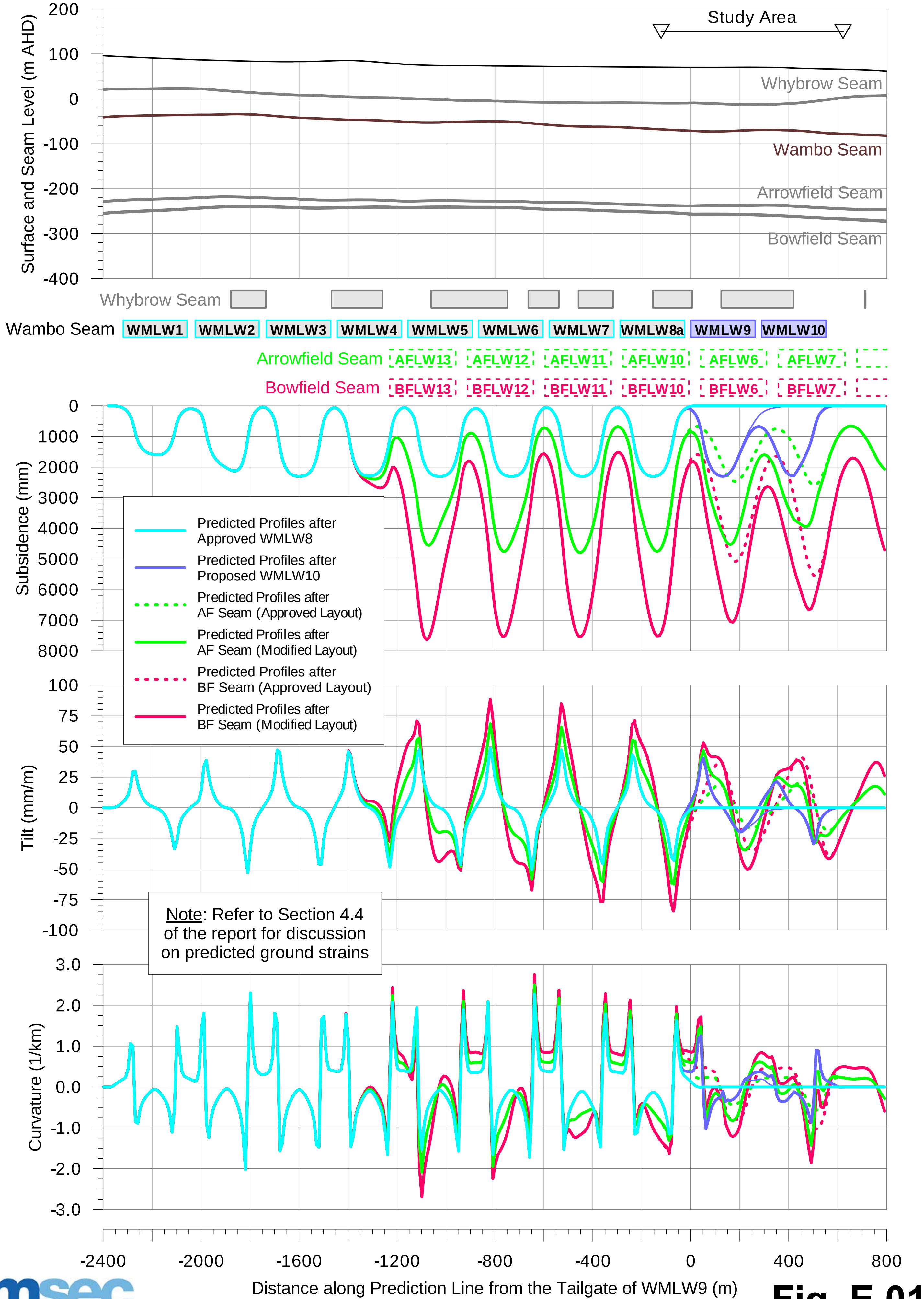
APPENDIX D. TABLES

Table D.01 - Maximum Predicted Subsidence Parameters for the Archaeological Sites within the Study Area due to Mining in the Wambo, Arrowfield and Bowfield Seams Based on the Approved and Modified Layouts

Site Name	Type	Predicted Total Subsidence Based on the Approved Layout (mm)	Predicted Total Subsidence Based on the Modified Layout (mm)	Incremental Change in Subsidence due to the Proposed Modification (mm)	Predicted Total Tilt Based on the Approved Layout (mm/m)	Predicted Total Tilt Based on the Modified Layout (mm/m)	Incremental Change in Tilt due to the Proposed Modification (mm/m)	Predicted Total Hogging Curvature Based on the Approved Layout (1/km)	Predicted Total Hogging Curvature Based on the Modified Layout (1/km)	Incremental Change in Hogging Curvature due to the Proposed Modification (1/km)	Predicted Total Sagging Curvature Based on the Approved Layout (1/km)	Predicted Total Sagging Curvature Based on the Modified Layout (1/km)	Incremental Change in Sagging Curvature due to the Proposed Modification (1/km)
Wambo Site 45	Isolated find	750	800	50	9	10	1	0.10	0.20	0.10	0.03	0.03	0.00
Wambo Site 46	Artefact scatter	3500	4800	1300	20	40	20	0.30	0.60	0.30	0.10	0.40	0.30
Wambo Site 47	Isolated find	500	500	0	6	7	1	0.10	0.10	0.00	0.01	0.01	0.00
Wambo Site 48	Isolated find	1700	1800	100	25	25	0	0.30	0.30	0.00	0.10	0.10	0.00
Wambo Site 55	Artefact scatter	3800	3800	0	40	35	-5	0.70	0.70	0.00	0.30	0.30	0.00
Wambo Site 56	Isolated find	4000	4000	0	20	20	0	0.40	0.50	0.10	0.40	0.40	0.00
Wambo Site 57	Artefact scatter	3100	3500	400	20	25	5	0.50	0.60	0.10	0.10	0.10	0.00
Wambo Site 58	Isolated find	4300	6400	2100	10	35	25	0.10	0.60	0.50	0.40	0.80	0.40
Wambo Site 59	Isolated find	3200	5200	2000	20	40	20	0.30	0.70	0.40	0.10	0.70	0.60
Wambo Site 60	Artefact scatter	2800	3200	400	15	20	5	0.50	0.70	0.20	0.10	0.30	0.20
Wambo Site 61	Artefact scatter	3700	3700	0	30	30	0	0.40	0.60	0.20	0.30	0.30	0.00
Wambo Site 98b	Artefact scatter	1800	1800	0	15	15	0	0.60	0.70	0.10	0.10	0.02	-0.08
Wambo Site 333	Artefact scatter	1900	3100	1200	15	35	20	0.30	0.50	0.20	0.05	0.50	0.45
Wambo Site 338	Artefact scatter	3000	5100	2100	20	35	15	0.30	0.60	0.30	0.10	0.60	0.50
Wambo Site 348	Artefact scatter	5100	5100	0	40	35	-5	0.60	0.60	0.00	0.80	0.70	-0.10
Wambo Site 351	Artefact scatter	3100	3100	0	20	20	0	0.60	0.70	0.10	0.20	0.20	0.00
Wambo Site 352	Artefact scatter	4400	6200	1800	25	20	-5	0.10	0.90	0.80	0.40	1.00	0.60
Wambo Site 353	Artefact scatter	3000	3100	100	20	20	0	0.40	0.60	0.20	0.10	0.10	0.00
Wambo Site 354	Artefact scatter	350	350	0	5	5	0	0.10	0.10	0.00	< 0.01	< 0.01	0.00
Wambo Site 356	Artefact scatter	3600	4500	900	20	45	25	0.30	0.60	0.30	0.10	0.30	0.20
Wambo Site 357	Artefact scatter	2300	3100	800	10	30	20	0.40	0.90	0.50	0.04	0.30	0.26
Wambo Site 358	Isolated find	4000	6400	2400	20	30	10	0.20	0.90	0.70	0.20	0.90	0.70
Wambo Site 360	Scar tree	3000	3300	300	15	25	10	0.50	0.60	0.10	0.10	0.10	0.00
Wambo Site 361	Isolated find	1700	3500	1800	15	50	35	0.50	2.00	1.50	0.10	2.00	1.90
Wambo Site 362	Artefact scatter	5300	6000	700	40	50	10	0.30	1.00	0.70	1.00	0.80	-0.20
Wambo Site 363	Artefact scatter	500	500	0	6	6	0	0.10	0.10	0.00	< 0.01	< 0.01	0.00
	Maximum	**5300**	**6400**	**2400**	**40**	**50**	**35**	**0.70**	**2.00**	**1.50**	**1.00**	**2.00**	**1.90**

APPENDIX E. FIGURES

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 1 due to Mining in the Wambo, Arrowfield and Bowfield Seams



msec

Fig. E.01

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 2 due to Mining in the Wambo, Arrowfield and Bowfield Seams

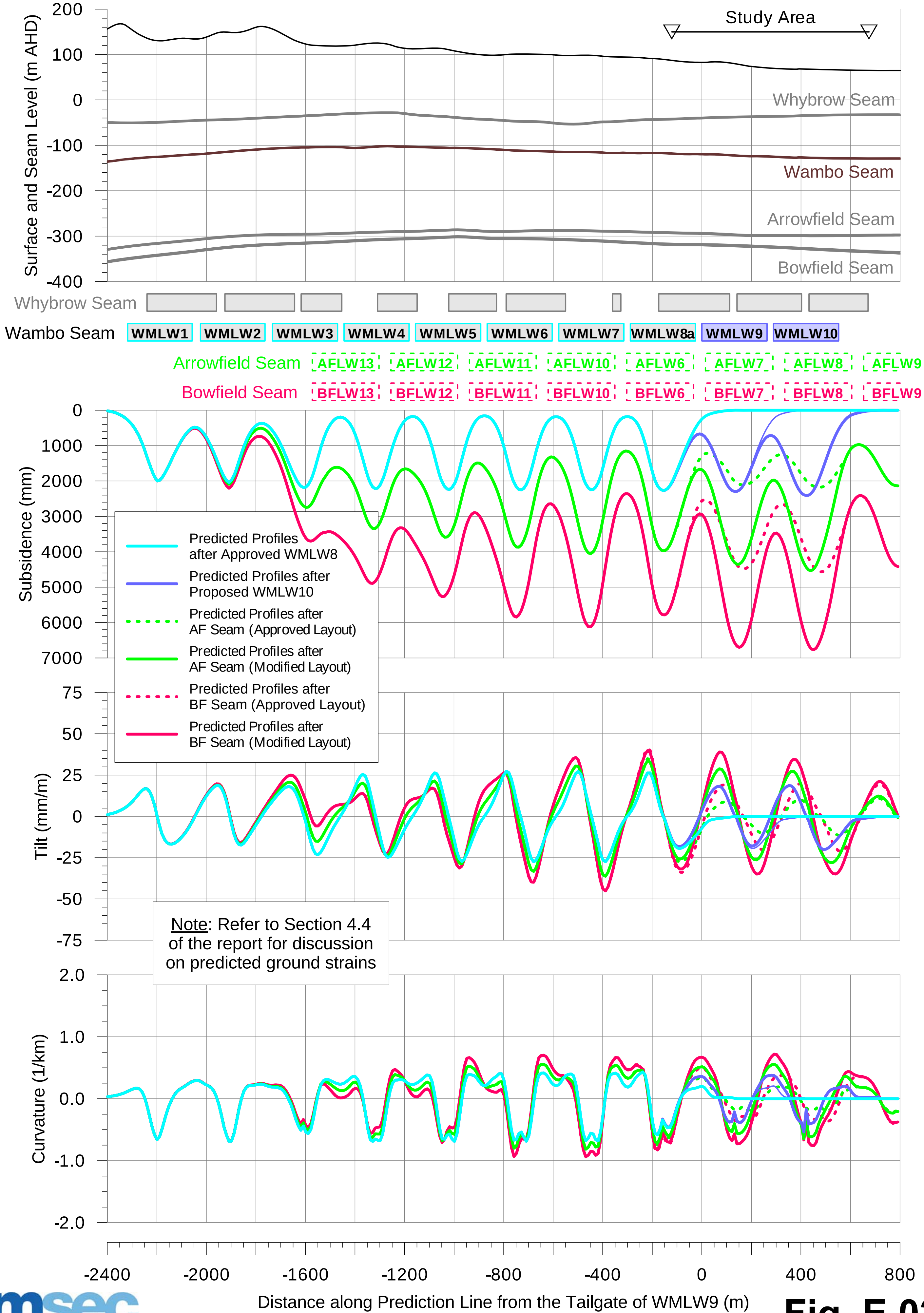


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Fig. E.02

Predicted Profiles of Conventional Subsidence, Tilt Along and Tilt Across the Alignment of the 11 kV Powerline Branch 1 due to Mining in the Wambo, Arrowfield and Bowfield Seams

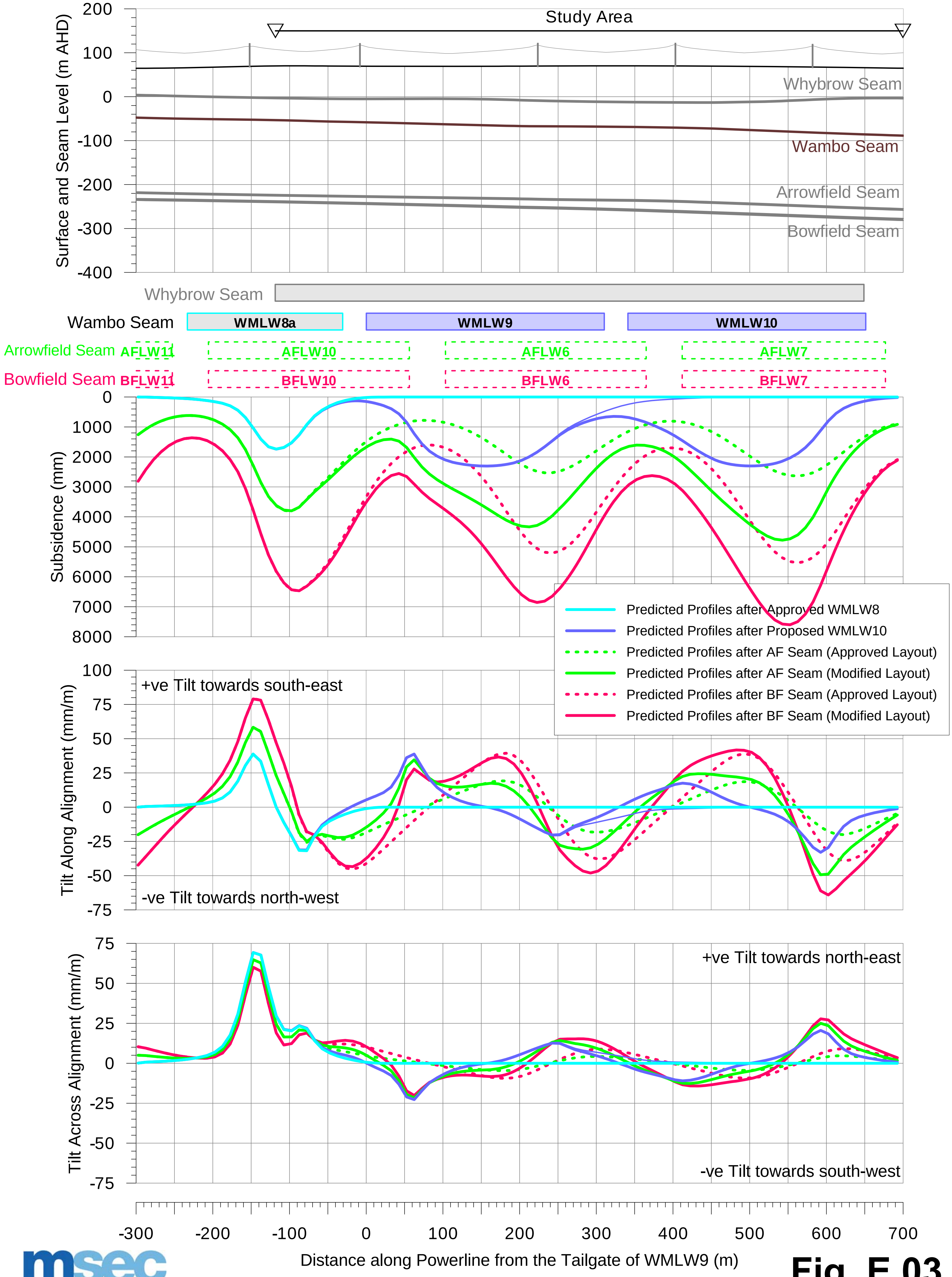

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Fig. E.03

Predicted Profiles of Conventional Subsidence, Tilt Along and Tilt Across the Alignment of the 11 kV Powerline Branch 2 due to Mining in the Wambo, Arrowfield and Bowfield Seams

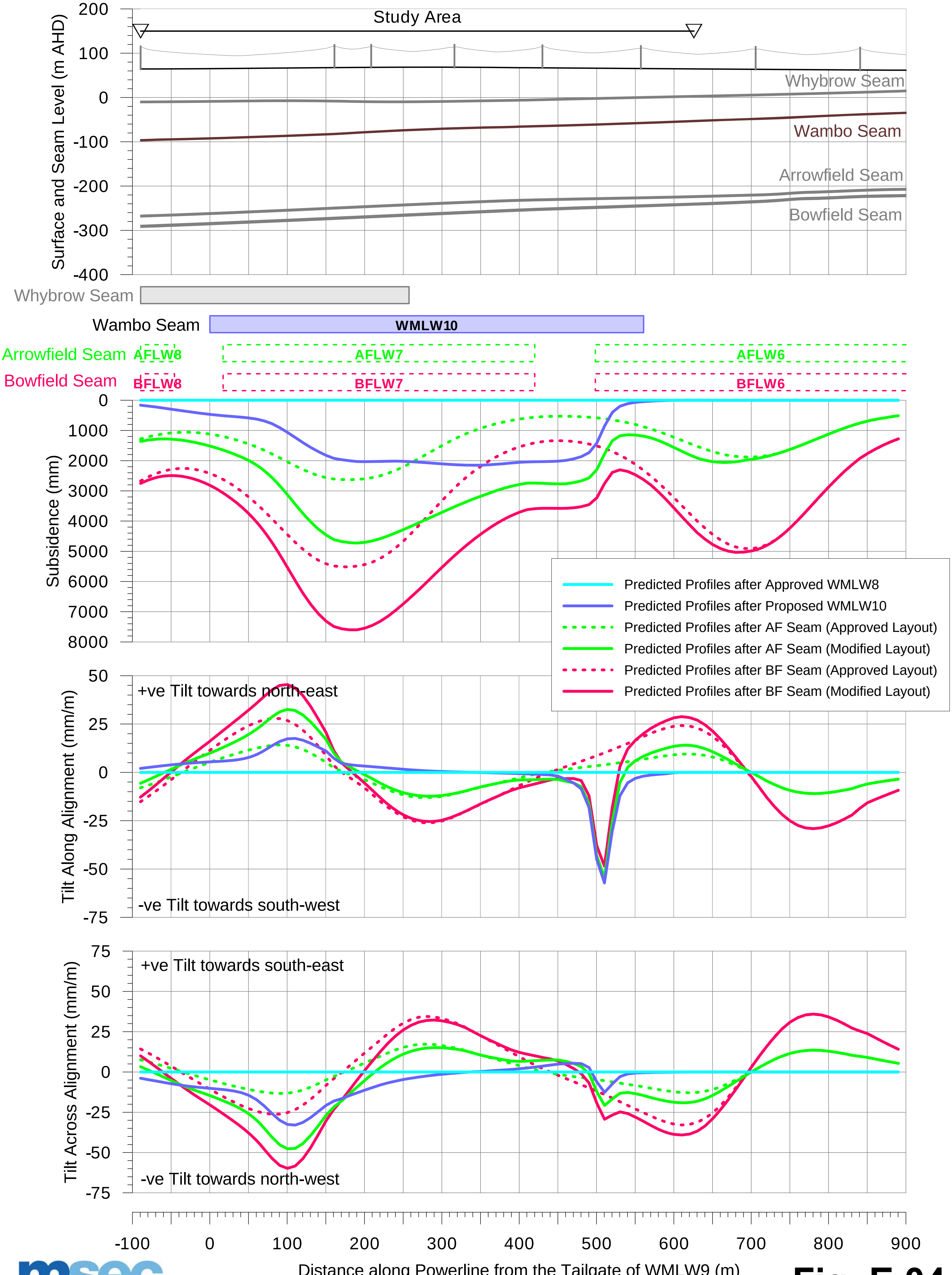

Fig. E.04

APPENDIX F. DRAWINGS

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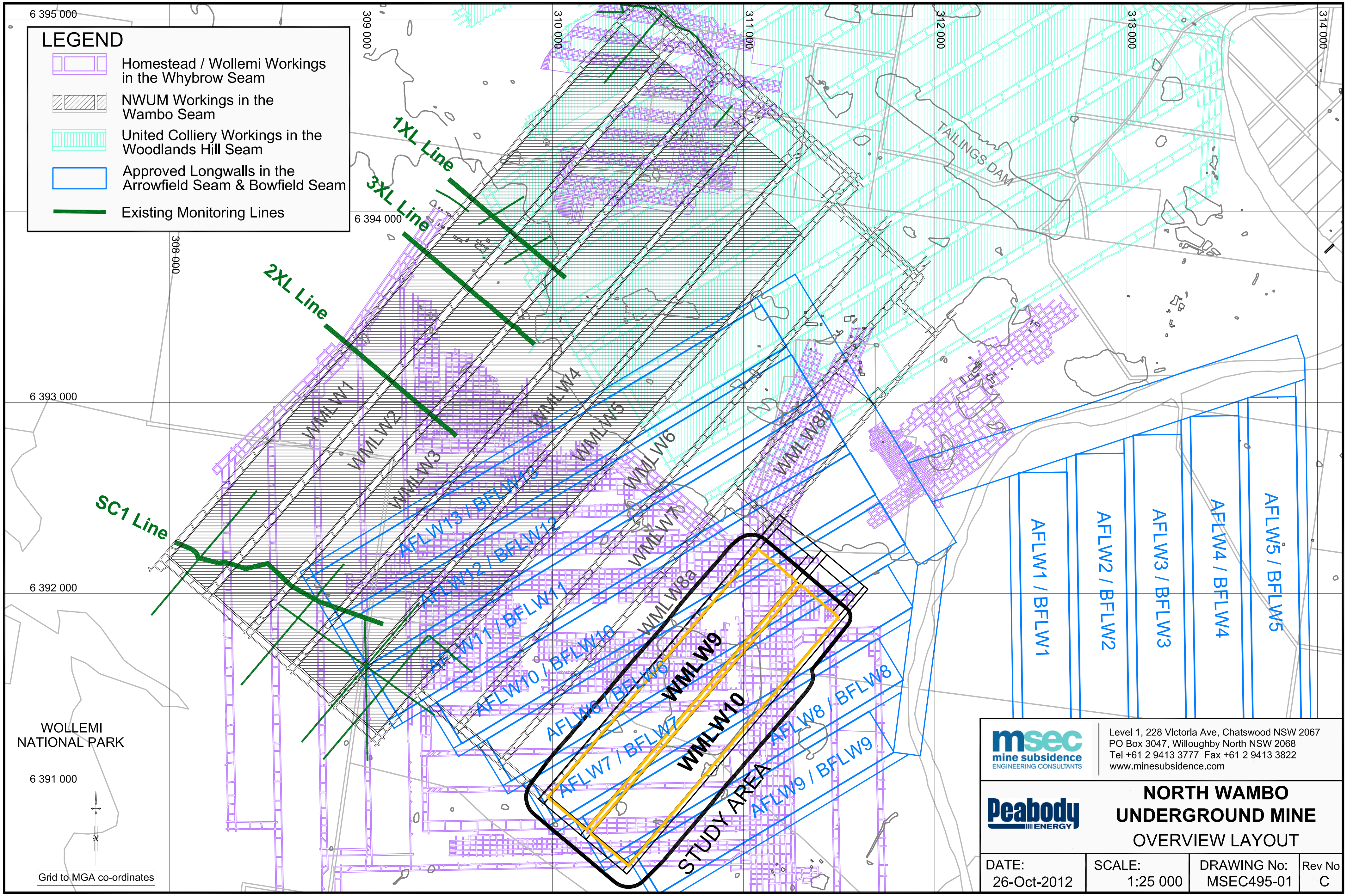

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NORTH WAMBO UNDERGROUND MINE

OVERVIEW LAYOUT

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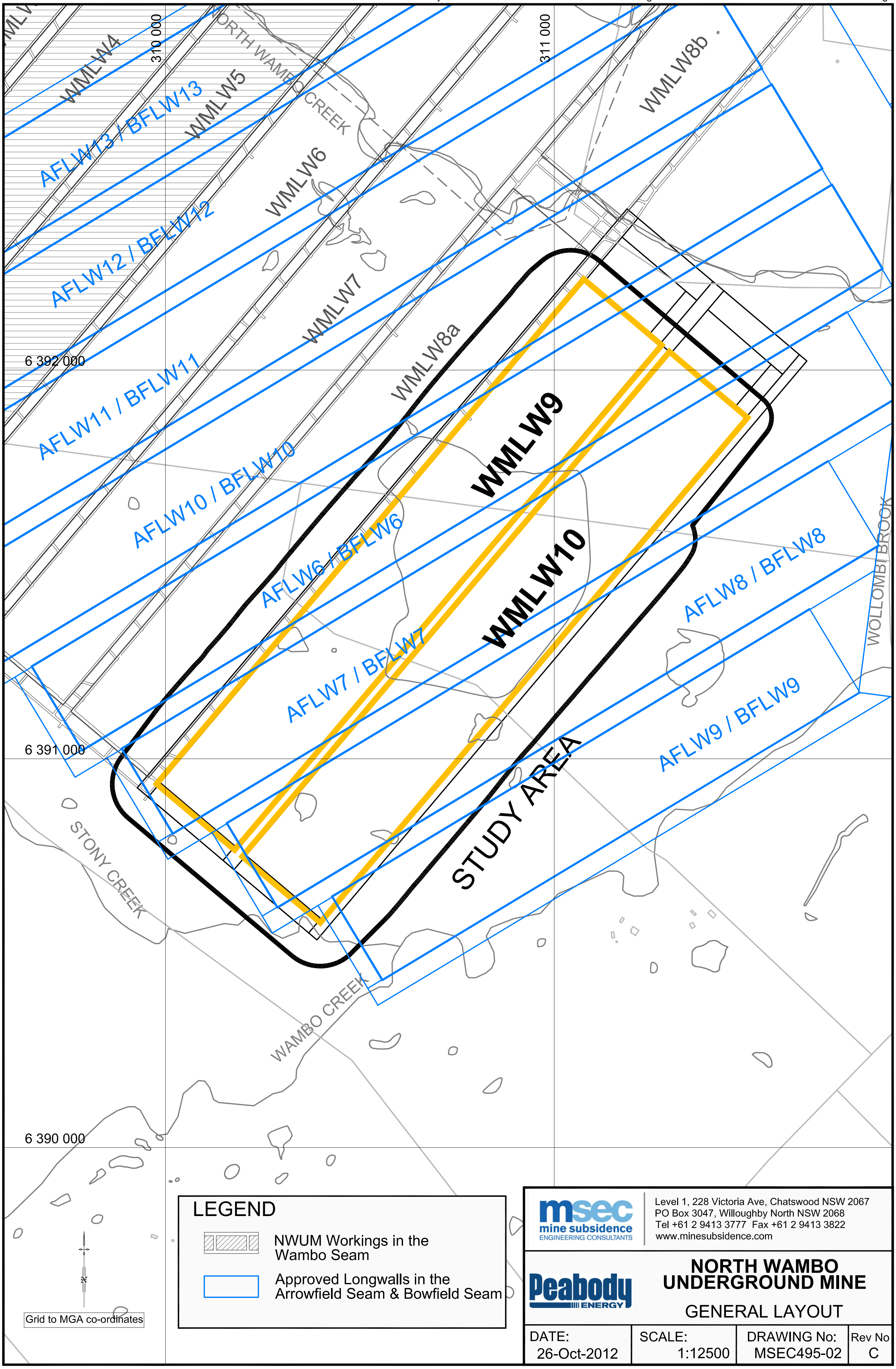

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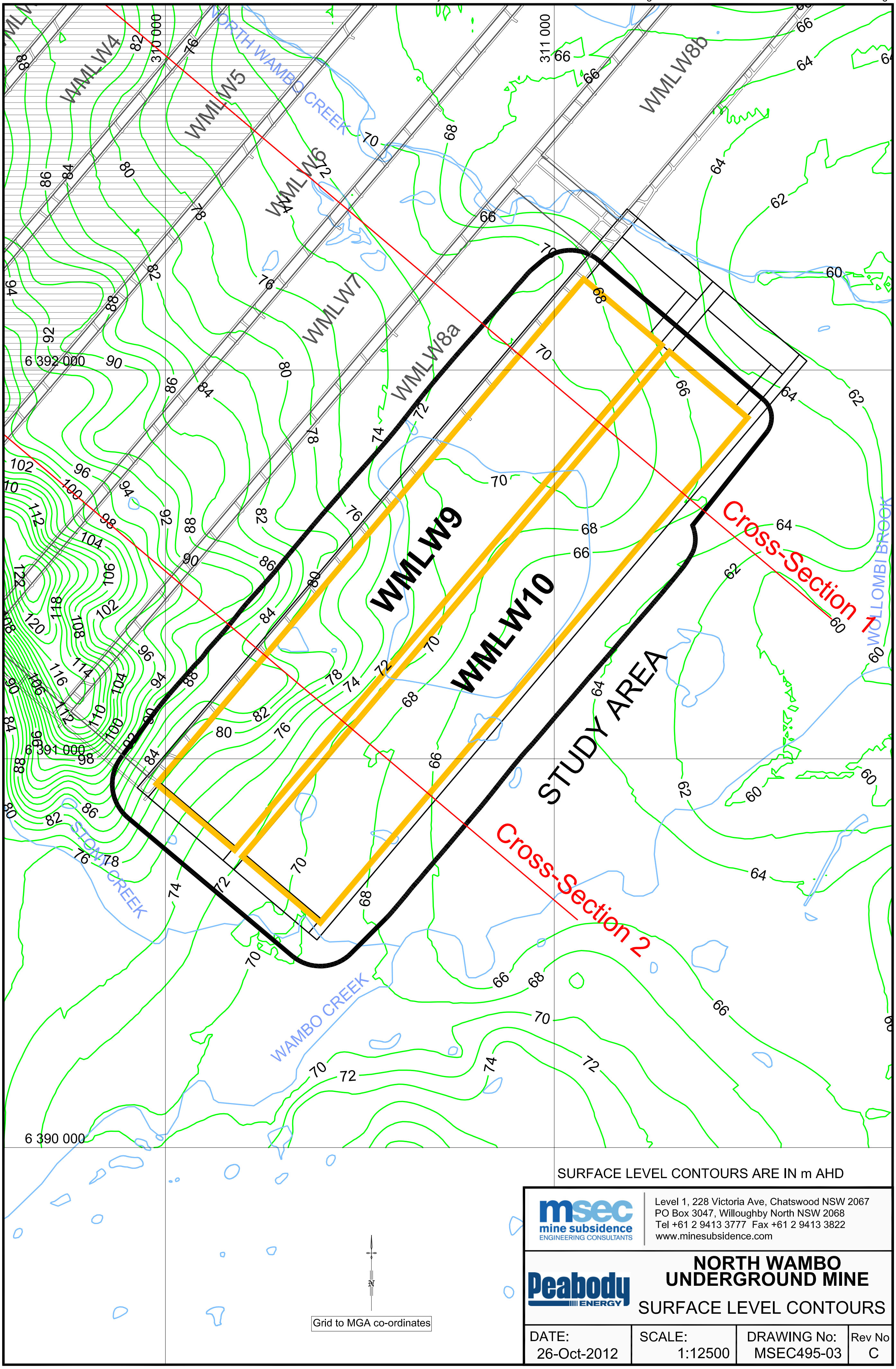

SURFACE LEVEL CONTOURS ARE IN m AHD

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SURFACE LEVEL CONTOURS

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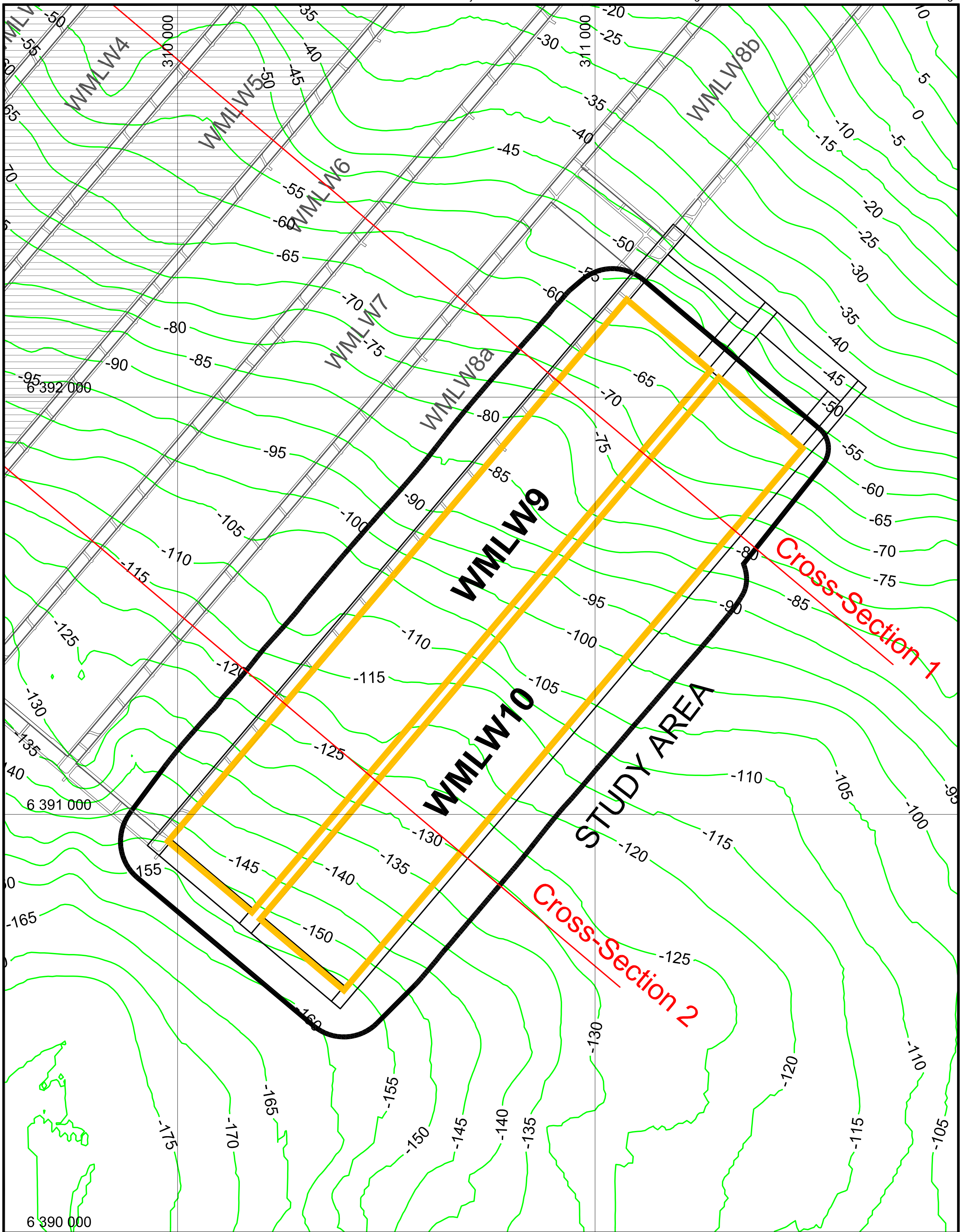

SEAM FLOOR CONTOURS ARE IN m AHD

Grid to MGA co-ordinates

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WAMBO SEAM FLOOR CONTOURS

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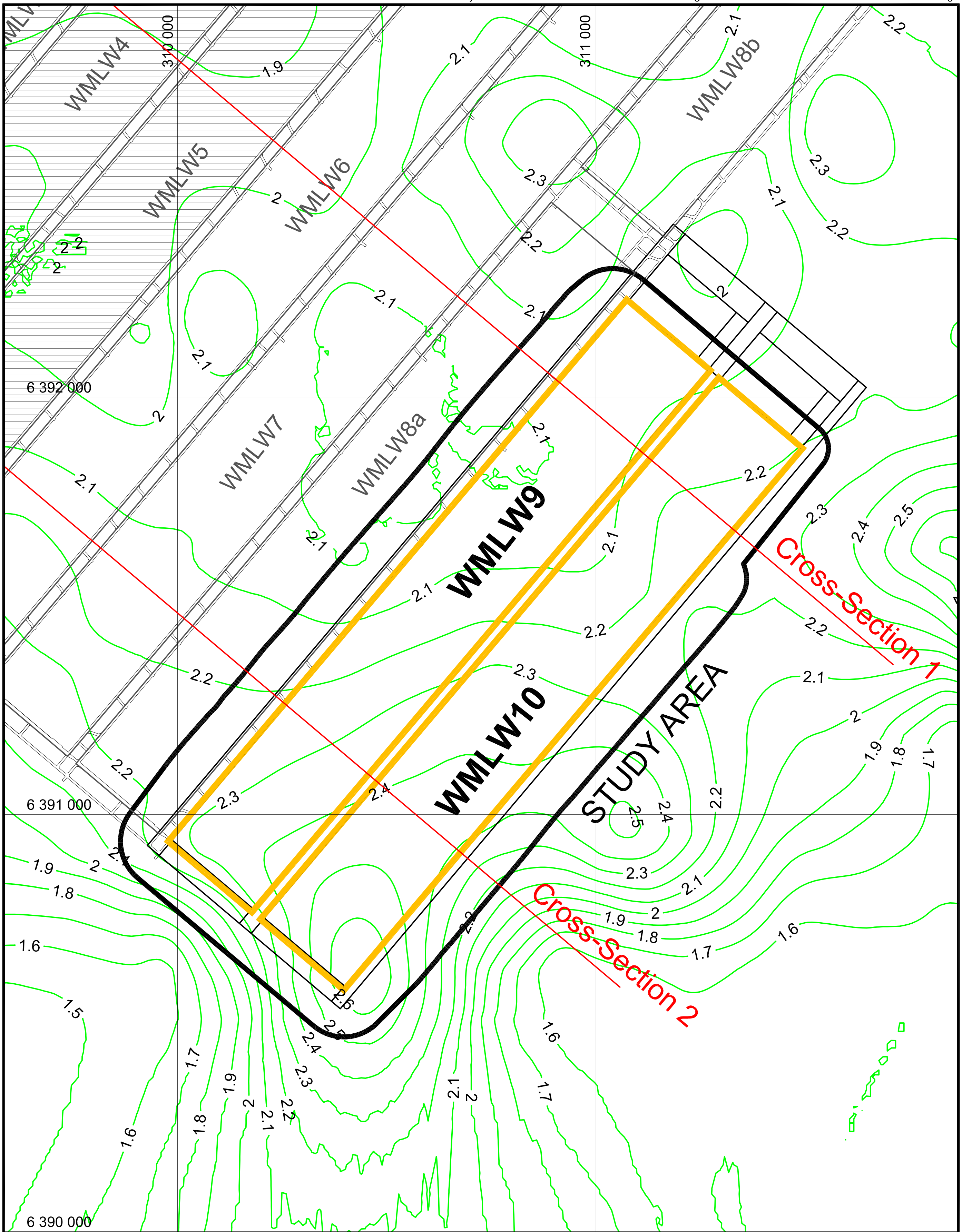

SEAM THICKNESS CONTOURS ARE IN METRES

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WAMBO SEAM THICKNESS CONTOURS

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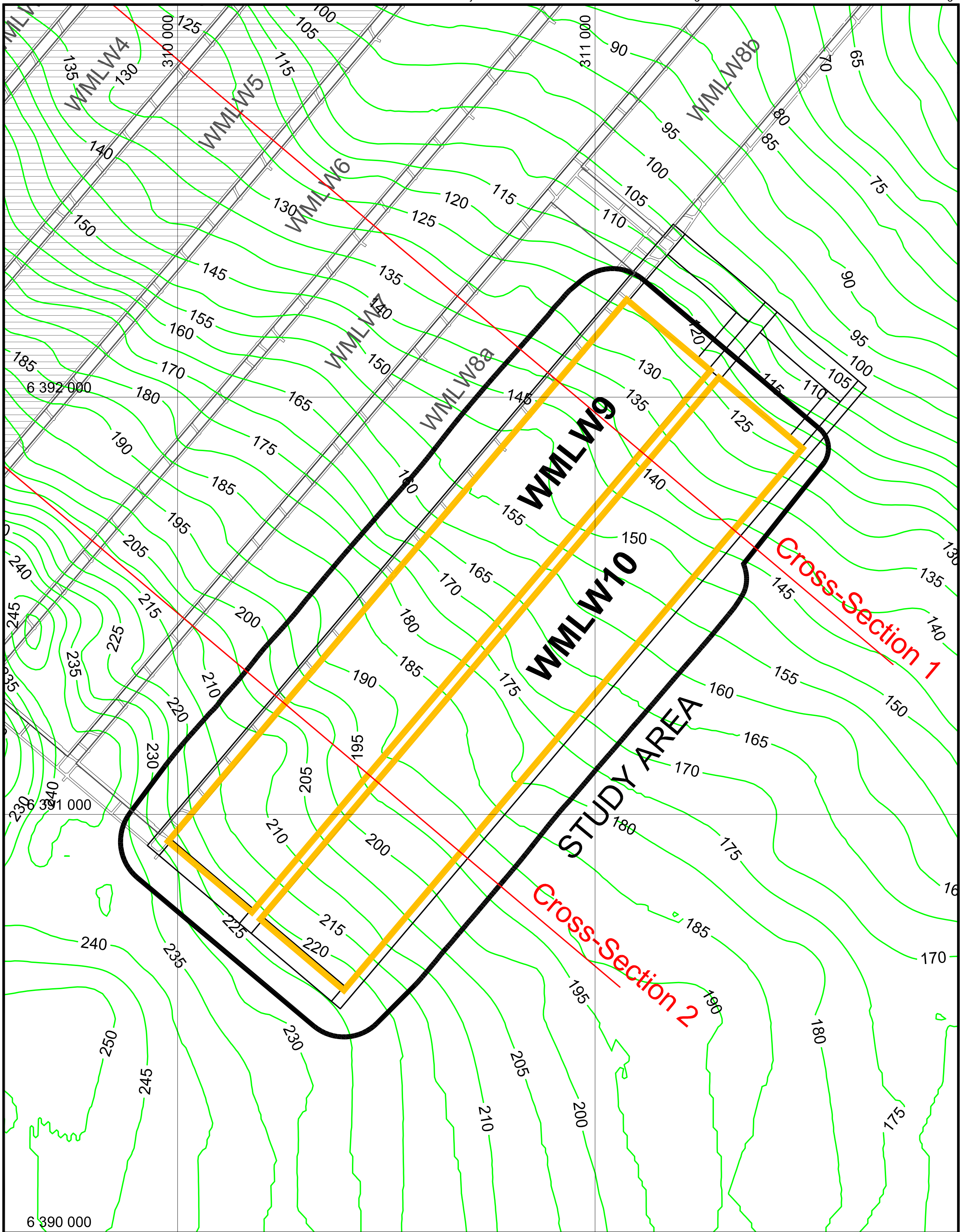

Grid to MGA co-ordinates

DEPTH OF COVER CONTOURS ARE IN METRES

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WAMBO SEAM DEPTH OF COVER CONTOURS

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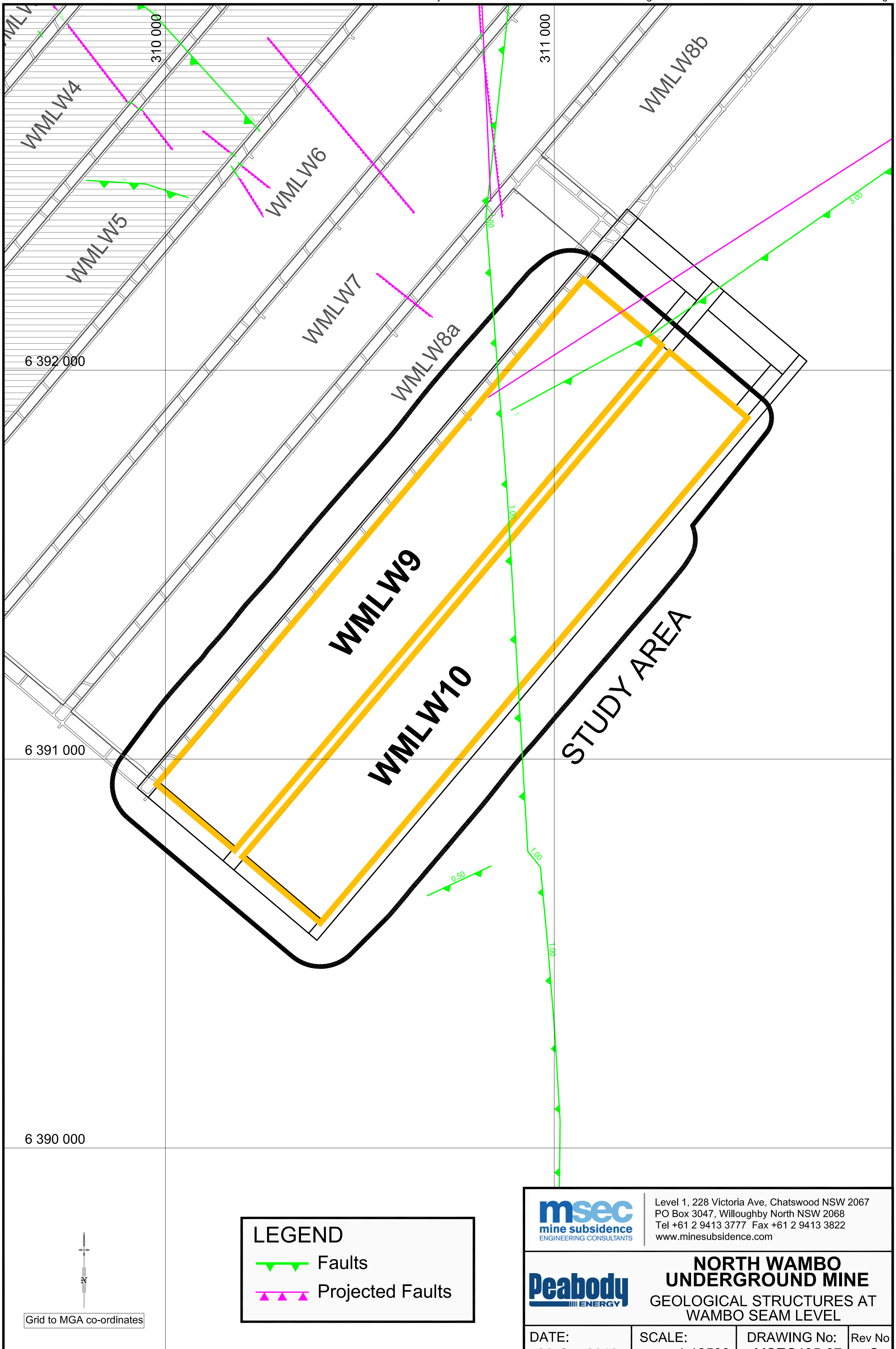

LEGEND
Faults
Projected Faults

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NORTH WAMBO UNDERGROUND MINE

GEOLOGICAL STRUCTURES AT WAMBO SEAM LEVEL

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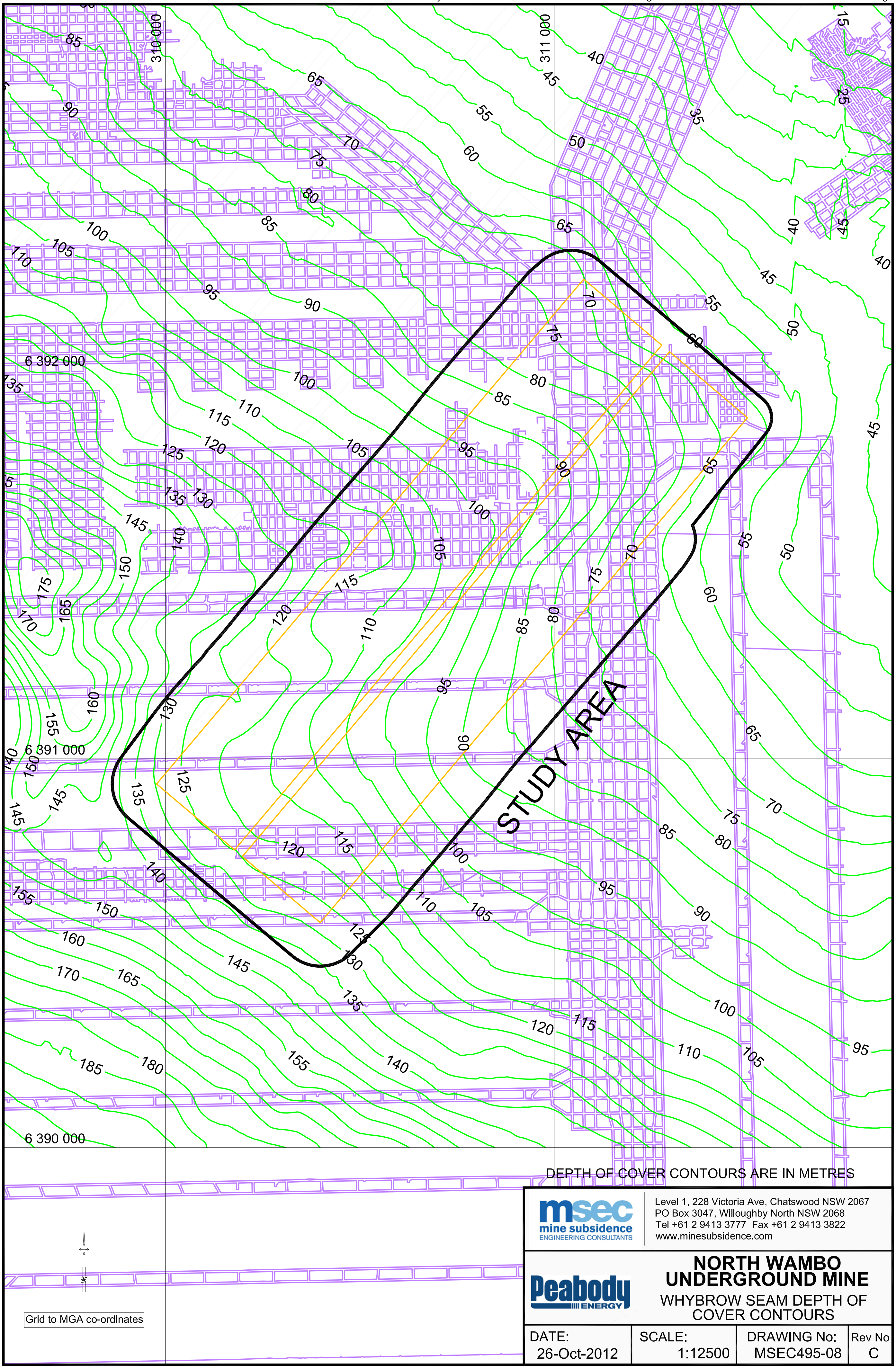

DEPTH OF COVER CONTOURS ARE IN METRES

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WHYBROW SEAM DEPTH OF COVER CONTOURS

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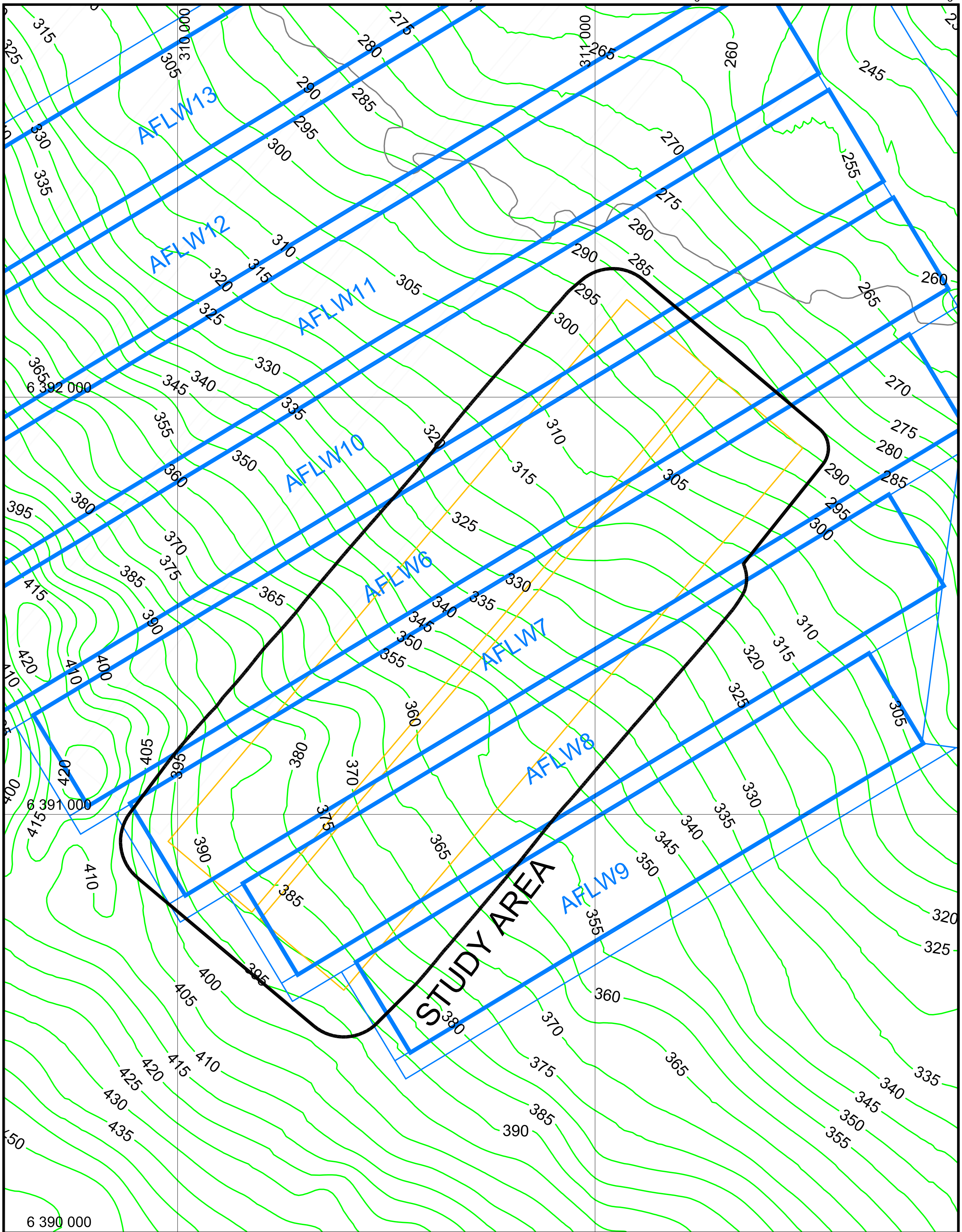

DEPTH OF COVER CONTOURS ARE IN METRES

Grid to MGA co-ordinates

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ARROWFIELD SEAM DEPTH OF COVER CONTOURS

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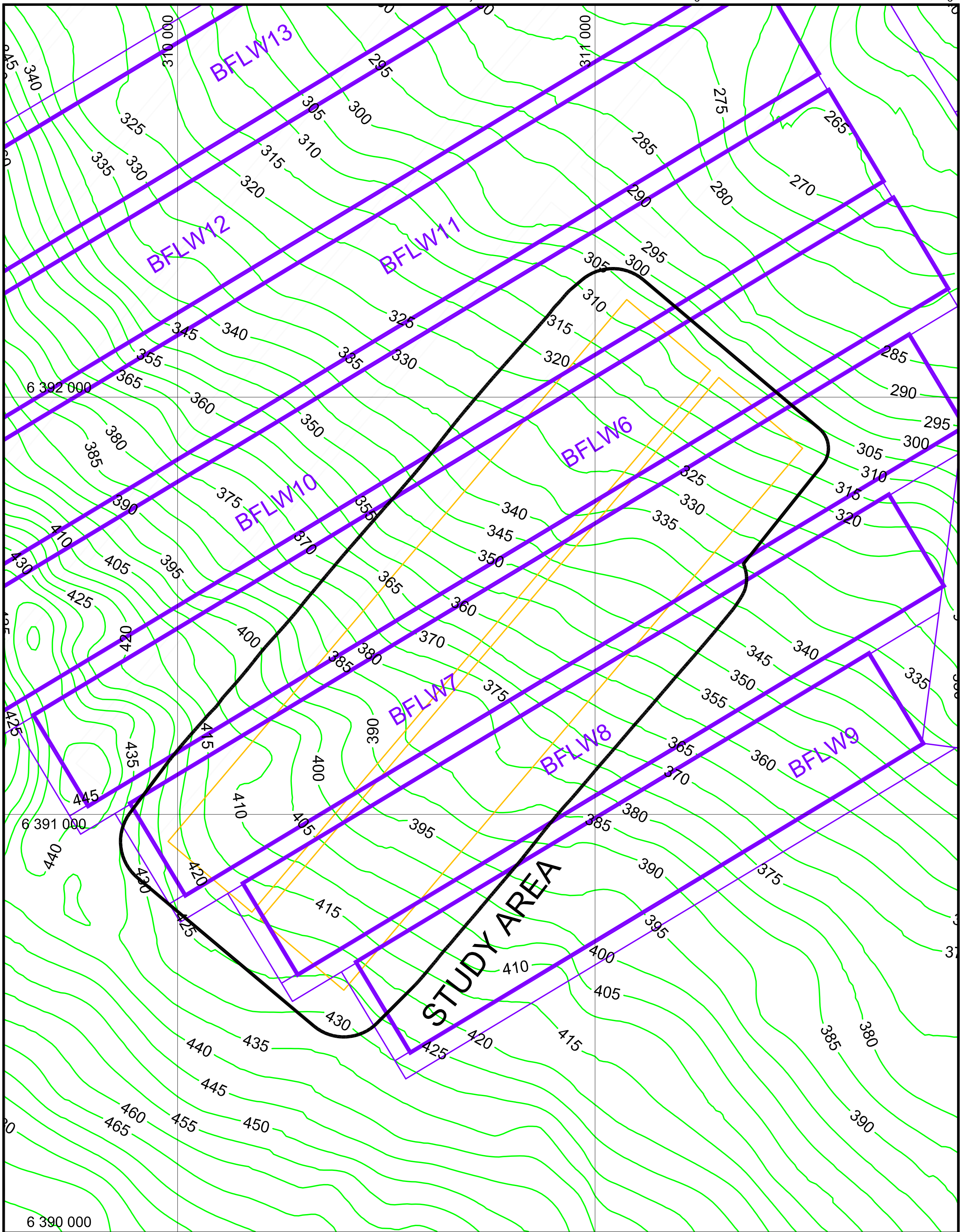

DEPTH OF COVER CONTOURS ARE IN METRES

Grid to MGA co-ordinates

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BOWFIELD SEAM DEPTH OF COVER CONTOURS

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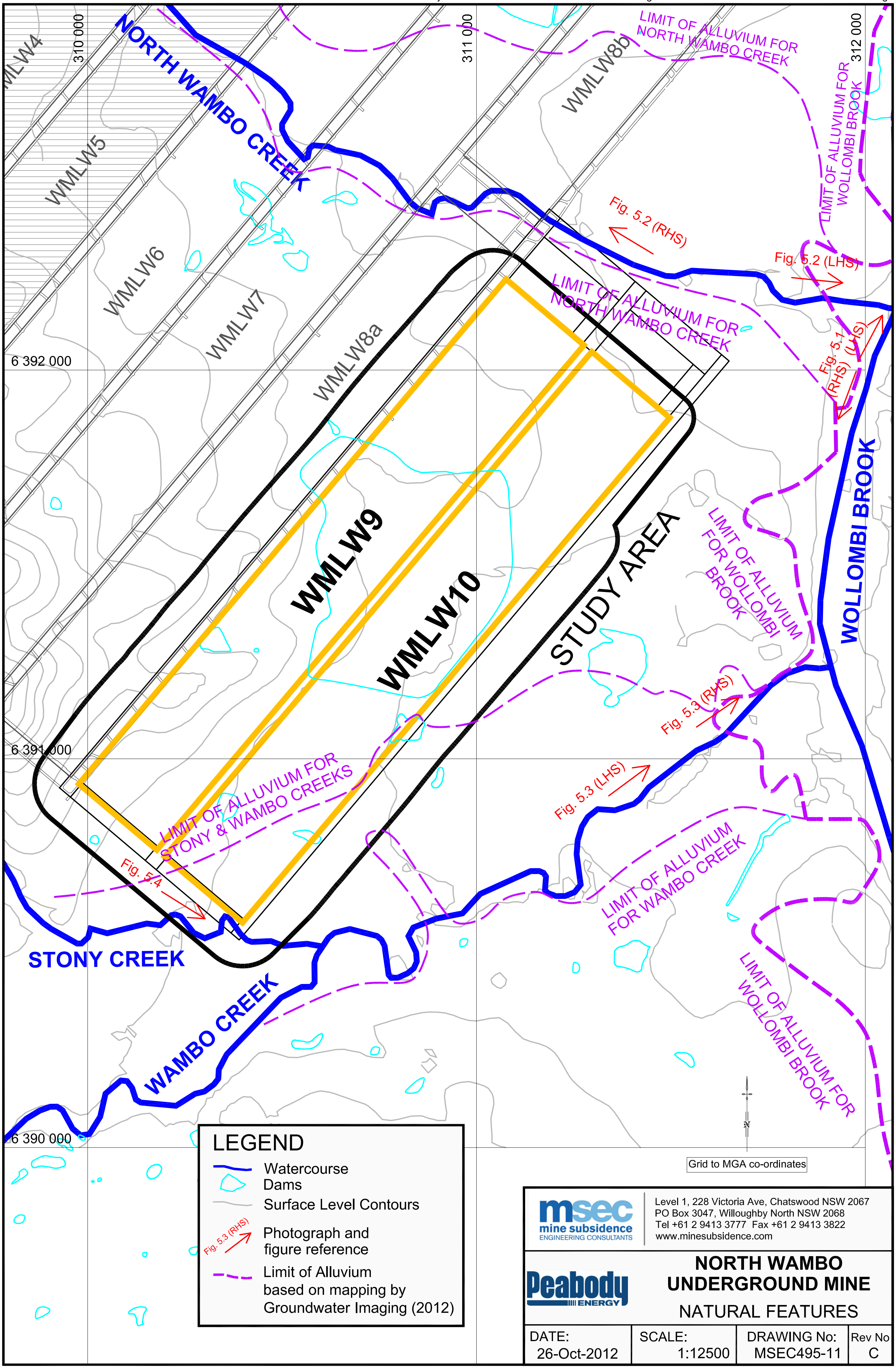

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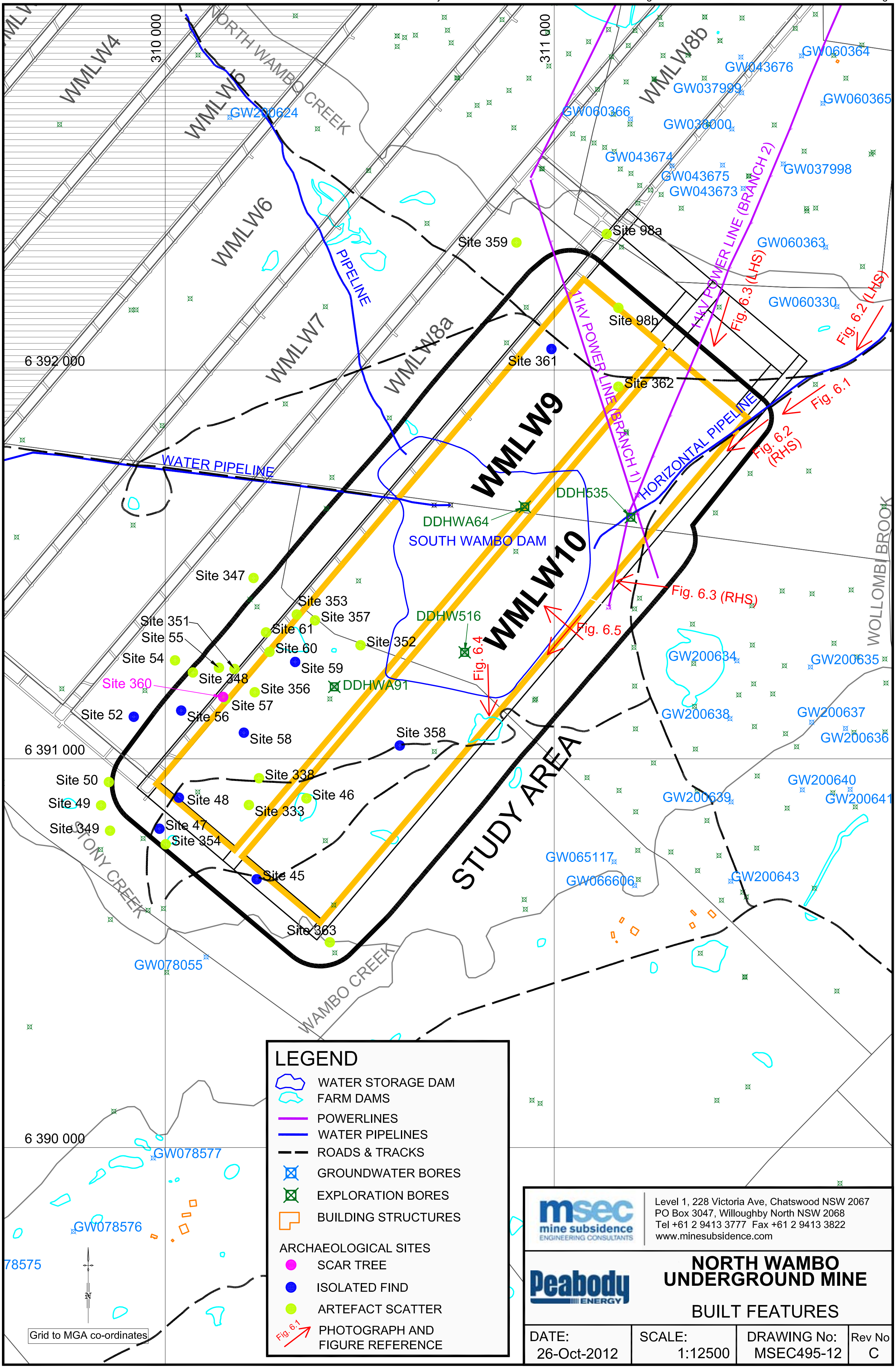

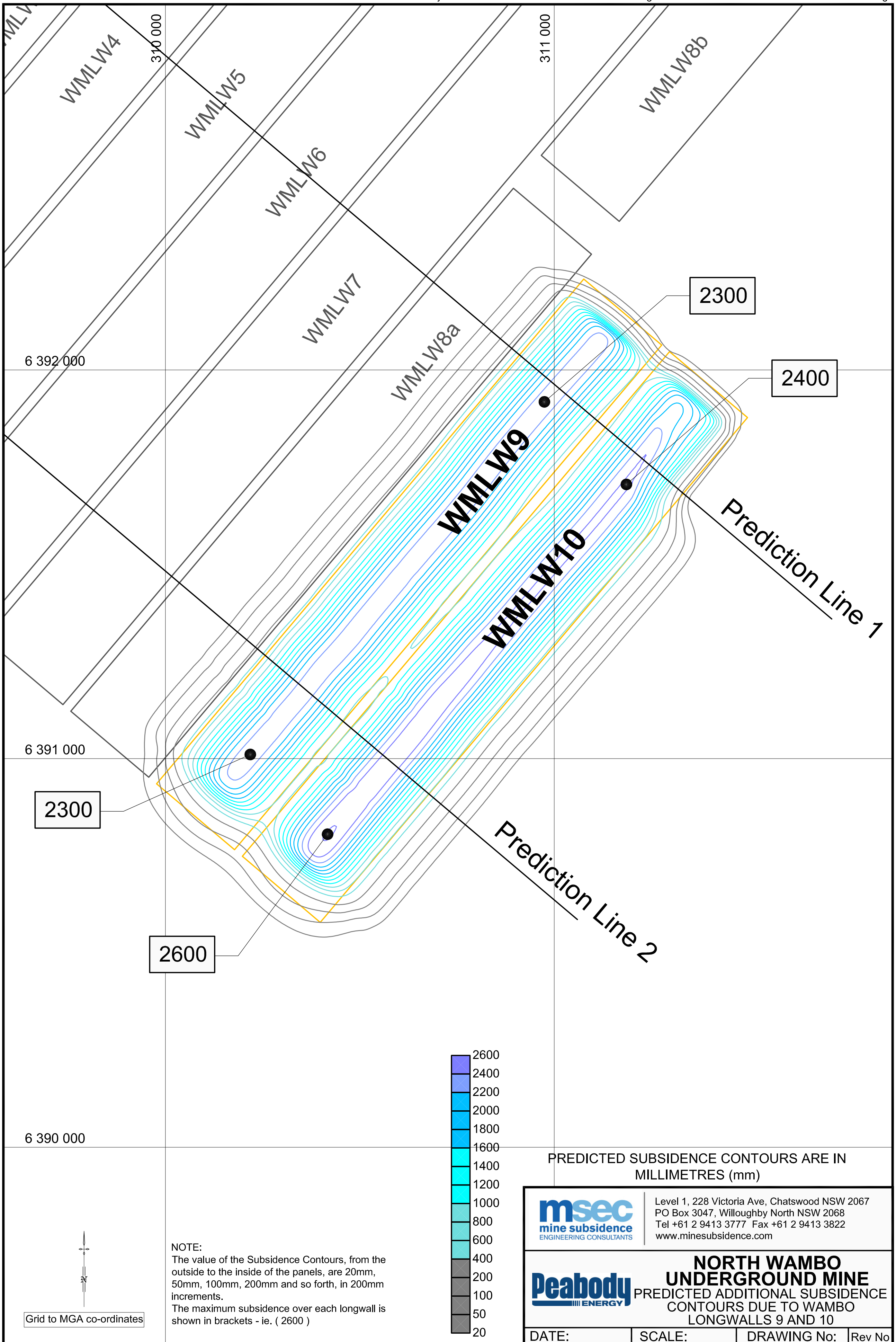

NOTE:
The value of the Subsidence Contours, from the outside to the inside of the panels, are 20mm, 50mm, 100mm, 200mm and so forth, in 200mm increments.
The maximum subsidence over each longwall is shown in brackets - ie. (2600)

PREDICTED SUBSIDENCE CONTOURS ARE IN MILLIMETRES (mm)

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PREDICTED ADDITIONAL SUBSIDENCE CONTOURS DUE TO WAMBO LONGWALLS 9 AND 10

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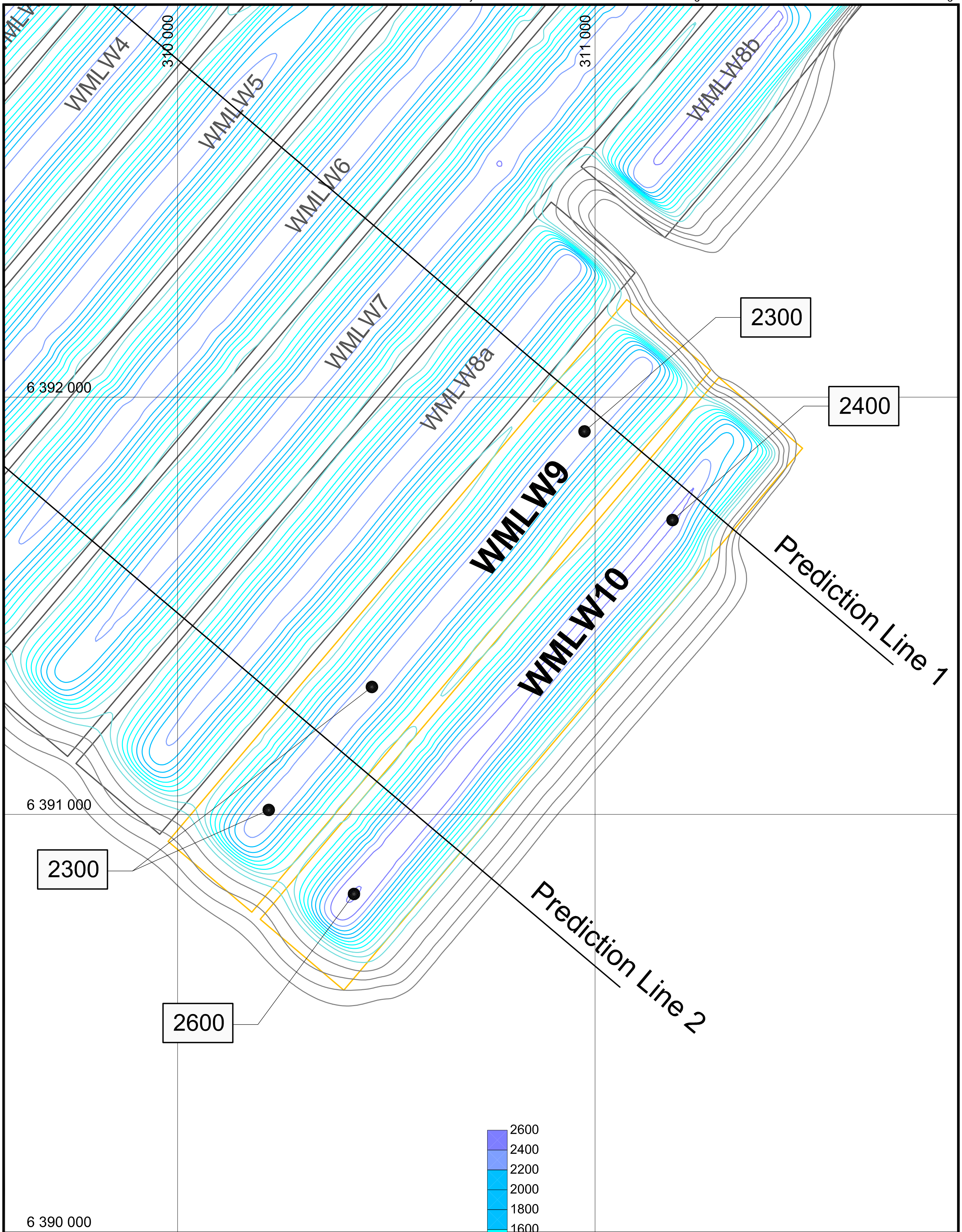

2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
100
50
20

PREDICTED SUBSIDENCE CONTOURS ARE IN MILLIMETRES (mm)

Grid to MGA co-ordinates

NOTE:
The value of the Subsidence Contours, from the outside to the inside of the panels, are 20mm, 50mm, 100mm, 200mm and so forth, in 200mm increments.
The maximum subsidence over each longwall is shown in brackets - ie. (2600)

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NORTH WAMBO UNDERGROUND MINE
PREDICTED TOTAL SUBSIDENCE CONTOURS DUE TO WAMBO LONGWALLS 1 TO 10

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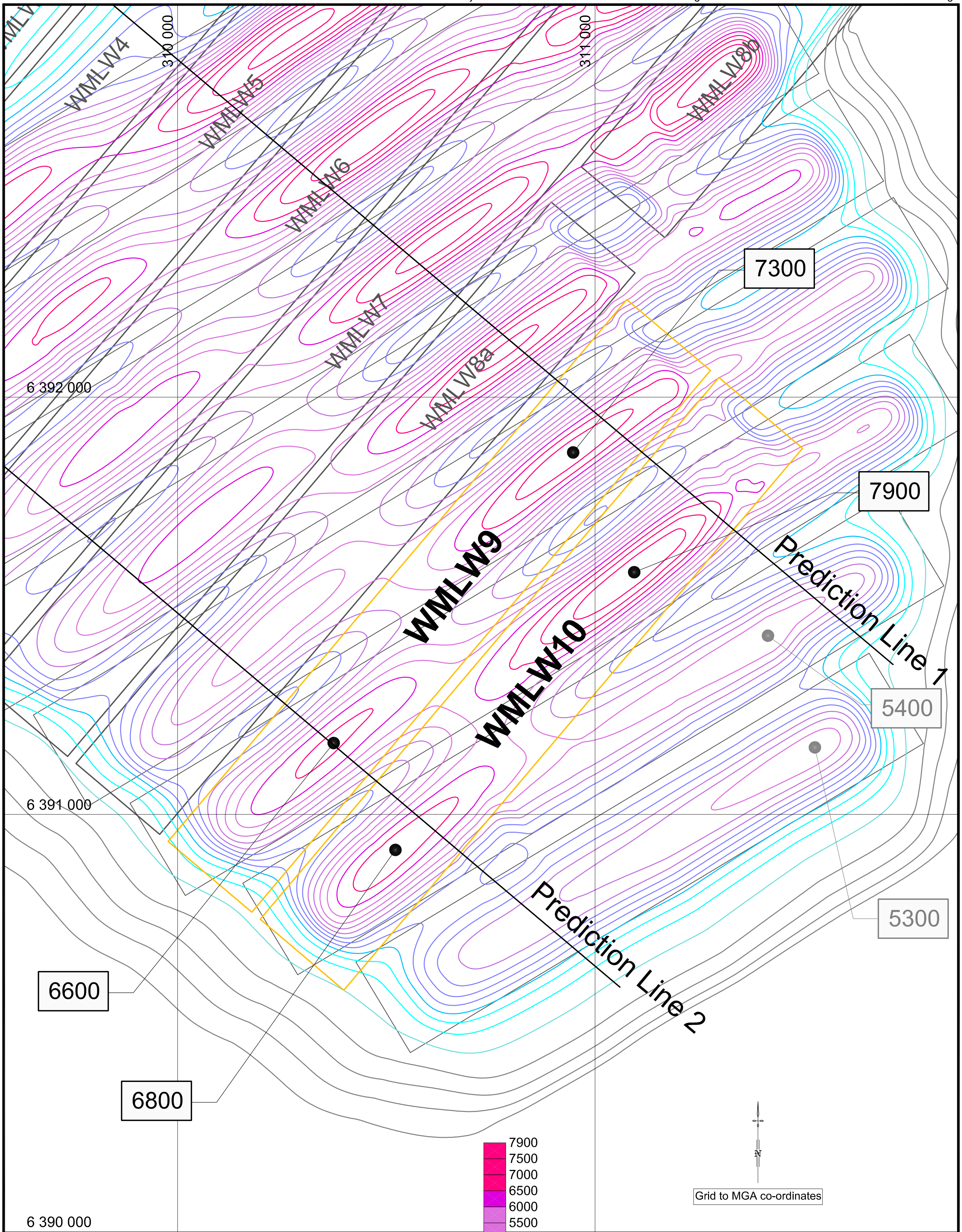

PREDICTED SUBSIDENCE CONTOURS
ARE IN MILLIMETRES (mm)

NOTE:
The value of the Subsidence Contours, from the outside to the inside of the panels, are 20mm, 50mm, 100mm, 200mm, 500mm and so forth, in 500mm increments.
The maximum subsidence over each longwall is shown in brackets - ie. (7900)

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NORTH WAMBO UNDERGROUND MINE
PREDICTED TOTAL SUBSIDENCE CONTOURS DUE TO WAMBO, ARROWFIELD & BOWFIELD SEAMS

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