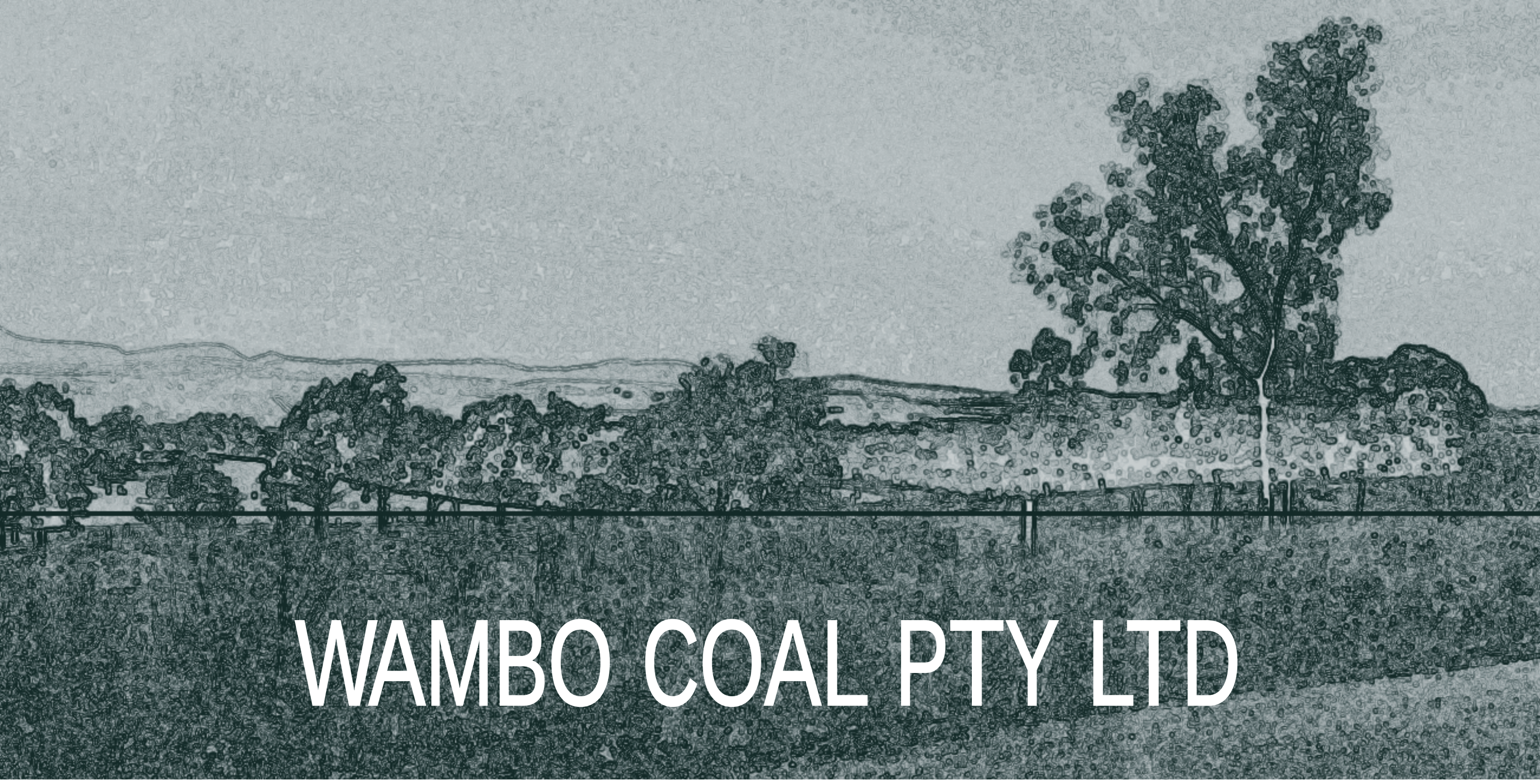

WAMBO COAL PTY LTD

NORTH WAMBO UNDERGROUND MINE
LONGWALL 10A MODIFICATION

ENVIRONMENTAL ASSESSMENT

APPENDIX A

Subsidence Assessment

Peabody ENERGY

WAMBO COAL:

North Wambo Underground Longwall 10A 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 Inclusion of the Proposed Longwall 10A in the Wambo Seam

DOCUMENT REGISTER

Revision	Description	Author	Checker	Date
01	Draft Issue	JB	-	30th May 14
A	Final Issue	JB	PD	24th Jul 14
B	Minor Revisions	JB	PD	8th Aug 14

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

Previous reports: Report No. MSEC495 (Rev. C) – 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.

Report No. MSEC663 (Rev. A) – Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of a Revised Extraction Plan for Longwalls 7 to 10 in the Wambo Seam.

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 MOD13) under Section 75W of the *Environmental Planning and Assessment Act 1979* (EP&A Act), by extracting one additional longwall in the Wambo Seam, referred to as Longwall 10A or WMLW10A.

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 North Wambo Underground Mine Modification Environmental Assessment (WCPL, 2012) and Report No. MSEC495,
- identify the natural and built features located above and in the vicinity of the proposed longwall, 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 Environment.

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 WMLW10A is 2,550 mm.

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 WMLW10A and by the predicted incremental 20 mm subsidence contour resulting from the extraction of the proposed longwall. 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, Wambo South Water Dam; an 11 kilovolt (kV) powerline; water pipelines; fences; farm dams; exploration bores; 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:-

- The banks of Wollombi Brook are located 125 metres east of WMLW10A, at its closest point to the proposed longwall. At this distance, the brook is not expected to experience any measurable tilts, curvatures or strains. The alluvium associated with the brook is predicted to experience around 20 mm vertical subsidence, due to the extraction of WMLW10A, and the additional tilts and curvatures are predicted to be negligible.

  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 26.5 degree angle of draw from extent of the proposed WMLW10A is located outside the 40 metre buffer from the nearest bank of Wollombi 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 WMLW10A. That is, the potential subsidence impacts on the Wollombi Brook, due to the extraction of the proposed longwall, 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 *HydroSimulations* (2014).

- The banks of North Wambo Creek are located at a distance of 270 metres north of the finishing end of WMLW10A, at is closest point to the proposed longwall. Whilst this creek could experience very low levels of subsidence, it is not expected to experience any measurable tilts, curvatures or strains resulting from the extraction of the proposed longwall.

  Wambo and Stony Creeks are partially located above the commencing end of WMLW10A. The total length of these creeks located directly above the proposed longwall is around 330 metres. The maximum predicted additional movements at these creeks, due to the extraction of WMLW10A, are 900 mm vertical subsidence, 15 mm/m tilt and 0.6 km^{-1} hogging curvature and 0.2 km^{-1} sagging curvature.

  Increased ponding is predicted to occur along the sections of Wambo and Stony Creeks located directly above the proposed WMLW10A. The depth of ponding resulting from the extraction of the approved, proposed and future longwalls in the Wambo, Arrowfield and Bowfield Seams is predicted to increase from 0.4 metres to 0.7 metres as a result of the proposed modification. Ponding further downstream adjacent to the tailgates of the future AFLW9 and BFLW9, which is up to 1.2 metres deep, is not predicted to change as a result of the proposed modification.

  If the mining induced ponding areas were to result in adverse impacts along these creeks, these could be remediated by excavating the channels downstream of the proposed and future longwalls and by increasing the heights of the banks above the proposed and future longwalls.

  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 effects of the proposed longwall.

- There were no steep slopes identified within the Study Area, apart from the localised areas around the creek banks and the walls of Wambo South Water Dam and the farm dams. The Wollemi Escarpment is located at a distance greater than 2 kilometres west of the proposed longwall, at its closest point.

- Unsealed roads used for the mining operations are located across the Study Area. Whilst there are no public roads within the Study Area, the road above WMLW10A is a right of way in favour of several private properties, the route of which may be varied on reasonable notice. 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 Wambo South Water Dam is owned by WCPL and has supplied water for mining activities. The dam is located immediately to the west of the proposed WMLW10A and directly above the approved WMLW9 and WMLW10.

  Only low levels of additional subsidence will develop at the Wambo South Water Dam as a result of the extraction of WMLW10A. Management strategies have been developed for the dam based on the approved WMLW9 and WMLW10 mining directly beneath it, including procedures to lower the water level in the dam prior to active subsidence and the establishment of methods to remediate the dam base and wall, if required. It is recommended that the existing management strategies are reviewed and, where required, are revised to include the effects of the proposed WMLW10A.

- 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.

- An 11 kV powerline owned by WCPL is partially located within the Study Area, above the approved WMLW10 and above the chain pillar between this approved longwall and the proposed WMLW10A. The maximum predicted subsidence parameters resulting from the approved, proposed and future longwalls in the Wambo, Arrowfield and Bowfield Seams, based on the *Modified Layout*, are the same as those predicted based on the *Approved Layout*. The impact assessments and proposed management strategies for the powerline do not change as a result of the proposed modification.

- There are five farm dams located within the Study Area. Surface cracking could occur in the bases or walls of the dams located directly above the proposed WMLW10A. 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 predicted change in freeboard for the farm dam located above the maingate of the proposed WMLW10A is likely to reduce the storage capacity and could potentially cause it to overflow. It is recommended that the water storage level of this dam is reduced during active subsidence and, if it were to be adversely impacted, it could be remediated by raising the earthen dam wall.

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.

CONTENTS

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.

Drawing No.	***Description***	***Revision***
MSEC697-01	Overall Layout	B
MSEC697-02	General Layout	B
MSEC697-03	Surface Level Contours	B
MSEC697-04	Wambo Seam Floor Contours	B
MSEC697-05	Wambo Seam Thickness Contours	B
MSEC697-06	Wambo Seam Depth of Cover Contours	B
MSEC697-07	Geological Structures Identified at Wambo Seam Level	B
MSEC697-08	Whybrow Depth of Cover Contours	B
MSEC697-09	Arrowfield Seam Depth of Cover Contours	B
MSEC697-10	Bowfield Seam Depth of Cover Contours	B
MSEC697-11	Natural Features	B
MSEC697-12	Built Features	B
MSEC697-13	Predicted Incremental Subsidence Contours due to Wambo Longwall 10A	B
MSEC697-14	Predicted Total Subsidence Contours due to Wambo Longwalls 1 to 10A	B
MSEC697-15	Predicted Cumulative Subsidence Contours due to Whybrow and Wambo Seams	B
MSEC697-16	Predicted Cumulative Subsidence Contours due to Whybrow, Wambo, Arrowfield and Bowfield Seams	B

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* (EP&A Act), in February 2004, which included the extraction of eight longwalls in the Wambo Seam 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 first eight approved longwalls in the Wambo Seam are referred to as WMLW1 to WMLW8 in this report.

WCPL then sought approval for the extraction of two additional longwalls in the Wambo Seam, referred to as WMLW9 and WMLW10 in this report, which was addressed in the *North Wambo Underground Mine Modification Environmental Assessment* (WCPL, 2012). Report No. MSEC495 (Rev. C) was issued in October 2012, which supported the Modification Application. WCPL was granted approved for the modification (DA 305-7-2003 MOD13) in July 2013.

The mining layout indicated in the Modification Application (WCPL, 2012) and in Report No. MSEC495, which included WMLW1 to WMLW10 in the Wambo and the future longwalls in the Arrowfield and Bowfield Seams, is referred to as the *Approved Layout* in this report.

WCPL is now seeking approval to modify the Wambo Development Consent (DA 305-7-2003) under Section 75W of the EP&A Act, by extracting one additional longwall in the Wambo Seam, referred to as WMLW10A. The mining layout including the approved longwalls and the proposed additional longwall 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. MSEC697-01, 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. MSEC697-02.

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 *North Wambo Underground Mine Modification Environmental Assessment* (WCPL, 2012) and Report No. MSEC495 based on the *Approved Layout*,
- identify the natural and built features located above and in the vicinity of the proposed longwall,
- 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 Report No. MSEC495, 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 Environment.

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 WMLW10A 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 longwall are indicated in this figure.

Fig. 1.1 Aerial Photograph Showing Locations of the Proposed WMLW10A

1.2. Mining Geometry

The longwall WMLW10A is proposed to be extracted in the Wambo Seam immediately to the south-east of the approved WMLW1 to WMLW10. 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. MSEC697-01. The existing workings in the Whybrow Seam are also shown in this drawing. A summary of the dimensions for the proposed WMLW10A is provided in Table 1.1.

Table 1.1 Geometry of the Proposed Longwall

Longwall	Overall Void Length Including Installation Heading (m)	Overall Void Width Including First Workings (m)	Overall Tailgate Chain Pillar Width (m)
WMLW10A	1,750	263	26

The width of the longwall extraction face (i.e. excluding the first workings) is around 253 metres. The longwall is 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 Drawings Nos. MSEC697-01 and MSEC697-02. The future longwalls 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. MSEC697-03 to MSEC697-06.

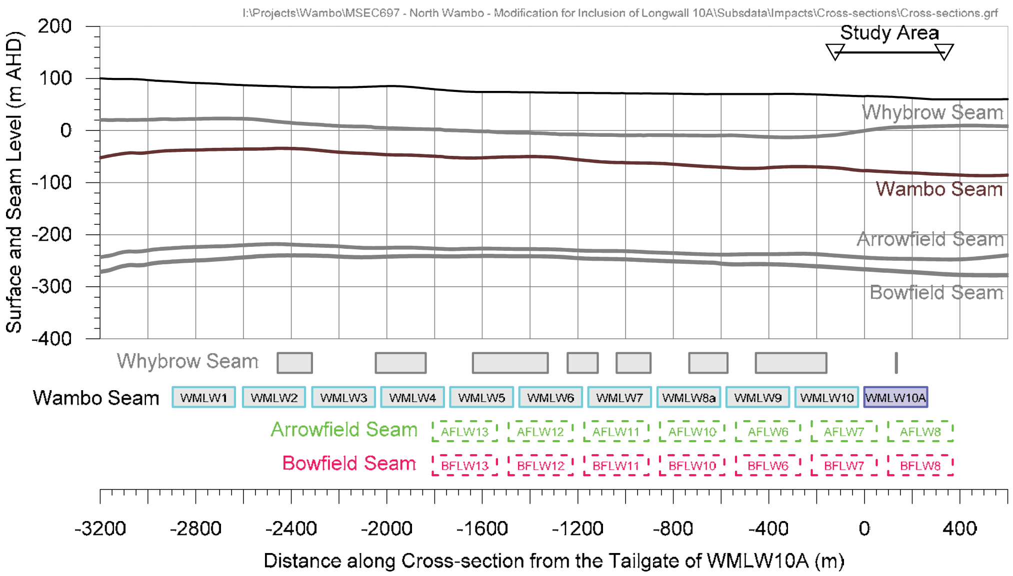

Fig. 1.2 Surface and Seam Levels along Cross-section 1

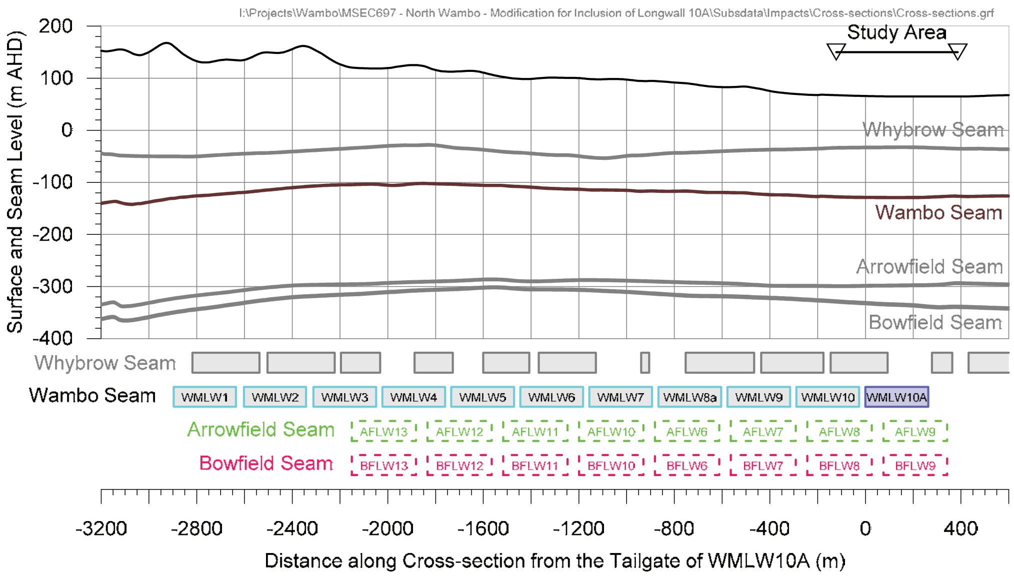

Fig. 1.3 Surface and Seam Levels along Cross-section 2

The surface level contours in the vicinity of the proposed WMLW10A are shown in Drawing No. MSEC697-03. 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). The Wollemi Escarpment is located more than 2 kilometres west of the proposed longwall, at its closest point.

The surface levels directly above the proposed WMLW10A vary from a low point of approximately 60 metres above Australian Height Datum (mAHD) above the longwall maingate, to a high point of approximately 70 mAHD above the longwall commencing end. The low point in the area is the Wollombi Brook, located east of the proposed longwall, which is at around 56 mAHD.

The seam floor contours, seam thickness contours and depth of cover contours for the Wambo Seam are shown in Drawings Nos. MSEC697-04, MSEC697-05, and MSEC697-06, 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 WMLW10A, varies between a minimum of 120 metres above the longwall finishing end and a maximum of 220 metres above the longwall commencing end.

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 longwall. The thickness of the Wambo Seam, within the extents of the proposed longwall, varies between 1.8 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 Drawings Nos. MSEC697-08, MSEC697-09 and MSEC697-10, respectively.

The depth of cover to the existing workings in the Whybrow Seam, directly above the proposed WMLW10A, varies between a minimum of 60 metres near the longwall finishing end and a maximum of 130 metres above the longwall commencing end. The interburden thickness between the Whybrow and Wambo Seam varies between around 75 metres and 95 metres within the extents of the proposed longwall.

The future longwalls in the Arrowfield and Bowfield Seams will be extracted directly beneath the proposed WMLW10A. The depths of cover to these seams, within the extents of the proposed longwall, vary between approximately 285 metres and 390 metres for the Arrowfield Seam, and between approximately 310 metres and 425 metres for the Bowfield Seam.

The interburden thicknesses, within the extents of the proposed longwall, 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 Newcastle Coal Measures. The Newcastle 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		
	Newcastle 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 approved WMLW10, DDH WA64 which is located above the chain pillar between the approved WMLW9 and WMLW10, and DDH WA91 which is located above the approved 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.

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

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. MSEC697-07. There is a north to south trending fault with a throw around 1 metre which crosses the through the middle of WMLW10A. There are no other faults identified within the Study Area.

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 longwall and, therefore, is unlikely to have any significant effect on the subsidence movements.

The surface lithology in the area can be seen in Fig. 1.4, which shows the proposed longwall and the Study Area overlaid on the *Geological Map of Doyles Creek 9032I*, which was published by the Department of Mineral Resources (DMR, 1988), now known as DTIRIS. The limits of alluvium which were mapped by Groundwater Imaging (2012) have also been shown in this figure as the magenta dashed lines.

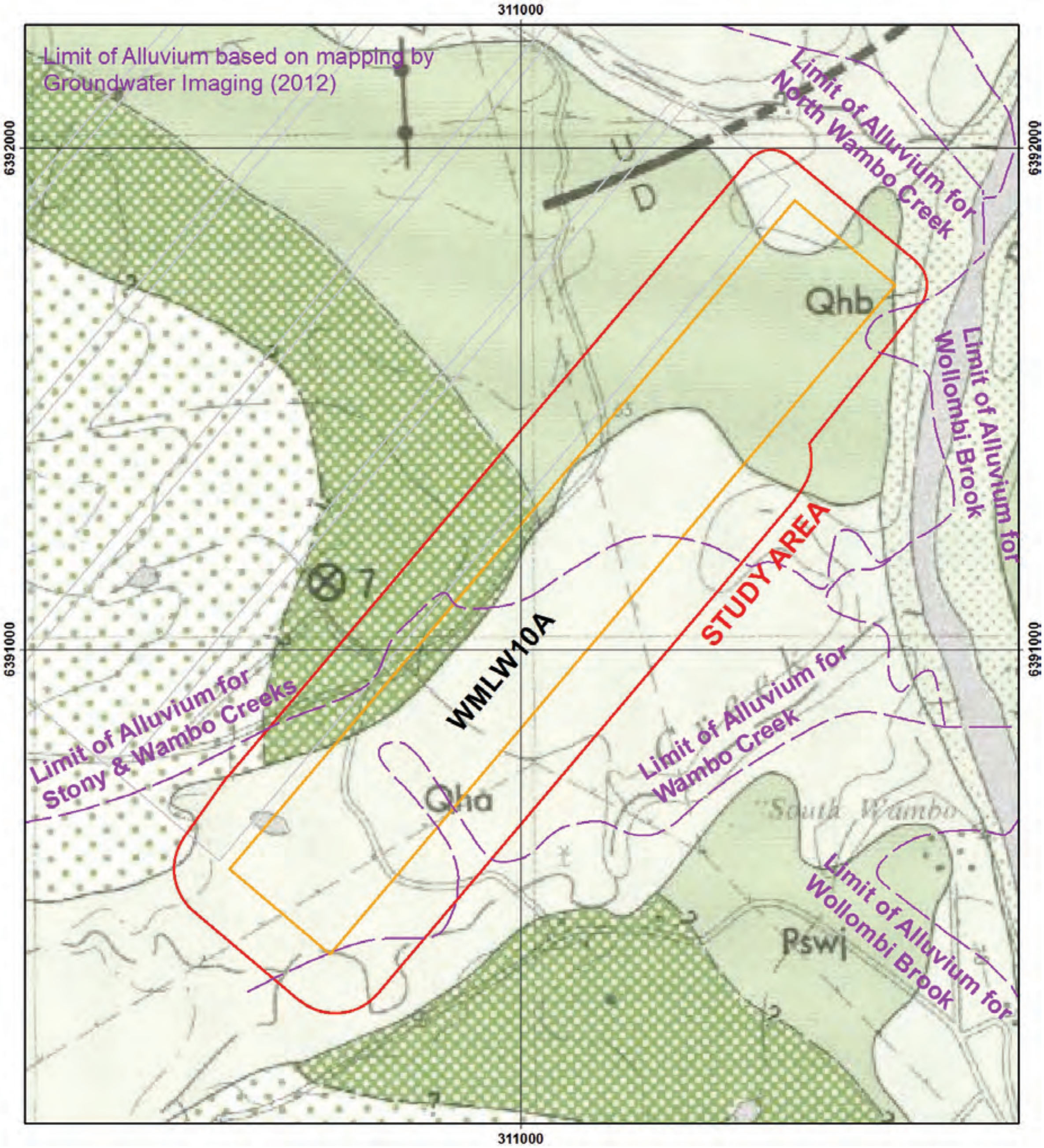

Fig. 1.4 Proposed WMLW10A Overlaid on Geological Map Doyles Creek 9032I

It can be seen from the above figure, that the surface lithology comprises Quaternary Alluvium (Qha) above the central and south-western end of the proposed WMLW10A and comprises the Jerrys Plains Subgroup of the Wittingham Coal Measures (Pswj) above the north-eastern end. There is an area above the longwall tailgate which comprises the Newcastle Coal Measures (Pslz).

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 WMLW10A 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 WMLW10A, and
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour resulting from the extraction of the proposed longwall.

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. MSEC697-06. It can be seen from this drawing that the depth of cover to the Wambo Seam, directly above the proposed WMLW10A, varies between a minimum of 120 metres above the longwall finishing end and a maximum of 220 metres above the longwall commencing end. 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 110 metres around the limits of the proposed extraction area.

The predicted limit of vertical subsidence, taken as the predicted 20 mm subsidence contour due to the extraction of WMLW10A, 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 longwall only are shown in Drawing No. MSEC697-13.

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 longwall, and is shown in Drawings Nos. MSEC697-01 and MSEC697-02.

There are areas that lie outside the Study Area that could 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

Some of the natural and built features 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 longwall and the Study Area have been overlaid on an extract of this CMA map in Fig. 2.1.

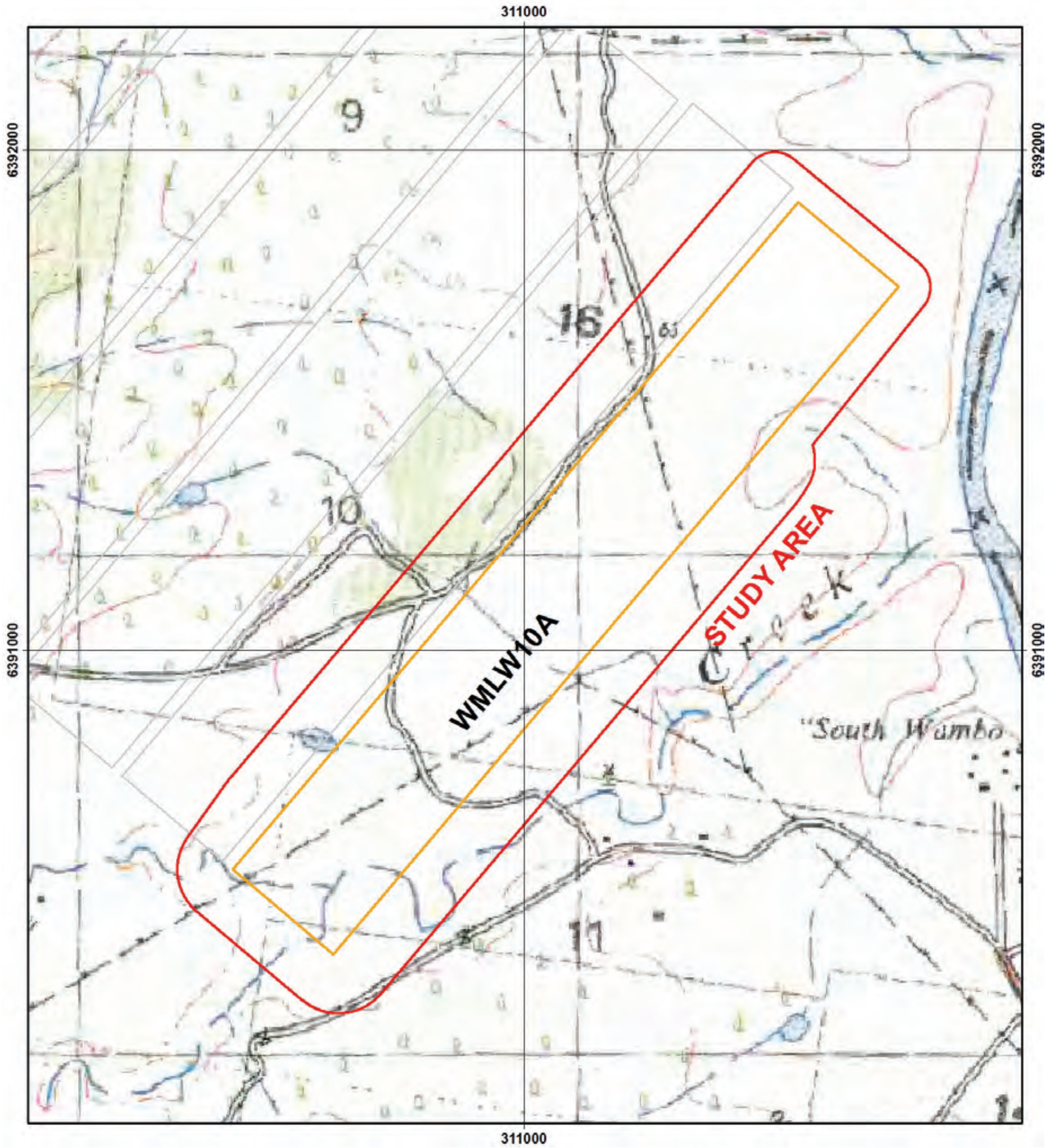

Fig. 2.1 Proposed WMLW10A Overlaid on CMA Map No. Doyles Creek 90321-N

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. MSEC697-11 and MSEC697-12. 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	×	
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	✓	6.2, 6.3, 6.4 & 6.12
Any Other Industrial, Commercial or Business Features	×	
AREAS OF ARCHAEOLOGICAL SIGNIFICANCE	✓	6.15
AREAS OF HISTORICAL SIGNIFICANCE	×	
ITEMS OF ARCHITECTURAL SIGNIFICANCE	×	
PERMANENT SURVEY CONTROL MARKS	×	6.16
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, Hunter and Western 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, Hunter and Western Coalfields. The prediction curves can 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 WMLW10A, 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 longwall. 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 WMLW10A is 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 longwall, 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. MSEC697-01.

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 WMLW10A (i.e. single-seam mining conditions) is around 120 metres and, therefore, the panel width-to-depth ratio is 2.2 (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, the Beltana No. 1 Underground Mine, 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.12 and C.13, 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.12 and C.13) 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 WMLW10A 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 NSW 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 WMLW10A

The interburden thickness between the Wambo and Whybrow Seams, within the extents of the proposed WMLW10A, varies between a minimum of 75 metres above the longwall finishing end and a maximum of 95 metres above the longwall commencing end.

Multi-seam monitoring data was gathered during the extraction of WMLW1 to WMLW7 at the NWUM. The main transverse lines were the XL1-Line, XL2-Line, XL4-Line, XL5-Line, XL6-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 remaining monitoring lines 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
	LW5	260	85	2.3	40	1.4	3.2	0.60
	LW6	260	90	2.3	45	1.5	2.8	0.65
	LW7	260	95	2.3	50	1.5	2.7	0.66
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
	LW5	260	140	2.2	45	1.8	1.9	0.84
	LW6	260	145	2.2	50	1.8	1.8	0.83
	LW7	260	155	2.2	60	1.6	1.7	0.71

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
XL4-Line	LW3	260	250	2.5	75	2.3	1.0	0.90
	LW4	260	235	2.5	80	2.1	1.1	0.85
	LW5	260	225	2.5	85	1.9	1.2	0.76
XL5-Line	LW6	260	240	2.5	65	2.3	1.1	0.91
	LW7	260	225	2.5	65	1.6	1.2	0.65
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 0.60 and 1.16 times the mining height, with an average around 0.81 times 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 existing 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 Longwalls 1 to 3 – below longwalls 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
NWUM (XL1-Line)	Woodlands Hill Wambo	LW2 to LW7 LW2 to LW7	30 ~ 45 80 ~ 95	N/A 1.5 ~ 1.9	3.0 2.3	a_1 = 0.65# 0.60 ~ 0.82	0.63 ~ 0.72
NWUM (XL2-Line)	Whybrow Wambo	LW10 and B&P LW1 to LW7	95 ~ 100 140 ~ 165	N/A 1.6 ~ 2.5	3.0 2.2	a_1 = 0.65# 0.71 ~ 1.16	0.68 ~ 0.86
NWUM (XL4-Line)	Whybrow Wambo	LW10 to LW12 LW3 to LW5	140 ~ 170 225 ~ 250	N/A 1.0 ~ 1.2	3.0 2.5	a_1 = 0.65# 0.76 ~ 0.90	0.70 ~ 0.76
NWUM (XL5-Line)	Whybrow Wambo	LW3 and B&P LW6 and LW7	150 ~ 170 225 ~ 240	N/A 1.1 ~ 1.2	3.0 2.5	a_1 = 0.65# 0.65 ~ 0.91	0.65 ~ 0.77
NWUM (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 Longwalls 1 and 2 (BSLW1 and BSLW2) beneath the previously extracted longwalls in the overlying Whybrow Seam. The additional subsidence observed along the monitoring lines, resulting from the extraction of BSLW1 and BSLW2, typically varied between 75 % and 100 % of the mining height (i.e. a_2 = 0.75 ~ 1.0) and, on average, was around 85 % of the mining height (i.e. a_2 = 0.85). 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 WMLW10A and the existing Homestead/Wollemi workings in the overlying Whybrow Seam typically varies between 75 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 WMLW10A.

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 WMLW10A varies between 1.8 metres and 2.6 metres, with an average extraction height around 2.3 metres (i.e. T_2 = 2.3).

The maximum predicted additional subsidence resulting from the extraction of the proposed WMLW10A, as a proportion of the extracted seam thickness, therefore, has been calculated as follows:-

Equation 2 $a_2 = (0.80 - 0.65)(3.0 / 2.3) + 0.80 = 1.00$

The maximum additional subsidence, due to the extraction of the proposed WMLW10A, 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 in 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 reactivate the existing goafs in the overlying 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 75 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.

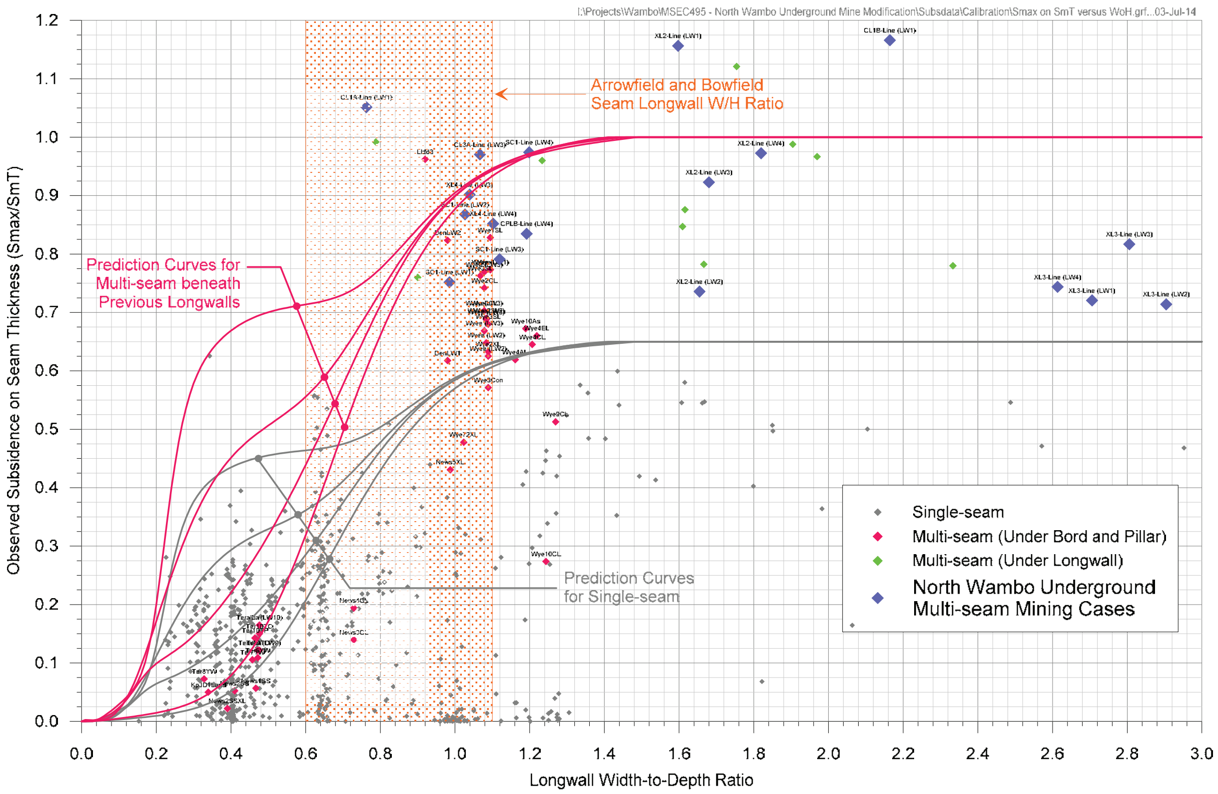

Fig. 3.1 Maximum Observed Subsidence versus Longwall Width-to-Depth Ratio for Historical Multi-seam Mining Cases

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 for super-critical multi-seam mining conditions, 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 to XL6-Line, SC1-Line, CL5A-Line, CL7A-Line, CL7B-Line and CPLB-Line at the NWUM are shown in Figs. C.01 to C.11, 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 maximum observed subsidence is less than the maximum predicted.

The maximum observed subsidence along these monitoring lines varies between 60 % and 116 % of the maximum predicted subsidence and, on average, was around 80 % of the predicted maxima. In some cases, the observed subsidence exceeded the predictions away from the maxima, due to the observed subsidence profiles extending further than predicted from the maxima and then beyond the active longwall. These flatter observed subsidence profiles, however, generally resulted in the observed tilts and curvatures being less than predicted.

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.

4.0 MAXIMUM PREDICTED SUBSIDENCE PARAMETERS FOR THE EXISTING, APPROVED, PROPOSED AND FUTURE LONGWALLS

4.1. Introduction

The following sections provide the maximum predicted conventional subsidence parameters resulting from the extraction of the existing longwalls in the Whybrow Seam, 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 NWUM, and other NSW Collieries, where the mining geometries are similar to those for the proposed longwall.

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. Maximum Predicted Subsidence Parameters due to Mining in the Wambo Seam Only

The predicted incremental conventional subsidence contours due to the extraction of WMLW10A only are shown in Drawing No. MSEC697-13. The predicted total conventional subsidence contours due to the extraction of WMLW1 to WMLW10A are shown in Drawing No. MSEC697-14.

These drawings show the predicted subsidence resulting from the extraction of the Wambo Seam only and, therefore, do not include the subsidence which previously developed during the extraction of the Homestead/Wollemi workings. The predicted contours include the effects of these existing workings on the subsidence which develops from the mining in the Wambo Seam (i.e. multi-seam conditions). The predicted cumulative subsidence due to mining in both the Whybrow and Wambo Seams are provided in Section 4.2.2.

A summary of the maximum predicted values of incremental conventional subsidence, tilt and curvature, due to the extraction of WMLW10A only, is provided in Table 4.1. A summary of the maximum predicted total conventional subsidence parameters within the Study Area, due to the extraction of WMLW1 to WMLW10A, is provided in Table 4.2.

Table 4.1 Maximum Predicted Incremental Conventional Subsidence, Tilt and Curvature due to the Extraction of the Proposed WMLW10A Only

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})
WMLW10A Only	2,550	50	2.0	2.0

Table 4.2 Maximum Predicted Total Conventional Subsidence, Tilt and Curvatures within the Study Area due the Extraction of the WMLW1 to WMLW10A

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 WMLW10A	2,600	50	2.0	2.0

The maximum predicted total subsidence within the Study Area, resulting from the mining in the Wambo Seam, is 2,600 mm which represents 100 % of the proposed extraction height of 2.6 metres. The maximum predicted subsidence occurs near the middle of WMLW10A.

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

4.2.2. Maximum Predicted Cumulative Subsidence Parameters due to Mining in Both the Whybrow and Wambo Seams

The existing Homestead/Wollemi workings were extracted in the overlying Whybrow Seam. The widths of the longwalls and total extraction panels in the Whybrow Seam, within the Study Area, vary between 160 metres and 210 metres. The depth of cover directly above these workings varies between 60 metres and 130 metres and, therefore, the panel width-to-depth ratios vary between 1.6 and 3.5.

The existing workings in the Whybrow Seam were supercritical in width and, therefore, the maximum subsidence is predicted to be 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 predicted cumulative subsidence contours, due to the existing workings in the overlying Whybrow Seam and the approved and proposed longwalls in the Wambo Seam, are shown in Drawing No. MSEC697-15. A summary of the maximum predicted cumulative conventional subsidence parameters within the Study Area, resulting from mining in both the Whybrow and Wambo Seams, is provided in Table 4.3.

Table 4.3 Maximum Predicted Cumulative Conventional Subsidence, Tilt and Curvatures within the Study Area Resulting from Mining in the Whybrow and Wambo Seams

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})
Whybrow Seam	2,000	90	3.0	3.0
Whybrow and Wambo Seams	4,500	100	> 3.0	> 3.0

The maximum predicted cumulative subsidence within the Study Area, resulting from mining in both the Whybrow and Wambo Seams, is 4,500 mm which represents 80 % of the combined extraction height of 5.6 metres, i.e. a_m = 0.80. This proportion is the same as that proposed in Section 3.3 based on the review of relevant multi-seam case studies from the NSW Coalfields.

The maximum predicted cumulative conventional tilt is 100 mm/m (i.e. 10 %), which represents a change in grade of 1 in 10. The maximum predicted cumulative conventional hogging and sagging curvatures are both greater than 3.0 km^{-1}, which represents a minimum radius of curvature of less than 0.3 kilometres. The maximum tilt and curvatures are primarily the result of the existing workings, due to the shallower depths of cover to the Whybrow Seam.

4.2.3. Maximum Predicted Cumulative Subsidence Parameters due to Mining in the Whybrow, Wambo, 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.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature within the Study Area, resulting from mining in the Wambo, Arrowfield and Bowfield Seams, is provided in Table 4.4. These values do not include the subsidence which previously developed during the extraction of the Homestead/Wollemi workings, but include the effects of these existing workings on the subsidence which develops from the mining in the Wambo, Arrowfield and Bowfield Seams.

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

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	2,600	50	2.0	2.0
Wambo and Arrowfield Seam	4,900	70	2.5	2.5
Wambo, Arrowfield and Bowfield Seams	7,700	90	3.0	3.0

The predicted total conventional subsidence contours due to the existing workings in the Whybrow Seam, the approved and proposed longwalls in the Wambo Seam and the future longwalls in the Arrowfield and Bowfield Seams, based on the *Modified Layout*, are shown in Drawing No. MSEC697-16.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature within the Study Area, resulting from mining in the Whybrow, Wambo, Arrowfield and Bowfield Seams, is provided in Table 4.5.

Table 4.5 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature due to Mining in the Whybrow, Wambo, Arrowfield and Bowfield Seams

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})
Whybrow and Wambo Seams	4,500	100	> 3.0	> 3.0
Whybrow, Wambo and Arrowfield Seams	6,900	> 100	> 3.0	> 3.0
Whybrow, Wambo, Arrowfield and Bowfield Seams	9,700	> 100	> 3.0	> 3.0

The maximum predicted total subsidence within the Study Area, due to mining in the Whybrow, Wambo, Arrowfield and Bowfield Seams, is 9,700 mm which represents around 75 % of the total extraction height of 13 metres.

The maximum predicted conventional tilt is greater than 100 mm/m (i.e. > 10 %), which represents a change in grade of greater than 1 in 10. The maximum predicted conventional hogging and sagging curvatures are both greater than 3.0 km^{-1}, which represents a minimum radius of curvature of less than 0.3 kilometres.

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

The predicted tilts and curvatures within the Study Area, resulting from the extraction of the existing workings in the overlying Whybrow Seam, are significantly greater than the predicted tilts and curvatures resulting from the approved, proposed and future mining in the Wambo, Arrowfield and Bowfield Seams. The reason for this is that the depths of cover to the Whybrow Seam are shallow, varying between 60 metres and 130 metres within the Study Area.

For this reason, the comparison of the predicted conventional subsidence parameters based on the Approved and Modified Layouts have been based on the extraction of the approved and proposed longwalls within the Wambo Seam and the future longwalls in the Arrowfield and Bowfield Seams (i.e. excluding the predicted movements resulting from the existing workings in the Whybrow Seam). However these comparisons include the effects of these existing workings on the subsidence which develops from the mining in the Wambo Seam, Arrowfield and Bowfield Seams.

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 4.6. The values are the maxima within the Study Area obtained using the calibrated Incremental Profile Method, as described in Section 3.3.

Table 4.6 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	7,600	90	3.0	3.0
Modified Layout	7,700	90	3.0	3.0

It can be seen from the above table, that the maximum predicted total vertical subsidence within the Study Area, based on the *Modified Layout*, of 7,700 mm is similar to but slightly greater (i.e. 2 %) 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 Nos. MSEC697-13 to MSEC697-16. The profiles are based on the extraction of the approved, proposed and future longwalls in the Wambo, Arrowfield and Bowfield Seam, but also include the effects of the existing workings in the overlying Whybrow Seam.

The predicted profiles resulting from the extraction of the approved WMLW1 to WMLW10 are shown as the solid cyan lines in these figures. The predicted profiles after the completion of the proposed WMLW10A 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 WMLW10A are expected to be similar to those observed, for multi-seam conditions, during the previously extracted WMLW1 to WMLW7 at the NWUM. These monitoring lines include the XL1-Line, XL2-Line, XL4-Line to XL6-Line and SC1-Line.

Extensive ground monitoring data has also been measured at Blakefield South Mine 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 WMLW10A, which vary between 1.2 and 2.2. 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 longwall, which varies between 75 metres and 95 metres.

The range of potential strains above the proposed WMLW10A has been determined using monitoring data from the previously extracted WMLW1 to WMLW7 at the NWUM, as well as from BSLW1 and BSLW2 at the Blakefield South Mine, where the mining geometry is reasonably similar to those for the proposed longwall. 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 longwall.

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 Blakefield South Mine, for survey bays that were located directly above goaf or the chain pillars that are located between the extracted longwalls, which has been referred to as "*above goaf*".

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.

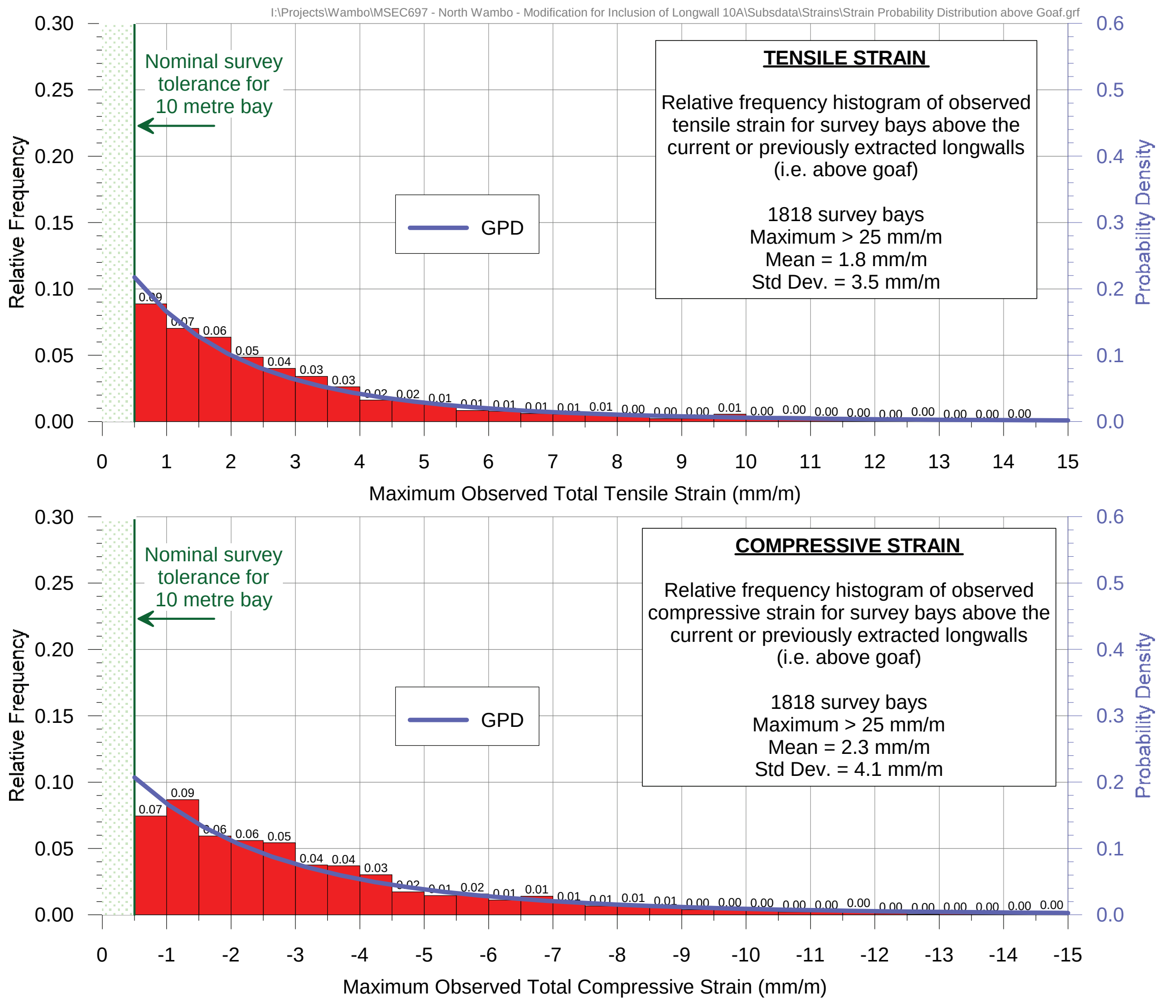

Fig. 4.1 Distributions of the Measured Maximum Tensile and Compressive Strains for Survey Bays Located Directly Above Goaf at the NWUM and Blakefield South Mine

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 9 mm/m compressive. The 99 % confidence levels for the maximum strains that the individual survey bays experienced at any time during mining were 16 mm/m tensile and 18 mm/m 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 Blakefield South Mine, is provided in Fig. 4.2.

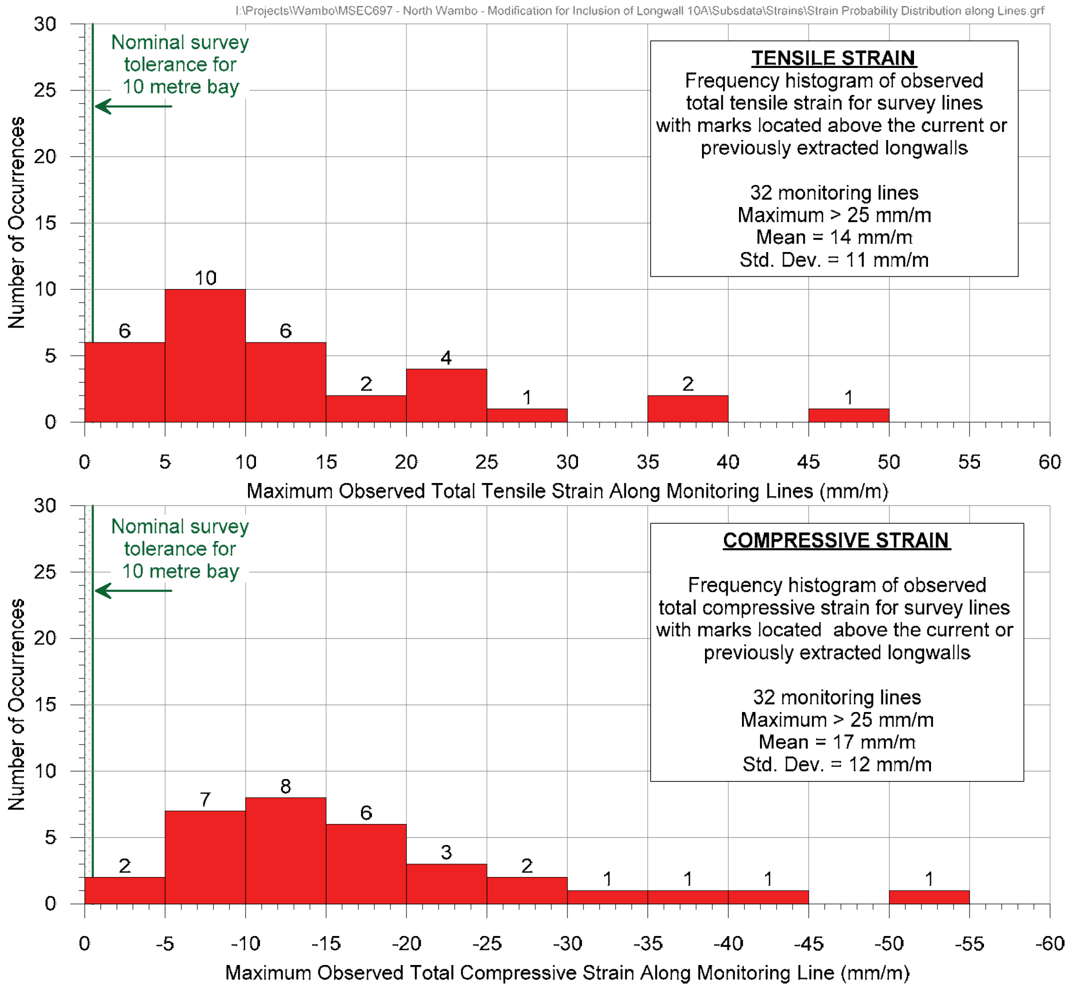

Fig. 4.2 Distributions of Measured Maximum Tensile and Compressive Strains along the Monitoring Lines at the NWUM and Blakefield South Mine

It can be seen from Fig. 4.2, that 16 of the 32 monitoring lines (i.e. 50 %) have recorded maximum total tensile strains of 10 mm/m, or less, and that 24 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 9 of the 32 monitoring lines (i.e. 28 %) have recorded maximum compressive strains of 10 mm/m, or less, and that 23 of the monitoring lines (i.e. 72 %) 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 approved, proposed and future longwalls, it is also likely that far-field horizontal movements will be experienced during the extraction of these 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.

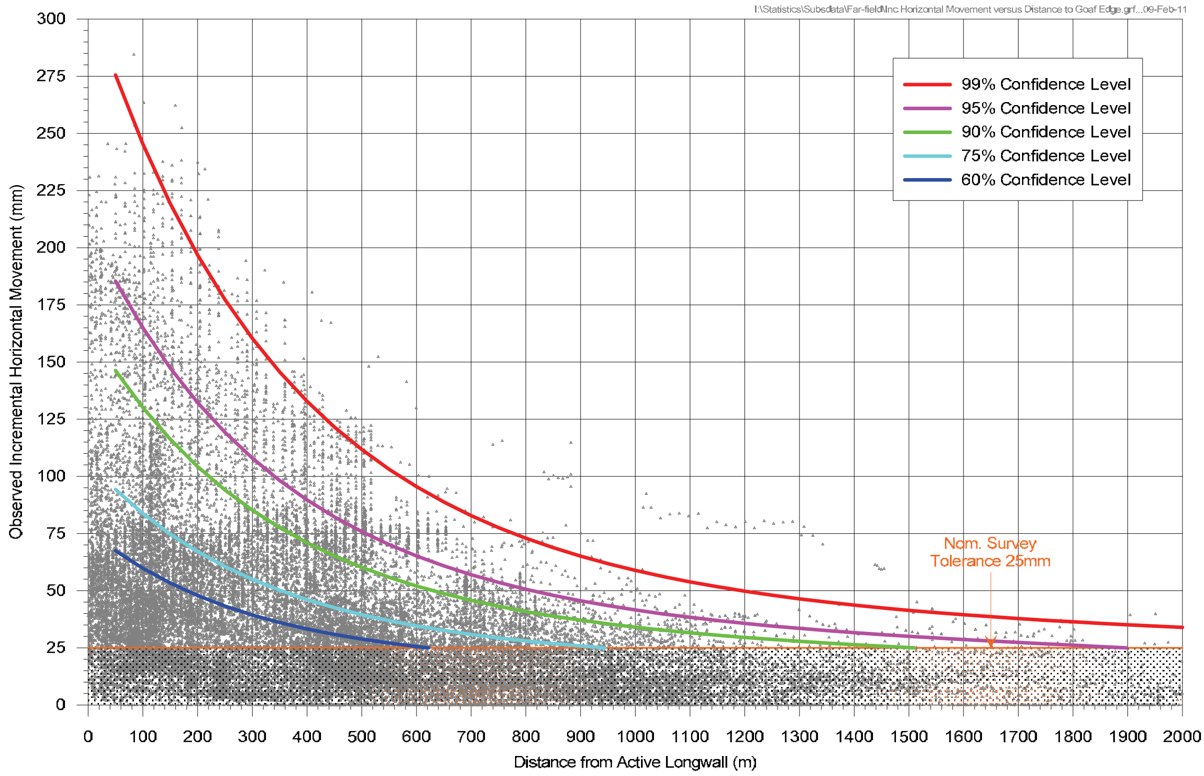

Fig. 4.3 Observed Incremental Far-Field Horizontal Movements

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 approved, proposed and future longwalls are very small and could only be detected by ground 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 magnitudes and extents of 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 longwall 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 are 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 WMLW10A 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 distance 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.

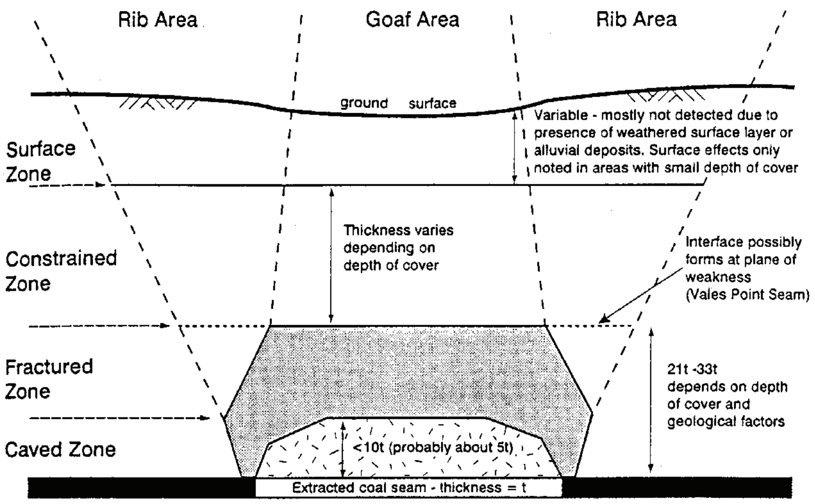

Fig. 4.6 Zones in the Overburden according to Forster (1995)

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

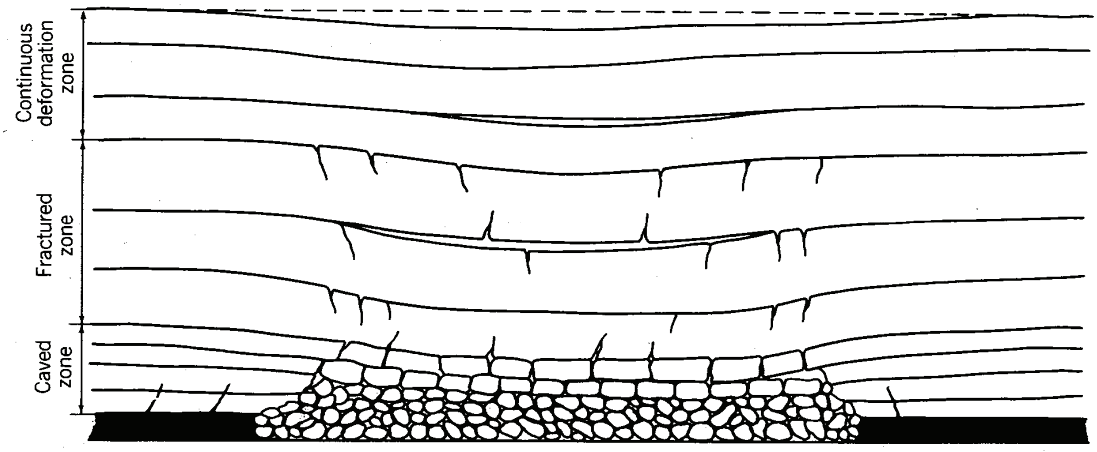

Fig. 4.7 Zones in the Overburden According to Peng and Chiang (1984)

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 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 that has undergone significant deformation and is supported by the material in the caved zone. This zone has 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 by the disturbed zone, 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/or 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.

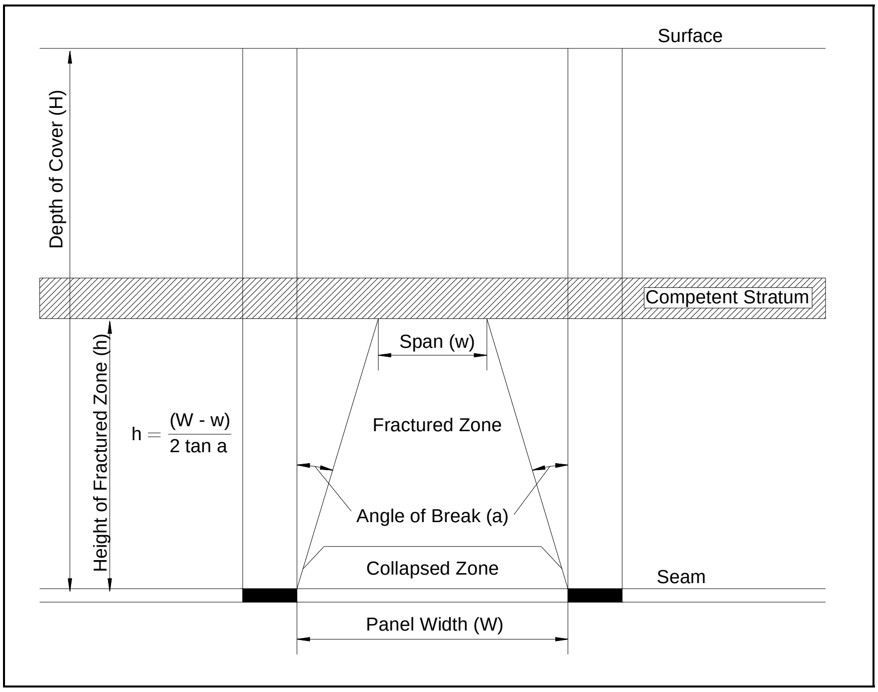

Fig. 4.8 Theoretical Model Illustrating the Development and Limit of the Fractured Zone

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).

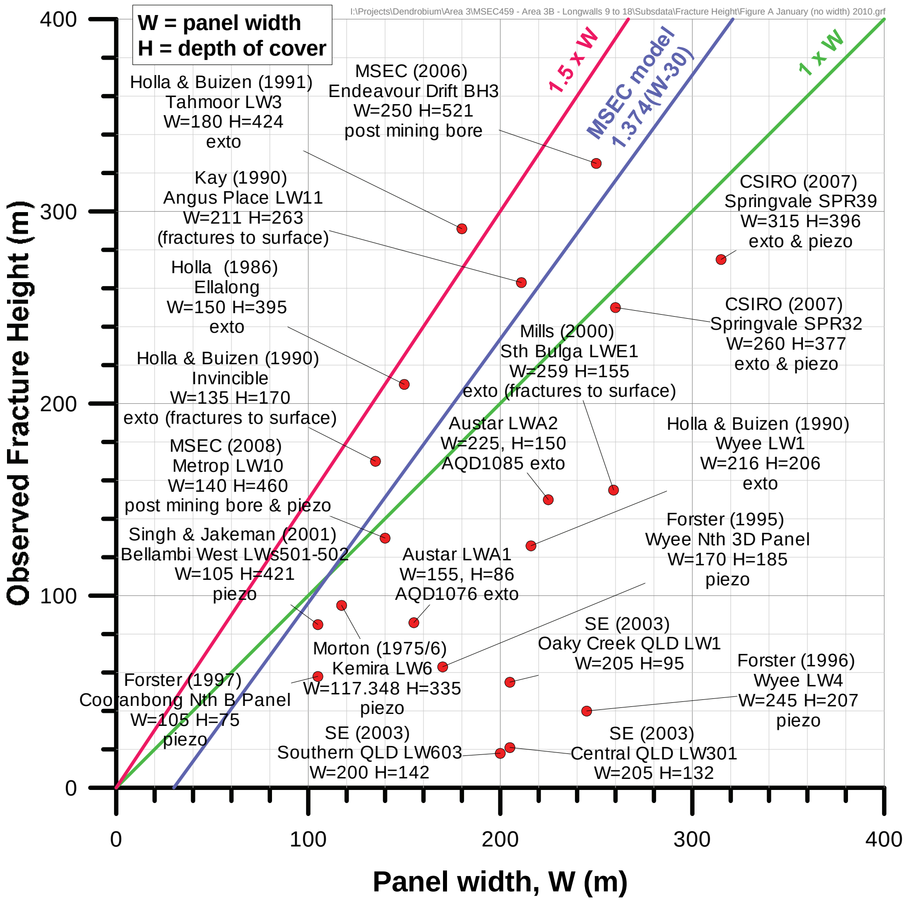

Fig. 4.9 Observed Fracture Heights versus Panel Width

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 WMLW10A, varies between 75 metres and 95 metres. Also, the depth of cover to the Wambo Seam, directly above the proposed longwall, varies between a minimum of 120 metres and a maximum of 220 metres. It is expected, therefore, that the fractured zone resulting from the extraction of the proposed WMLW10A 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 seven 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 *HydroSimulations* (2014). 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.

The predicted tilts and curvatures within the Study Area, resulting from the extraction of the existing workings in the overlying Whybrow Seam, are significantly greater than the predicted tilts and curvatures resulting from the approved, proposed and future mining in the Wambo, Arrowfield and Bowfield Seams. The reason for this is that the depths of cover to the Whybrow Seam are shallow, varying between 60 metres and 130 metres within the Study Area.

For this reason, the comparison of the predicted conventional subsidence parameters based on the Approved and Modified Layouts have been based on the extraction of the approved and proposed longwalls within the Wambo Seam and the future longwalls in the Arrowfield and Bowfield Seams (i.e. excluding the predicted movements resulting from the existing workings in the Whybrow Seam). However, these comparisons include the effects of these existing workings on the subsidence which develops from the mining in the Wambo Seam, Arrowfield and Bowfield Seams.

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. MSEC697-11. The brook is situated outside of the Study Area, with the banks of the brook located at a distance of 125 metres east of the finishing end of WMLW10A, at its closest point to the proposed longwall. 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 is a sensitive feature.

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 longwall, 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. MSEC697-11, which is based on the geophysical mapping undertaken by *Groundwater Imaging* (2012). The alluvium associated with the brook is located immediately to the east of the maingate of WMLW10A, at its closest point, near the finishing end of the proposed longwall.

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. MSEC697-11.

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 WMLW10A only, is provided in Table 5.1. The predictions include the effects 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 WMLW10A

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	WMLW10A Only	< 20	< 0.5	< 0.01	< 0.01

The section of Wollombi Brook in the vicinity of the proposed longwall 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 longwall.

A summary of the maximum predicted additional subsidence, tilts and curvatures for alluvium associated with Wollombi Brook, due to the extraction of the proposed WMLW10A only, is provided in Table 5.2. The predictions include the effects of the existing workings in the overlying Whybrow Seam.

Table 5.2 Maximum Predicted Additional Subsidence, Tilts and Curvatures for the Alluvium Associated with Wollombi Brook due to the Extraction of the Proposed WMLW10A

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})
Alluvium associated with Wollombi Brook	WMLW10A Only	20	0.5	0.01	0.01

The maximum predicted subsidence parameters provided in the above table, occur where the alluvium is located immediately adjacent to the maingate of WMLW10A, near the finishing end of the proposed longwall. Elsewhere, the alluvium is predicted to experience less than 20 mm of vertical subsidence and negligible additional tilts and curvatures.

5.2.3. Comparisons of Predictions for the Wollombi Brook

The predicted additional subsidence at Wollombi Brook, due to the extraction of the proposed WMLW10A, 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*. While the alluvium associated with Wollombi Brook could experience very low levels of vertical subsidence (i.e. around 20 mm), based on the Modified Layout, it is not predicted to experience any measurable tilts or curvatures.

5.2.4. Impact Assessments for Wollombi Brook

The banks of Wollombi Brook are located at a distance of 125 metres east of the finishing end of WMLW10A, at its closest point to the proposed longwall. 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 vertical subsidence, it would not be expected to experience any measurable tilts, curvatures or ground strains.

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 WMLW10A is located outside this subsidence exclusion zone (i.e. the 40 metre buffer), as illustrated in Fig. 5.2, which is a cross-section taken where the brook is located closest to the proposed longwall.

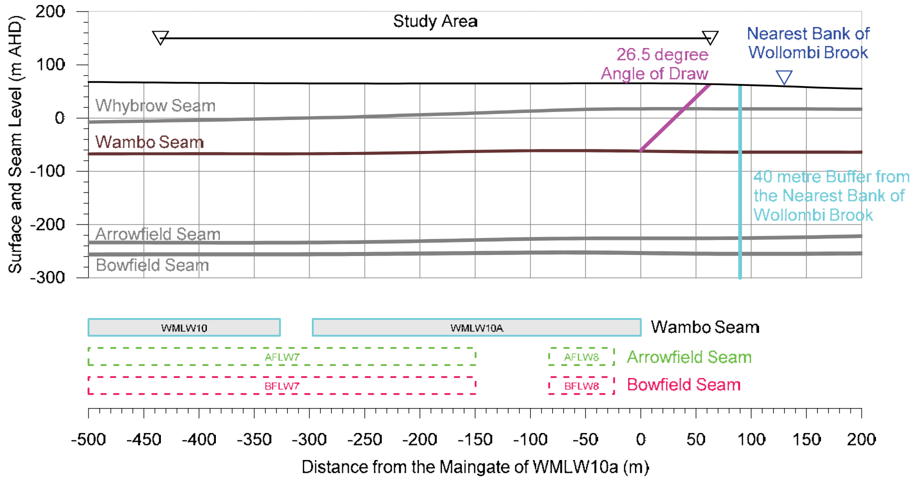

Fig. 5.2 Exclusion Zone for Wollombi Brook

It can be seen from the above figure, that the 26.5 degree angle of draw from extent of the proposed WMLW10A is located outside the 40 metre buffer from the nearest bank of Wollombi 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 WMLW10A. That is, the impact assessments based on the *Modified Layout* are the same as those 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 *HydroSimulations* (2014).

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 WMLW10A. That is, the potential subsidence impacts on the Wollombi Brook and the associated alluvium, due to the extraction of the proposed longwall, would still be expected to be negligible.

5.2.6. Recommendations for Wollombi Brook

It is recommended that existing management strategies for the Wollombi Brook are reviewed based on the inclusion of WMLW10A, including the piezometers to measure the groundwater levels and the ground monitoring lines to measure the actual limit of vertical subsidence. The appropriate management strategies and monitoring for Wollombi Brook will be finalised during the Extraction Plan stage for the proposed longwall.

5.3. North Wambo, Wambo and Stony Creeks

5.3.1. Description of the Creeks

The locations of the creeks in the vicinity of the proposed WMLW10A are shown in Drawing No. MSEC697-11.

North Wambo Creek is located outside the Study Area, with the banks of the creek located at a distance of 270 metres north of the finishing end of WMLW10A, at their closest point to the proposed longwall. Wambo and Stony Creeks are partially located above the commencing end of WMLW10A. The total length of these creeks located directly above the proposed longwall is around 330 metres.

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 longwall 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 and Quaternary Alluvium. 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. 5.3, Fig. 5.4 and Fig. 5.5, respectively. The locations of these photographs are indicated in Drawing No. MSEC697-11.

Fig. 5.3 Photographs of North Wambo Creek

Fig. 5.4 Photographs of Wambo Creek

Fig. 5.5 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 WMLW10A, is provided in Table 5.3. The predictions include the effects 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 WMLW10A

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	WMLW10A Only	< 20	< 0.5	< 0.01	< 0.01
Wambo Creek	WMLW10A Only	900	15	0.6	0.2
Stony Creek	WMLW10A Only	450	5	0.1	0.03

The maximum predicted cumulative movements along Wambo Creek, resulting from mining in the Whybrow, Wambo, Arrowfield and Bowfield Seams, are 4,350 mm vertical subsidence, 85 mm/m tilt and greater than 3.0 km^{-1} hogging and sagging curvatures. The maximum predicted cumulative movements along Stoney Creek are 3,450 mm vertical subsidence, 30 mm/m tilt and 0.9 km^{-1} hogging curvature and 0.4 km^{-1} sagging curvature.

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 longwall.

The banks of North Wambo Creek are located at distance of 270 metres north of the finishing end of WMLW10A, at their closest point to the proposed longwall. It is unlikely, therefore, that this creek would experience any measurable tilts, curvatures or strains resulting from the extraction of the proposed longwall.

The sections of Wambo and Stony Creeks located directly above the proposed longwall could experience the full range of predicted strains, which is discussed 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.

5.3.3. Comparisons of Predictions for the Creeks

The predicted additional subsidence at North Wambo Creek, due to the extraction of the proposed WMLW10A, is less than 20 mm. The total predicted subsidence parameters for this creek, based on the *Modified Layout*, therefore, are the same as those based on the *Approved Layout*.

The comparison of the maximum predicted total conventional subsidence parameters for Wambo and Stony Creeks, based on the *Approved Layout* and the *Modified Layout*, is provided in Table 5.4. The values are based on the extraction of the approved and proposed longwalls within the Wambo Seam and the future longwalls in the Arrowfield and Bowfield Seams (i.e. excluding the predicted movements resulting from the existing workings in the Whybrow Seam). However these comparisons include the effects of these existing workings on the subsidence which develops from the mining in the Wambo Seam, Arrowfield and Bowfield Seams.

Table 5.4 Comparison of Maximum Predicted Subsidence Parameters for Wambo and Stony Creeks due to Mining in the Wambo, Arrowfield and Bowfield Seams

Location	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})
Wambo Creek	Approved Layout	1,600	15	0.2	0.2
	Modified Layout	2,400	30	0.7	0.3
Stony Creek	Approved Layout	1,000	7	0.1	0.01
	Modified Layout	1,500	12	0.3	0.03

The predicted subsidence movements along the sections of Wambo and Stony Creeks located above the proposed WMLW10A and the future longwalls in the Arrowfield and Bowfield Seams increase as a result of the proposed modification. The total length of these creeks which will experience increased vertical subsidence greater than 20 mm is around 950 metres.

The predicted cumulative tilts and curvatures along Wambo and Stony Creeks, directly above the proposed WMLW10A and the future longwalls in the Arrowfield and Bowfield Seams, are less than the maxima predicted above the existing workings in the Whybrow Seam further downstream (i.e. where the depths of cover are the shallowest). Further discussions on the potential impacts on these creeks due to the extraction of the additional proposed longwall are provided in the following section.

5.3.4. Impact Assessments for the Creeks

The banks of North Wambo Creek are located at distance of 270 metres north of the finishing end of WMLW10A, at their closest point to the proposed longwall. At this distance, this creek is predicted to experience less than 20 mm of vertical subsidence. While it is possible that North Wambo Creek could experience very low levels of subsidence, it would not be expected to experience any significant tilts, curvatures or ground strains.

The extraction of the proposed WMLW10A could result in increased levels of ponding along Wambo Creek, upstream of the longwall maingate, where the mining induced tilts oppose and are greater than the natural stream gradients that exist before mining. Mining could also potentially result in an increased likelihood of scouring of the beds along Wambo and Stony Creeks, downstream of the longwall edges, where the mining induced tilts considerably increase the natural stream gradients that exist before mining.

The natural surface levels and grades and the predicted post mining surface levels and grades along Wambo Creek are illustrated in Fig. 5.6 based on the Approved Layout and Fig. 5.7 based on the Modified Layout. The profiles are based on the extraction of the approved and proposed longwalls within the Wambo Seam and the future longwalls in the Arrowfield and Bowfield Seams (i.e. excluding the predicted movements resulting from the existing workings in the Whybrow Seam). However these comparisons include the effects of these existing workings on the subsidence which develops from the mining in the Wambo Seam, Arrowfield and Bowfield Seams.

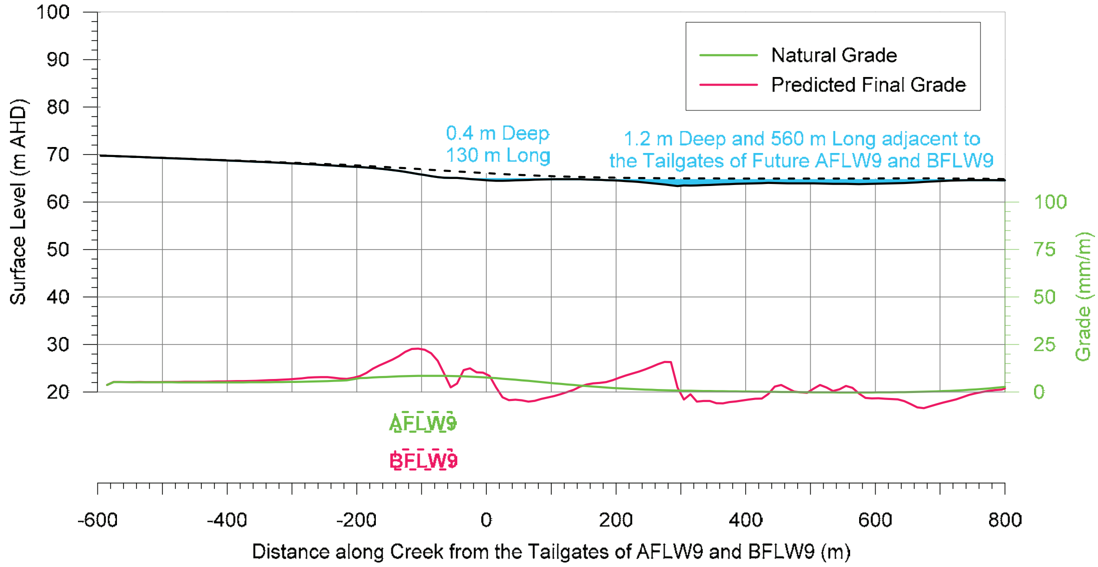

Fig. 5.6 Natural and Predicted Post-Mining Levels and Grades along Wambo Creek based on the Approved Layout

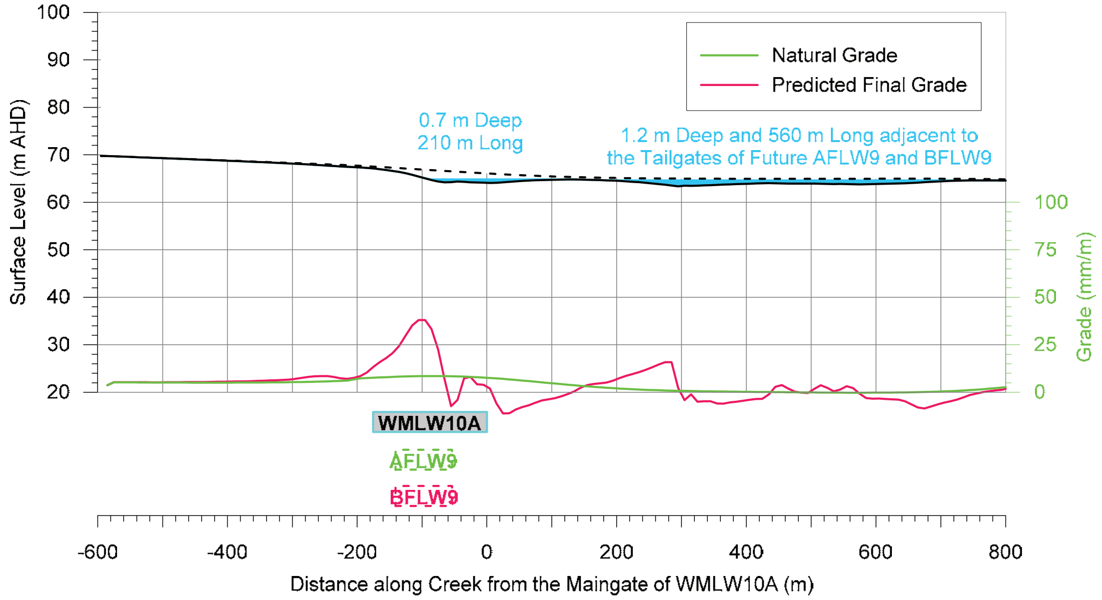

Fig. 5.7 Natural and Predicted Post-Mining Levels and Grades along Wambo Creek based on the Modified Layout

It can be seen from the above figures, that increased ponding is predicted to occur upstream of the maingate of the proposed WMLW10A. The depth of ponding is predicted to increase from 0.4 metres to 0.7 metres and the extent is predicted to increase from 130 metres to 210 metres, as a result of the proposed modification. The ponding adjacent to the tailgates of the future AFLW9 and BFLW9 is not predicted to change as a result of the proposed modification, which is up to 1.2 metres deep and 560 metres long.

If the mining induced ponding areas were to result in adverse impacts, these could be remediated by regrading the beds of Wambo and Stony Creeks, so as to re-establish the natural gradients. The creek has shallow incisions in the natural surface soils and, therefore, it is expected that the mining induced ponding areas could be reduced by excavating the channels downstream of the proposed and future longwalls and by increasing the heights of the banks above the proposed and future longwalls.

Fracturing of the uppermost bedrock has been observed in the past, as a result of mining, where the tensile strains have been greater than 0.5 mm/m or where the compressive strains have been greater than 2 mm/m. It is likely, therefore, that fracturing would occur in the uppermost bedrock along the sections of the creeks located directly above the proposed and future longwalls.

Wambo and Stony Creeks have shallow incisions into the surface soils, but have exposed bedrock and isolated outcropping along the lower reaches. Cracking in the beds of the streams would only be visible at the surface where the depths of the surface soils are shallow, or where the bedrock is exposed.

The creeks are 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 WMLW10A 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 seven 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*".

After the completion of the necessary remediation measures, including regrading and infilling of the larger surface cracking, the long term impacts on Wambo and Stony Creeks, based on the *Modified Layout*, are expected to be 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 be no measurable tilts, curvatures and strains along North Wambo Creek. In this case, it would still be unlikely that this creek would experience any adverse impacts as a result of the extraction of the proposed WMLW10A.

Wambo and Stony Creeks would experience increased subsidence where they are located directly above and adjacent to the proposed and future longwalls. The predicted tilts, curvatures and strains would still be less than the maxima predicted above the existing workings in the Whybrow Seam further downstream (i.e. where the depths of cover are the shallowest).

Whilst additional works would be required to re-establish the creek grades and to repair the larger surface cracking, these methods of repair would not be expected to change. After the completion of the necessary remediation measures, the long term impacts on Wambo and Stony Creeks, based on the *Modified Layout*, are expected to be the same as 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 effects of the proposed WMLW10A.

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 *HydroSimulations* (2014).

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 are no natural steep slopes which have been identified within the Study Area, that is, the natural grades are 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 Wambo South Water Dam and the farm dams.

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 2 kilometres west of the proposed longwall, at its closest point. It is not expected, therefore, that the extraction of WMLW10A would have an adverse impact on the Wollemi National Park or the associated escarpment.

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 creeks.

5.7. Land Prone to Flooding or Inundation

The land within the Study Area 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.

The predicted post-mining surface level contours after the completion of the existing, approved and proposed longwalls in the Wambo, Arrowfield and Bowfield Seams are illustrated in Fig. 5.8. The existing farm dams are indicated by the dark blue hatching in this figure. The extents of the predicted topographical depressions after the completion of WMLW10A are illustrated by the green hatching. The extents of the predicted topographical depressions, after the completion of mining in the Wambo, Arrowfield and Bowfield Seams, are illustrated by the cyan hatching based on the *Approved Layout* and by the purple hatching based on the *Modified Layout*.

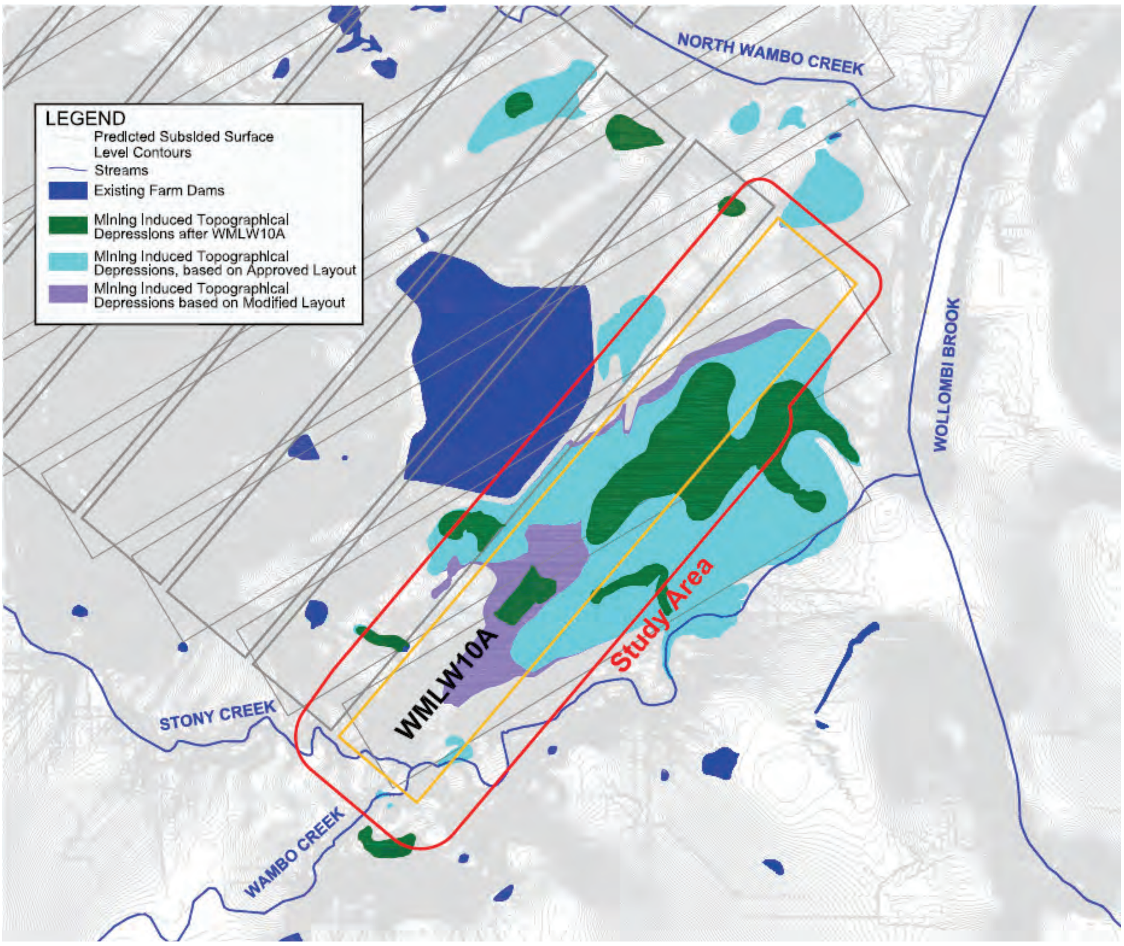

Fig. 5.8 Predicted Post Mining Surface Level Contours and Topographical Depressions

It can be seen from the above figure, that a topographical depression extends over the middle part of the Study Area after the completion of mining in the Wambo, Arrowfield and Bowfield Seams. The difference between the cyan and purple hatching indicates the increased extent of the topographical depression as a result of the proposed modification.

There is the potential for increased ponding within the Study Area based on both the Approved and Modified Layouts. It is highlighted, however, that the potential for increased ponding is also dependent on a number of other factors, including rainfall, catchment sizes, surface water runoff, permeation and evaporation and, therefore, the actual extents and depths of ponding are expected to be smaller than the topographical depressions.

The maximum depth of the topographical depression within the Study Area after the completion of WMLW10A is 2.0 metres. The maximum depth of the topographical depression after the completion of mining in the Wambo, Arrowfield and Bowfield Seams is 5.0 metres based on the *Approved Layout* and 6.5 metres based on the *Modified Layout*.

The potential for increased ponding within the Study Area, after the completion of the Wambo, Arrowfield and Bowfield Seams, could affect the land use in area including access along the unsealed roads. It is also recommended that management strategies are developed as part of the Extraction Plan process for the future longwalls in the Arrowfield and Bowfield Seams, so that access can be maintained along the unsealed roads.

Further discussions on the potential impacts on surface water drainage are provided by the specialised surface water consultant in the report by *Evans and Peck* (2014).

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 Environment and Heritage* (2014).

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* (2014) and *Niche Environment and Heritage* (2014).

The vegetation communities in the area were identified by *FloraSearch* (2014) and these have been reproduced in Fig. 5.9. The Endangered Ecological Communities (EECs) identified within the Study Area are:

- Forest Red Gum – Grey Gum dry open forest (Community 2);
- Grey Box – Narrow-leaved Ironbark shrubby woodland (Community 3); and
- A threatened flora species *Acacia Pendula* has also been recorded.

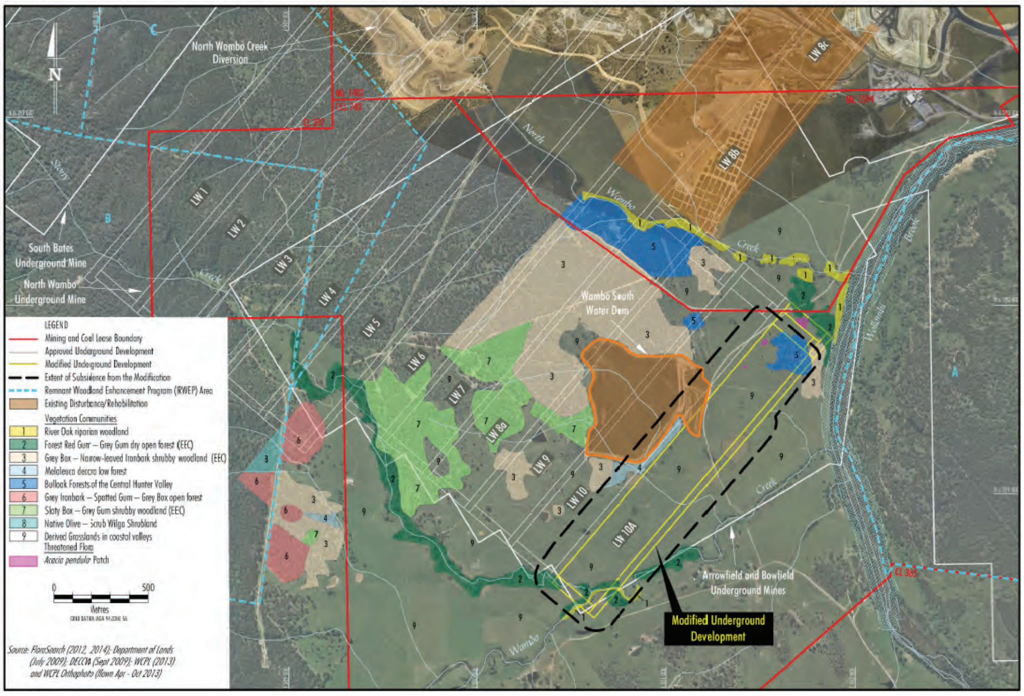

Fig. 5.9 Vegetation Communities Identified within the Study Area (after FloraSearch, 2014)

Surface cracking could occur in the locations of the EECs, which is discussed in Section 4.7. It is unlikely, however, that the surface cracking would result in adverse impacts on the EECs. It is possible, however, that if remediation of the surface was required after mining, that these works could potentially impact these locations.

The EECs are located outside the extents of the predicted topographical depressions, which is discussed in Section 5.7. It is not expected, therefore, that there would be any adverse changes in the surface water drainage in these locations.

Further discussions on the potential impacts on the EECs are provided by the specialised ecology consultant in the report by *FloraSearch* (2014).

5.10. National Parks or Wilderness Areas

The *Wollemi National Park* is located west of WMLW10A and the Study Area, at a distance more than 1 kilometre from the proposed longwall.

5.11. Natural Vegetation

The land has been generally cleared within the Study Area. There is natural vegetation along the alignments of the creeks and adjacent to the water storage dam, which can be seen from the aerial photograph in Fig. 1.1. A detailed survey of the natural vegetation has been undertaken and is described and assessed in the report prepared by *FloraSearch* (2014).

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.

The predicted tilts and curvatures within the Study Area, resulting from the extraction of the existing workings in the overlying Whybrow Seam, are significantly greater than the predicted tilts and curvatures resulting from the approved, proposed and future mining in the Wambo, Arrowfield and Bowfield Seams. The reason for this is that the depths of cover to the Whybrow Seam are shallow, varying between 60 metres and 130 metres within the Study Area.

For this reason, the comparison of the predicted conventional subsidence parameters based on the Approved and Modified Layouts have been based on the extraction of the approved and proposed longwalls within the Wambo Seam and the future longwalls in the Arrowfield and Bowfield Seams (i.e. excluding the predicted movements resulting from the existing workings in the Whybrow Seam). However these comparisons include the effects of these existing workings on the subsidence which develops from the mining in the Wambo Seam, Arrowfield and Bowfield Seams.

6.1. Public Utilities

As listed in Table 2.1, there were no Public Utilities identified within the Study Area. There are unsealed roads, drainage culverts, an 11 kilovolt (kV) powerline and water pipelines, which are owned and maintained by WCPL, 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. MSEC697-12. Whilst there are no public roads within the Study Area, the road above the approved WMLW10 and the proposed WMLW10A is a right of way in favour of several 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. MSEC697-12.

Fig. 6.1 Photograph of an Unsealed Road

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

6.2.2. Predictions for the Unsealed Roads

The predicted profiles of conventional subsidence, tilt and curvature along the unsealed road located above the approved WMLW10 and the proposed WMLW10A, based on the *Approved Layout* and *Modified Layout*, are illustrated in Fig. E.03, in Appendix E. The profiles are based on the extraction of the approved, proposed and future longwalls in the Wambo, Arrowfield and Bowfield Seam, but also include the effects of the existing workings in the overlying Whybrow Seam.

The predicted profiles resulting from the extraction of the approved WMLW1 to WMLW10 are shown as the solid cyan lines in these figures. The predicted profiles after the completion of the proposed WMLW10A 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.

A summary of the maximum predicted additional subsidence, tilts and curvatures for the unsealed road, due to the extraction of the proposed WMLW10A, is provided in Table 6.1. The predictions include the effects of the existing workings in the overlying Whybrow Seam.

Table 6.1 Maximum Predicted Additional Subsidence, Tilts and Curvatures for the Unsealed Road due to the Extraction of the Proposed WMLW10A

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})
Unsealed Roads	WMLW10A Only	2,300	30	0.7	0.7

The maximum predicted cumulative movements along the unsealed roads, resulting from mining in the Whybrow, Wambo, Arrowfield and Bowfield Seams, are 8,500 mm vertical subsidence, 60 mm/m tilt and 3.0 km^{-1} hogging and sagging curvatures.

6.2.3. Comparisons of Predictions for the Unsealed Roads

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 6.2. The values are based on the extraction of the approved and proposed longwalls within the Wambo Seam and the future longwalls in the Arrowfield and Bowfield Seams (i.e. excluding the predicted movements resulting from the existing workings in the Whybrow Seam). However, these comparisons include the effects of these existing workings on the subsidence which develops from the mining in the Wambo Seam, Arrowfield and Bowfield Seams.

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

Location	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})
Unsealed Roads	Approved Layout	5,950	35	0.6	0.6
	Modified Layout	7,500	50	1.0	1.0

It can be seen from the above table, that the maximum predicted subsidence parameters for the unsealed roads within the Study Area increase as a result of the proposed modification. The maximum predicted tilts and curvatures within the Study Area are similar to the maxima predicted above the existing workings in the Whybrow Seam to the east of the Study Area (i.e. where the depths of cover are the shallowest). Further discussions on the potential impacts on these roads due to the extraction of the additional proposed longwall are provided in the following section.

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 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

Management strategies have previously been developed for the unsealed roads which have already been directly mined beneath at the NWUM. It is recommended that the existing management strategies for the roads be reviewed and, where required, are revised to include the effects of the proposed WMLW10A. It is recommended that these roads are visually monitored during active subsidence.

6.3. Water Pipelines

6.3.1. Description of the Water Pipelines

There are water pipelines located within the Study Area which supply water for mining activities. The locations of these pipelines are shown in Drawing No. MSEC697-12. 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. MSEC697-12.

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 follow the alignment of the unsealed road above the approved WMLW10. The predicted profiles of conventional subsidence, tilt and curvature along the unsealed road and, hence, along he pipelines, based on the *Approved Layout* and *Modified Layout*, are illustrated in Fig. E.03, in Appendix E. The profiles are based on the extraction of the approved, proposed and future longwalls in the Wambo, Arrowfield and Bowfield Seam, and include the effects of the existing workings in the overlying Whybrow Seam.

A summary of the maximum predicted additional subsidence, tilts and curvatures for the pipelines, due to the extraction of the proposed WMLW10A, is provided in Table 6.3. The predictions include the effects of the existing workings in the overlying Whybrow Seam.

Table 6.3 Maximum Predicted Additional Subsidence, Tilts and Curvatures for the Water Pipelines due to the Extraction of the Proposed WMLW10A

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})
Water Pipelines	WMLW10A Only	150	5	0.2	0.2

It can be seen that only small additional subsidence movements are predicted along the pipeline due to the extraction of the proposed WMLW10A.

The maximum predicted cumulative movements along the pipelines, resulting from mining in the Whybrow, Wambo, Arrowfield and Bowfield Seams, are 9,500 mm vertical subsidence, 70 mm/m tilt and 3.0 km^{-1} hogging and sagging curvatures.

6.3.3. Comparisons of Predictions for the Water Pipelines

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 6.4. The values are based on the extraction of the approved and proposed longwalls within the Wambo Seam and the future longwalls in the Arrowfield and Bowfield Seams (i.e. excluding the predicted movements resulting from the existing workings in the Whybrow Seam). However these comparisons include the effects of these existing workings on the subsidence which develops from the mining in the Wambo Seam, Arrowfield and Bowfield Seams.

Table 6.4 Comparison of the Maximum Predicted Subsidence Parameters for the Water Pipelines due to Mining in the Wambo, Arrowfield and Bowfield Seams

Location	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})
Pipelines	Approved Layout	7,500	50	1.0	1.0
	Modified Layout	7,500	50	1.0	1.0

It can be seen from the above table, that the maximum predicted subsidence parameters for the water pipelines within the Study Area, based on the *Modified Layout*, are the same as the maxima predicted based on the *Approved Layout*. There are small increases in the predicted subsidence parameters along the pipelines, away from the maxima, above the chain pillar between the approved WMLW10 and the proposed WMLW10A.

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

Management strategies have previously been developed for the water pipelines which have already been directly mined beneath at the NWUM. It is recommended that the existing management strategies for the pipelines be reviewed and, where required, are revised to include the effects of the proposed WMLW10A. It is recommended that these pipelines are visually monitored during active subsidence.

6.4. Electrical Infrastructure

6.4.1. Description of the Electrical Infrastructure

An 11 kilovolt (kV) powerline owned by WCPL is partially located within the Study Area, above the approved WMLW10 and above the chain pillar between this approved longwall and the proposed WMLW10A. The powerline comprises aerial cables supported by timber poles. Photographs of the 11 kV powerline are provided in Fig. 6.3. The locations of these photographs are indicated in Drawing No. MSEC697-12.

Fig. 6.3 Photographs of the 11 kV Powerline

An 11 kV powerline owned by Ausgrid, which was identified in the *North Wambo Underground Mine Modification Environmental Assessment* (WCPL, 2012), has since been decommissioned and removed.

6.4.2. Predictions for the Electrical Infrastructure

A summary of the maximum predicted additional subsidence, tilts and curvatures for the 11 kV powerline, due to the extraction of the proposed WMLW10A, is provided in Table 6.5. The predictions include the effects of the existing workings in the overlying Whybrow Seam. The cables are supported by timber poles above the ground and, therefore, they are not adversely impacted by ground strain.

Table 6.5 Maximum Predicted Additional Subsidence and Tilts for the 11 kV Powerline due to the Extraction of the Proposed WMLW10A

Location	Longwall	Maximum Predicted Additional Subsidence (mm)	Maximum Predicted Additional Tilt along Alignment (mm/m)	Maximum Predicted Additional Tilt across Alignment (mm/m)
11 kV Powerline	WMLW10A Only	600	5	10

The maximum predicted additional movements occur for the section of powerline located above the chain pillar between the approved WMLW10 and the proposed WMLW10A. The predicted subsidence parameters away from this location decrease and less than 20 mm additional subsidence is predicted outside the Study Area.

The maximum predicted cumulative movements along the powerline, resulting from mining in the Whybrow, Wambo, Arrowfield and Bowfield Seams, are 8,100 mm vertical subsidence and greater than 100 mm/m tilt.

6.4.3. Comparisons of Predictions for the Electrical Infrastructure

The comparison of the maximum predicted conventional subsidence parameters for the 11 kV powerline within the Study Area, based on the *Approved Layout* and the *Modified Layout*, is provided in Table 6.6. The values are based on the extraction of the approved and proposed longwalls within the Wambo Seam and the future longwalls in the Arrowfield and Bowfield Seams (i.e. excluding the predicted movements resulting from the existing workings in the Whybrow Seam). However these comparisons include the effects of these existing workings on the subsidence which develops from the mining in the Wambo Seam, Arrowfield and Bowfield Seams.

Table 6.6 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	7,600	50	60
Modified Layout	7,600	50	60

It can be seen from the above table, that the maximum predicted subsidence parameters for the 11 kV powerline within the Study Area, based on the *Modified Layout*, are the same as the maxima predicted based on the *Approved Layout*. There are increases in the predicted subsidence parameters along the powerline, away from the maxima, above the chain pillar between the approved WMLW10 and the proposed WMLW10A.

6.4.4. Impact Assessments for the Electrical Infrastructure

The maximum predicted total tilts for the 11 kV powerline within the Study Area due to mining in the Wambo, Arrowfield and Bowfield Seams, based on both the *Approved Layout* and *Modified Layout*, are 50 mm/m (i.e. 5 %) along the alignment and 60 mm/m (i.e. 6 %) across the alignment.

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 powerline prior to the approved, 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

Management strategies have previously been developed for the 11 kV powerlines which have already been directly mined beneath at the NWUM. It is recommended that the existing management strategies for the powerlines be reviewed and, where required, are revised to include the effects of the proposed WMLW10A.

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 within the Study Area has been generally 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. MSEC697-12.

Fig. 6.4 Photograph of a Typical Farm Dam

The farm dams have surface areas varying between 900 m^2 and 19,200 m^2 and have maximum lengths varying between 50 metres and 200 metres. The farm dams are owned by WCPL.

6.9.2. Predictions for the Farm Dams

A summary of the maximum predicted additional subsidence, tilts and curvatures for the farm dams, due to the extraction of the proposed WMLW10A, is provided in Table 6.7. The predictions include the effects of the existing workings in the overlying Whybrow Seam.

Table 6.7 Maximum Predicted Additional Subsidence, Tilts and Curvatures for the Farm Dams due to the Extraction of the Proposed WMLW10A

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})
Dam 1	WMLW10A Only	2,100	25	0.6	0.6
Dam 2	WMLW10A Only	500	15	0.4	0.1
Dam 3	WMLW10A Only	2,400	30	0.6	0.9
Dam 4	WMLW10A Only	250	7	0.2	0.1
Dam 5	WMLW10A Only	< 20	< 0.5	< 0.01	< 0.01

The maximum predicted cumulative movements along the farm dams, resulting from mining in the Whybrow, Wambo, Arrowfield and Bowfield Seams, are 9,400 mm vertical subsidence, 100 mm/m tilt and greater than 3.0 km^{-1} hogging and sagging curvatures.

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 longwall, 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. The values are based on the extraction of the approved and proposed longwalls within the Wambo Seam and the future longwalls in the Arrowfield and Bowfield Seams (i.e. excluding the predicted movements resulting from the existing workings in the Whybrow Seam). However these comparisons include the effects of these existing workings on the subsidence which develops from the mining in the Wambo Seam, Arrowfield and Bowfield Seams.

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	5,300	50	0.7	0.7
Modified Layout	7,400	60	1.0	1.0

It can be seen from the above table, that the maximum predicted subsidence parameters for the farm dams within the Study Area increase as a result of the proposed modification. The maximum predicted tilts and curvatures, based on the *Modified Layout*, are around 20 % to 30 % greater than those predicted based on the *Approved Layout*. Further discussions on the potential impacts on these dams due to the extraction of the additional proposed longwall are provided in the following section.

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 60 mm/m (i.e. 6.0 %), which represents a change in grade of 1 in 17. 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.

A summary of the predicted changes in freeboard for the farm dams within the Study Area, due to the approved, proposed and future longwalls in the Wambo, Arrowfield and Bowfield Seams, is provided in Table 6.9.

Table 6.9 Predicted Changes in Freeboard for the Farm Dams due to Mining in the Wambo, Arrowfield and Bowfield Seams

Location	Maximum Predicted Change in Freeboard (mm)
Dam 1	2,200
Dam 2	250
Dam 3	100
Dam 4	750
Dam 5	< 50

The maximum predicted change in freeboard at Dam 1 is 2,200 mm, which occurs around the perimeter of the dam which is located directly above the proposed WMLW10A. The change in freeboard at this dam is likely to reduce the storage capacity and could potentially cause it to overflow. It is recommended that the water storage level in Dam 1 is reduced during the extraction of the proposed WMLW10A directly beneath it. If the storage capacity of this dam were to be adversely affected as a result of mining, it could be re-instated by re-designing the earthen dam wall for an increase dam wall height.

The changes in freeboard at the remaining dams within the Study Area are 250 mm, or less, which are unlikely to affect the storage capacities of these dams or to cause them to overflow.

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 located directly above mining 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

Management strategies have previously been developed for the farm dams which have already been directly mined beneath at the NWUM. It is recommended that the existing management strategies for the farm dams be reviewed and, where required, are revised to include the effects of the proposed WMLW10A.

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. MSEC697-12. The locations and details of these were obtained from the Department of Natural Resources using the *Natural Resource Atlas* website (NRAtlas, 2012).

There is one groundwater bore (Ref. GW200634) within the Study Area, which is owned by WCPL and used for monitoring, which is located 100 metres east of the proposed WMLW10A. There are also a number of additional bores located in the vicinity of the Study Area, primarily to the north and east of the proposed longwall, adjacent to Wollombi Brook. These groundwater bores are owned by WCPL and their intended uses are for stock, irrigation, exploration, mining and monitoring. The information obtained from NRAtlas indicates that none of the bores in the immediate vicinity of the proposed longwall 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 *HydroSimulations* (2014).

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. Wambo South Water Dam

6.12.1. Description of the Wambo South Water Dam

The *Wambo South Water Dam* is partially located within the Study Area, to the west of the proposed WMLW10A, and directly above the approved WMLW9 and WMLW10. The dam is owned by WCPL and supplies water for mining activities.

The location of the Wambo South Water Dam is shown in Drawing No. MSEC697-12. 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 Wambo South Water Dam, taken in August 2012, are provided in Fig. 6.5. The locations of these photographs are indicated in Drawing No. MSEC697-12. Since these photographs were taken, the water level in the Wambo South Water Dam has been lowered substantially as a management measure for the approved WMLW9 and WMLW10.

Fig. 6.5 Photographs of the Wambo South Water Dam

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

6.12.2. Predictions for the Wambo South Water Dam

A summary of the maximum predicted additional subsidence, tilts and curvatures for the Wambo South Water Dam, due to the extraction of the proposed WMLW10A, is provided in Table 6.10. The predictions include the effects of the existing workings in the overlying Whybrow Seam.

Table 6.10 Maximum Predicted Additional Subsidence, Tilts and Curvatures for the Wambo South Water Dam due to the Extraction of the Proposed WMLW10A

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})
Wambo South Water Dam	WMLW10A Only	200	5	0.1	0.1

The maximum predicted cumulative movements for the Wambo South Water Dam, resulting from mining in the Whybrow, Wambo, Arrowfield and Bowfield Seams, are 9,700 mm vertical subsidence, 100 mm/m tilt and greater than 3.0 km^{-1} hogging and sagging curvatures.

The Wambo South Water Dam is located directly above the proposed longwall 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 longwall, 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 Wambo South Water Dam

The comparison of the maximum predicted conventional subsidence parameters for the Wambo South Water 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 Wambo South Water 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	7800	75	1.5	1.5
Modified Layout	7800	75	1.5	1.5

It can be seen from the above table, that the maximum predicted subsidence parameters for the Wambo South Water Dam, based on the *Modified Layout*, are the same as those predicted based on the *Approved Layout*. Additional subsidence, up to 200 mm, will develop along the south-eastern perimeter of the dam, due to the extraction of the proposed WMLW10A, but this occurs away from the location of maxima directly above the approved WMLW9 and WMLW10.

6.12.4. Impact Assessments for the Wambo South Water Dam

The maximum predicted subsidence parameters for the Wambo South Dam due not change as a result of the proposed modification. Only low level additional subsidence will develop at the dam due to the extraction of the proposed WMLW10A, which only represents around 3 % of the maximum total subsidence resulting from the extraction of the approved, proposed and future longwalls in the Wambo, Arrowfield and Bowfield Seams.

The Wambo South Water Dam is owned by WCPL. Management strategies have been developed for the Wambo South Water Dam based on the approved WMLW9 and WMLW10 mining directly beneath it. It is recommended that the existing management strategies for the dam are reviewed and, where required, are revised to include the effects of the proposed WMLW10A.

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

If the actual mine subsidence movements exceeded those predicted by a factor of 2 times, the additional subsidence at the Water South Water Dam, due to the extraction of the proposed WMLW10A, would still only represent around 6 % of the total subsidence resulting from the extraction of the approved, proposed and future longwalls in the Wambo, Arrowfield and Bowfield Seams. The management strategies for the dam would not change.

6.12.6. Recommendations for the Wambo South Water Dam

Management strategies have been developed for the Wambo South Water Dam based on the approved WMLW9 and WMLW10 mining directly beneath it. It is recommended that the existing management strategies for the dam be reviewed and, where required, are revised to include the effects of the proposed WMLW10A.

6.13. Exploration Bores

The locations of the exploration bores in the vicinity of the proposed longwall are shown in Drawing No. MSEC697-12. The exploration bores are located directly above the proposed longwall 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. Wambo Homestead Complex

The Wambo Homestead Complex is located north of the Study Area. The Curtilage for the complex is located at a minimum distance of 300 metres from the finishing end of WMLW10A and is shown in Drawing No. MSEC697-12. The building structures associated with the complex are located more than 1 kilometre from the proposed longwall.

The maximum predicted incremental vertical subsidence within the Curtilage, resulting from the extraction of WMLW10A, is in the order of survey tolerance (i.e. not measureable). It is unlikely, therefore, that there would be any adverse impacts within the Curtilage, including to the building structures associated with the Wambo Homestead Complex , even if the predictions were exceeded by a factor of 2 times.

6.15. Archaeological Sites

6.15.1. 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. MSEC697-12. 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
Site 40	100 metres east of WMLW10A	Artefact scatter
Site 41	130 metres east of WMLW10A	Artefact scatter
Site 42	115 metres south of WMLW10A	Artefact scatter
Site 336	Above the maingate of WMLW10A	Artefact scatter
Site 363	25 metres south-west of WMLW10A	Artefact scatter
Site 371	Directly above WMLW10A	Isolated Find
Site 372	Directly above WMLW10A	Isolated Find
Site 373	45 metres east of WMLW10A	Isolated Find
Site 374	Directly above WMLW10A	Isolated Find

The archaeological sites within the Study Area comprise artefact scatters and isolated finds. Other areas of archaeological significance were also identified within the Study Area including *Bleached Sand* and *Sandstone Outcrops*. There are grinding groove sites located outside and to the east of the Study Area and a scarred tree located outside and to the north of the Study Area. Descriptions of the archaeological sites within the Study Area are provided in the report by *RPS* (2014).

6.15.2. 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 values are based on the extraction of the approved and proposed longwalls within the Wambo Seam and the future longwalls in the Arrowfield and Bowfield Seams (i.e. excluding the predicted movements resulting from the existing workings in the Whybrow Seam). These predictions do, however, include the effects of these existing workings on the subsidence which develops from the mining in the Wambo Seam, Arrowfield and Bowfield Seams.

A summary of the maximum predicted additional subsidence, tilts and curvatures for the archaeological sites, due to the extraction of the proposed WMLW10A, is provided in Table 6.13. The predictions include the effects of the existing workings in the overlying Whybrow Seam.

Table 6.13 Maximum Predicted Additional Subsidence, Tilts and Curvatures for the Archaeological Sites due to the Extraction of the Proposed WMLW10A

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})
Artefact Scatters	WMLW10A Only	100	5	0.4	0.07
Isolated Finds	WMLW10A Only	1,500	30	2.5	2.9
Bleached Sand	WMLW10A Only	1,200	50	2.5	2.5
Sandstone Outcrops	WMLW10A Only	< 20	< 0.5	< 0.01	< 0.01

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 longwall, 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.

6.15.3. Comparisons of Predictions for the Archaeological Sites

The comparison of the maximum predicted conventional subsidence parameters for the archaeological sites within the Study Area, based on the *Approved Layout* and the *Modified Layout*, is provided in Table 6.14. The values are based on the extraction of the approved and proposed longwalls within the Wambo Seam and the future longwalls in the Arrowfield and Bowfield Seams (i.e. excluding the predicted movements resulting from the existing workings in the Whybrow Seam). However these comparisons include the effects of these existing workings on the subsidence which develops from the mining in the Wambo Seam, Arrowfield and Bowfield Seams.

Table 6.14 Comparison of the Maximum Predicted Subsidence Parameters for the Archaeological Sites due to Mining in Wambo, Arrowfield and Bowfield Seams

Layout	Location	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
Approved Layout	Artefact Scatters	800	15	0.5	0.03
	Isolated Finds	4,500	35	0.5	1.0
	Bleached Sand	3,700	50	0.7	0.8
	Sandstone Outcrops	1,900	40	0.7	0.4
Modified Layout	Artefact Scatters	900	20	0.9	0.5
	Isolated Finds	4,500	55	3.0	3.0
	Bleached Sand	3,700	55	3.0	3.0
	Sandstone Outcrops	1,900	40	0.7	0.4

It can be seen from the above table, that the maximum predicted subsidence parameters for the artefact scatters, isolated finds and the bleached sand, based on the Modified Layout, are greater than those predicted based on the Approved Layout. The maximum predicted subsidence parameters for the sandstone outcrops do not change as a result of the proposed modification. Further discussions on the potential impacts on these sites due to the extraction of the additional proposed longwall are provided in the following section.

6.15.4. Impact Assessments for the Artefact Scatters and Isolated Finds

There are five sites comprising artefact scatters within the Study Area, being Sites 40, 41, 42, 336 and 363. There are also four sites comprising isolated finds within the Study Area, being Sites 371, 372, 373 and 374.

The maximum predicted total tilt for the artefact scatters and isolated finds due to mining in the Wambo, Arrowfield and Bowfield Seams, based on the *Modified Layout*, is 55 mm/m (i.e. 5.5 %), which represents a change in grade of 1 in 18. The maximum predicted additional tilt, due to the proposed modification, is 30 mm/m (i.e. 3.3 %), which represents a change in grade of 1 in 33. It is unlikely that these sites would experience any adverse impacts resulting from the mining induced tilts.

The maximum predicted total curvature for these sites due to mining in the Wambo, Arrowfield and Bowfield Seams, based on the *Modified Layout*, is 3.0 km^{-1} hogging and sagging, which represents a minimum radius of curvature of 0.3 kilometres. The maximum predicted additional curvatures, due to the proposed modification, are 2.5 km^{-1} hogging and 2.9 km^{-1} sagging, which represent minimum radii of curvature of 0.4 kilometres and 0.3 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 artefact scatters and isolated finds are provided in a report by *RPS* (2014).

6.15.5. Impact Assessments for the Bleached Sand

The bleached sand is partially located above the finishing (i.e. north-eastern) end of WMLW10A. This area is predicted to experience a maximum tilt of 55 mm/m (i.e. 5.5 %, or 1 in 18) and a maximum curvature of 3.0 km^{-1} (i.e. a minimum radius of curvature of 0.3 kilometres).

It is not expected that any significant surface cracking would occur in the bleached sand due to its unconsolidated nature. It is unlikely, therefore, that the bleached sand would experience any adverse impacts resulting from the extraction WMLW10A.

Further assessments of the potential impacts on the bleached sand are provided in a report by *RPS* (2014).

6.15.6. Impact Assessments for the Sandstone Outcrops

The sandstone outcrops are located at a minimum distance of 50 metres east of WMLW10A, at their closest points to the proposed longwall. The grinding groove sites are located outside the Study Area and are at a minimum distance of 125 metres from WMLW10A at their closest point.

At these distances, the outcrops and grinding groove sites are predicted to experience less than 20 mm of vertical subsidence. While it is possible that sandstone outcrops could experience very low levels of vertical subsidence, they would not be expected to experience any measurable tilts, curvatures or ground strains.

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

It is unlikely, therefore, that the sandstone outcrops and the associated grinding groove sites would experience any adverse impacts due to the extraction of WMLW10A, even if the predictions were exceeded by a factor of 2.

Further assessments of the potential impacts on the sandstone outcrops and associated grinding groove sites are provided in a report by *RPS* (2014).

6.16. 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. MSEC697-12, which are located at distances greater than 1.5 kilometres from the proposed longwall.

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 longwall. 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

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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 approval to extract longwalls in the Whybrow, 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.

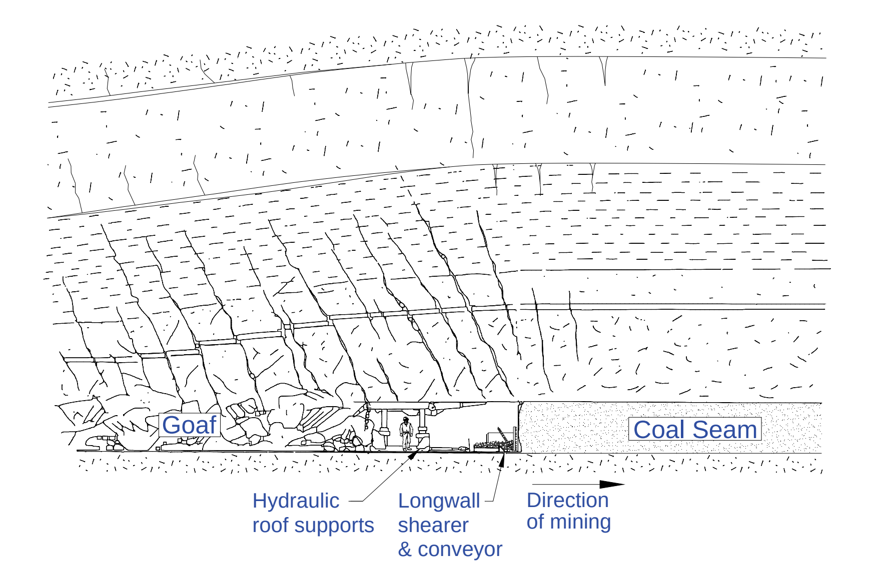

Fig. B. 1 Cross-section along the Length of a Typical Longwall at the Coal Face

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 WMLW10A 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 WMLW10A. 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.

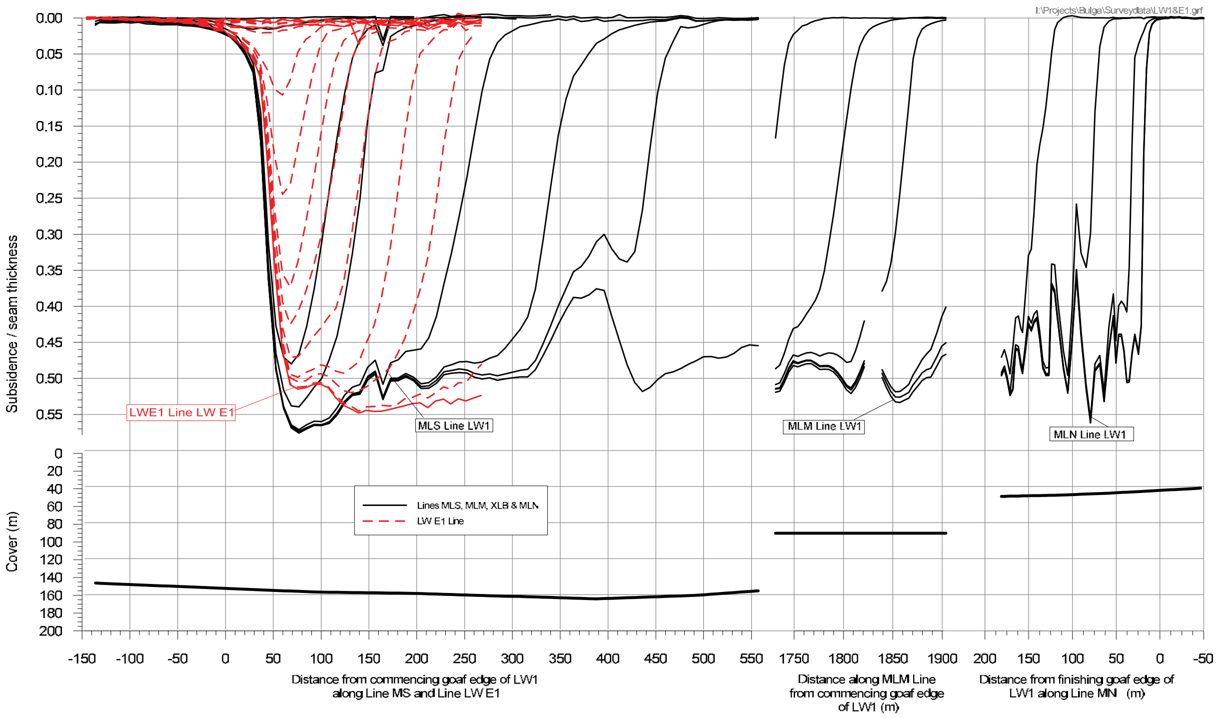

Fig. B. 2 Observed Subsidence Profiles at South Bulga Colliery

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.

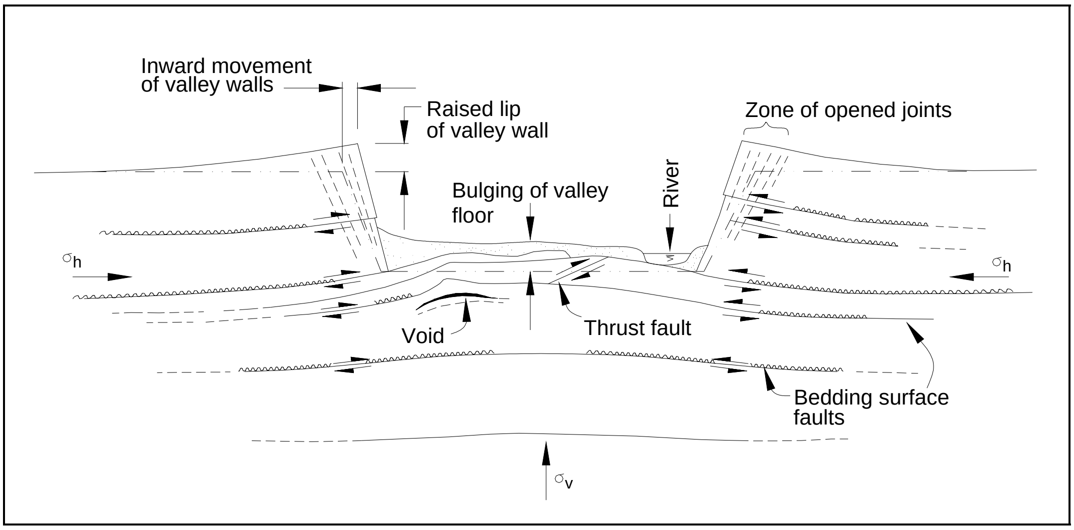

Fig. B. 3 Valley Formation in Flat-Lying Sedimentary Rocks (after Patton and Hendren 1972)

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 existing, proposed and future 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

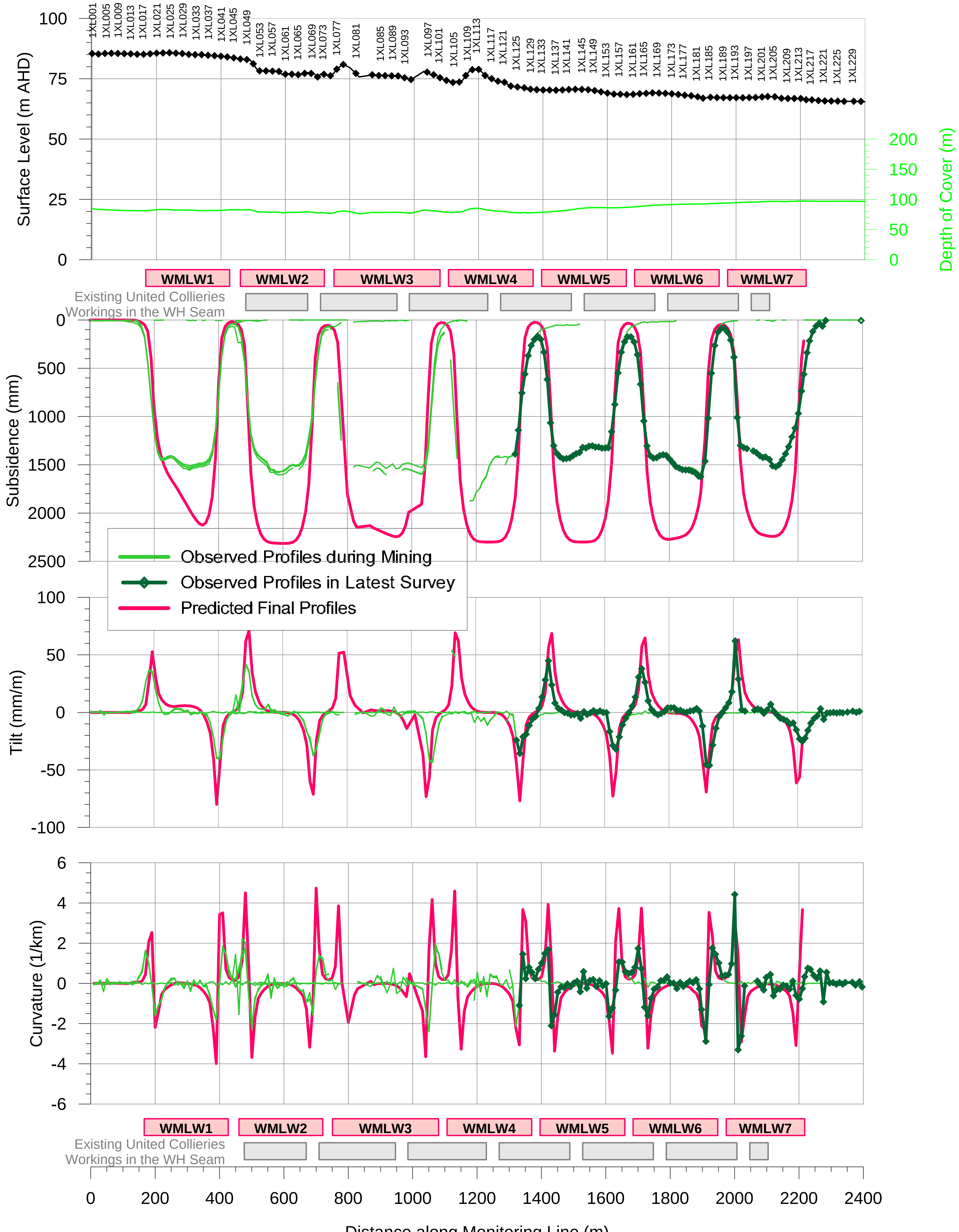

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Fig. C.01

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

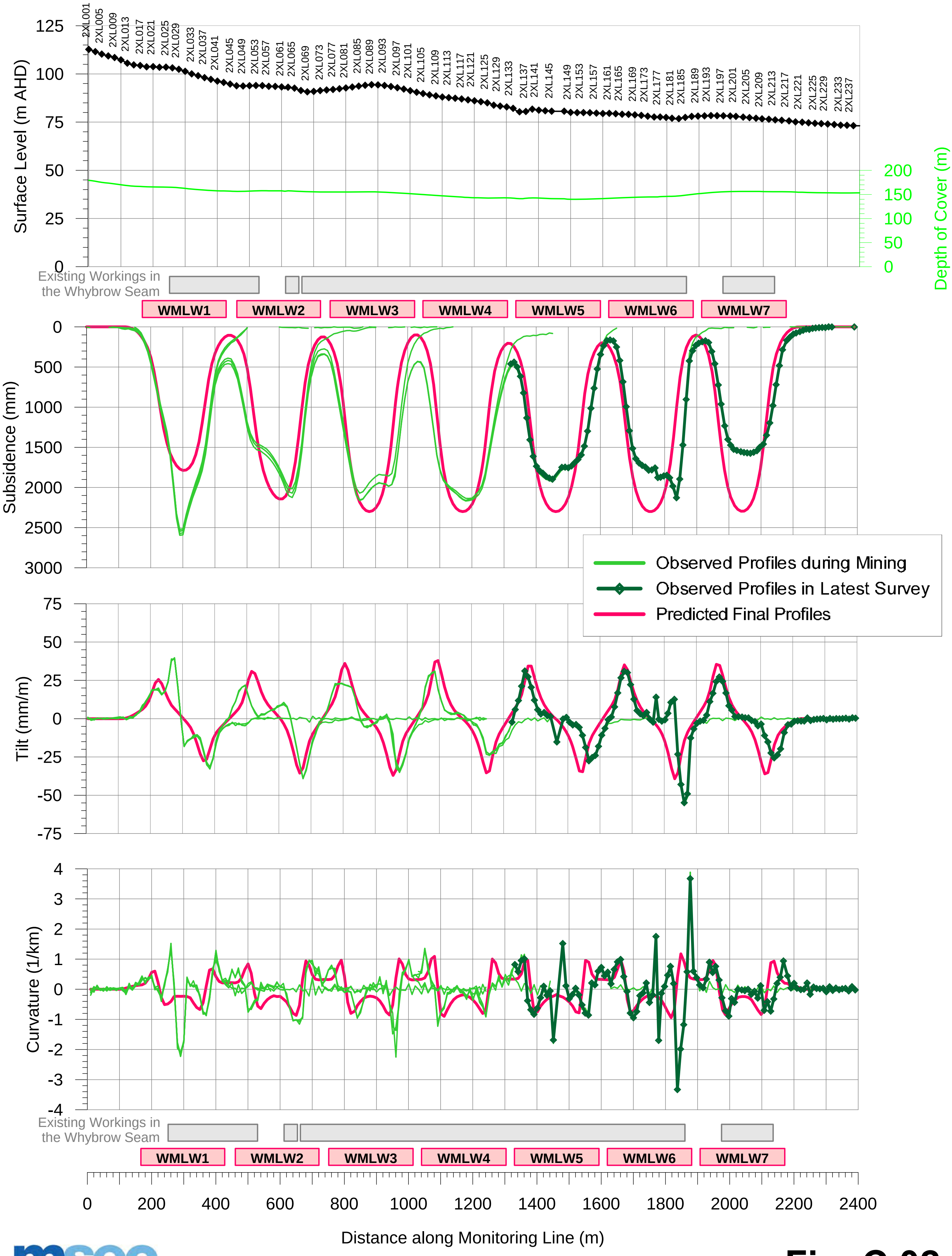

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Fig. C.02

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

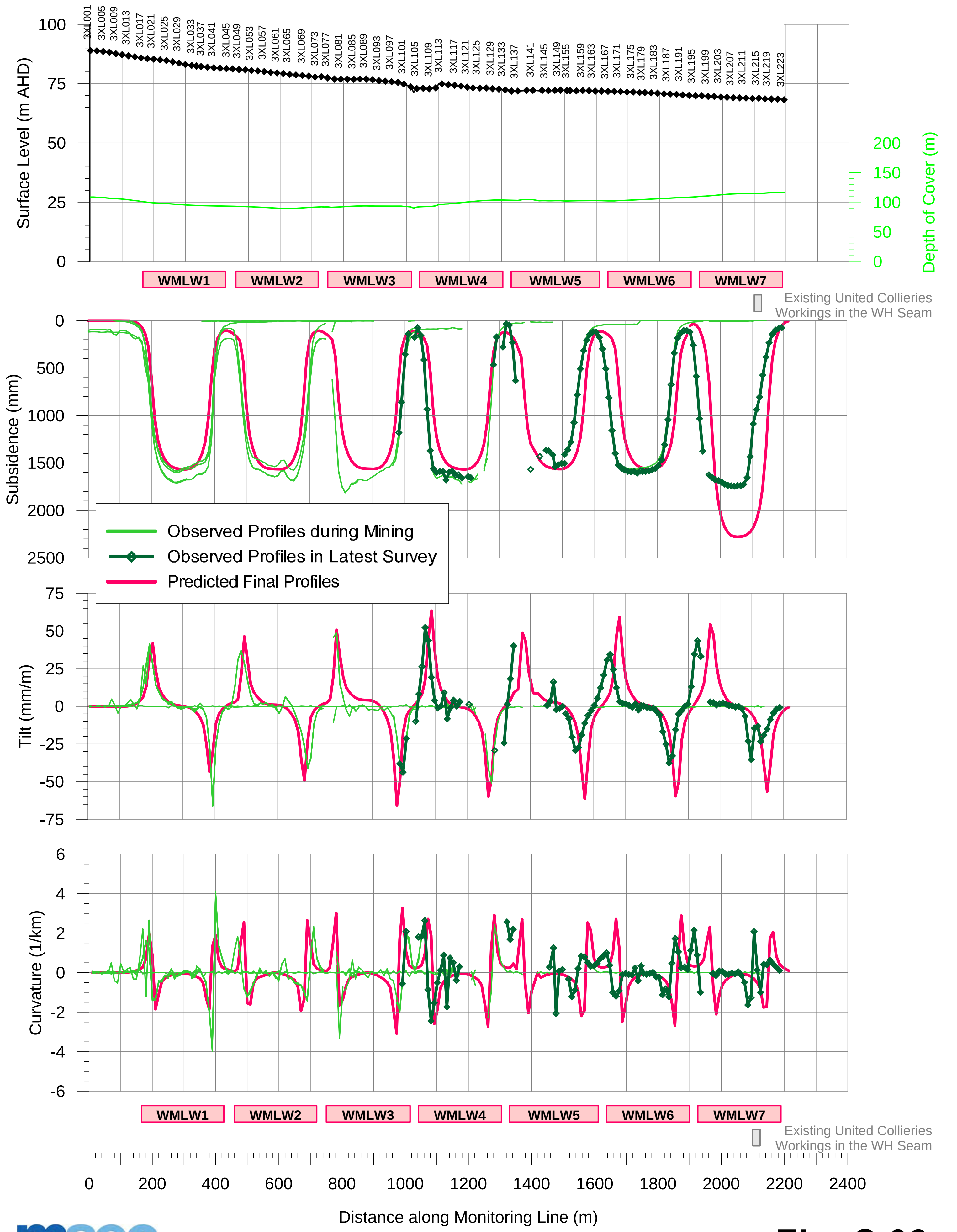

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Fig. C.03

Profiles of Observed and Back-Predicted Subsidence, Tilt and Curvature along the XL4-Line at the North Wambo Underground Mine

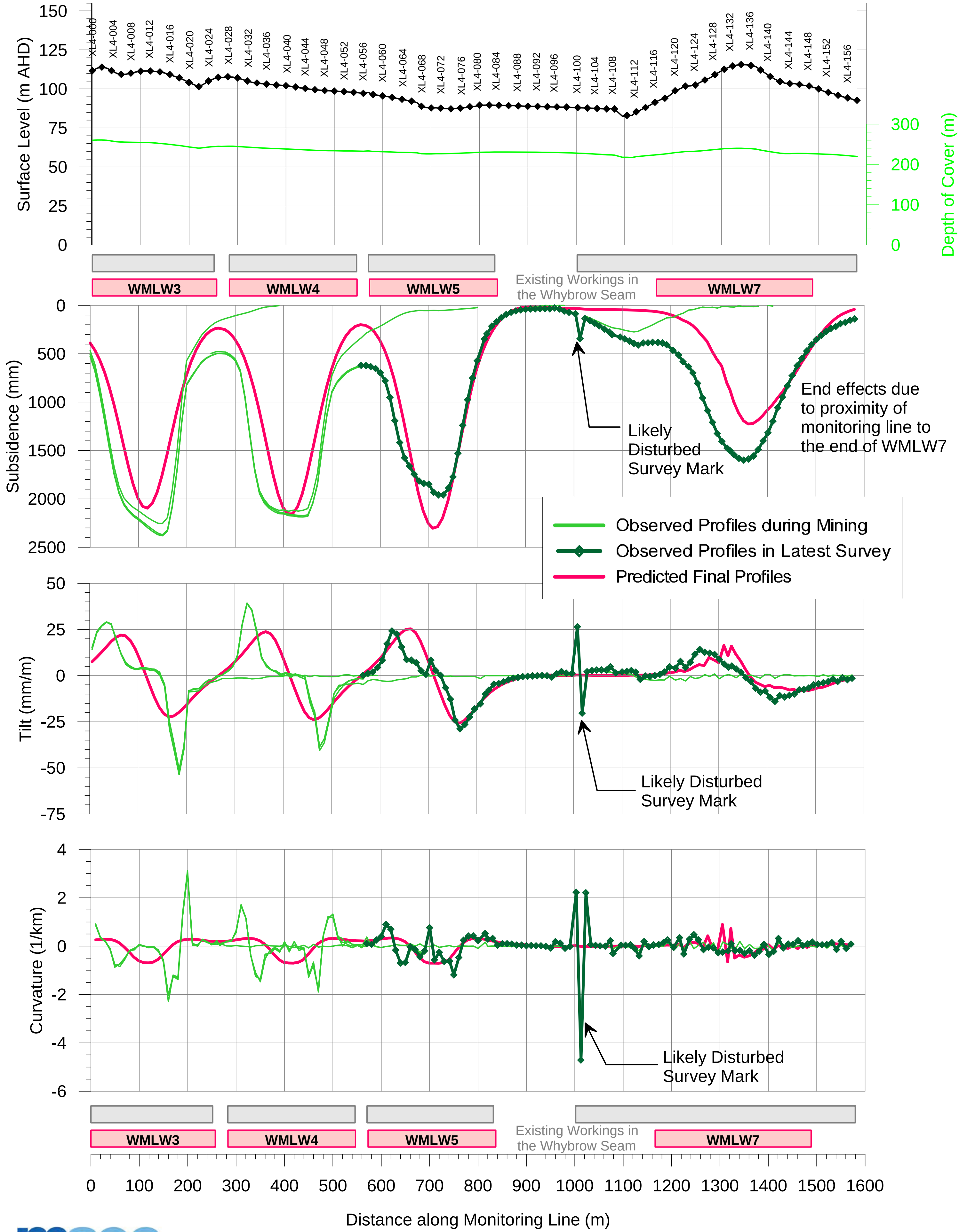

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Fig. C.04

Profiles of Observed and Back-Predicted Subsidence, Tilt and Curvature along the XL5-Line at the North Wambo Underground Mine

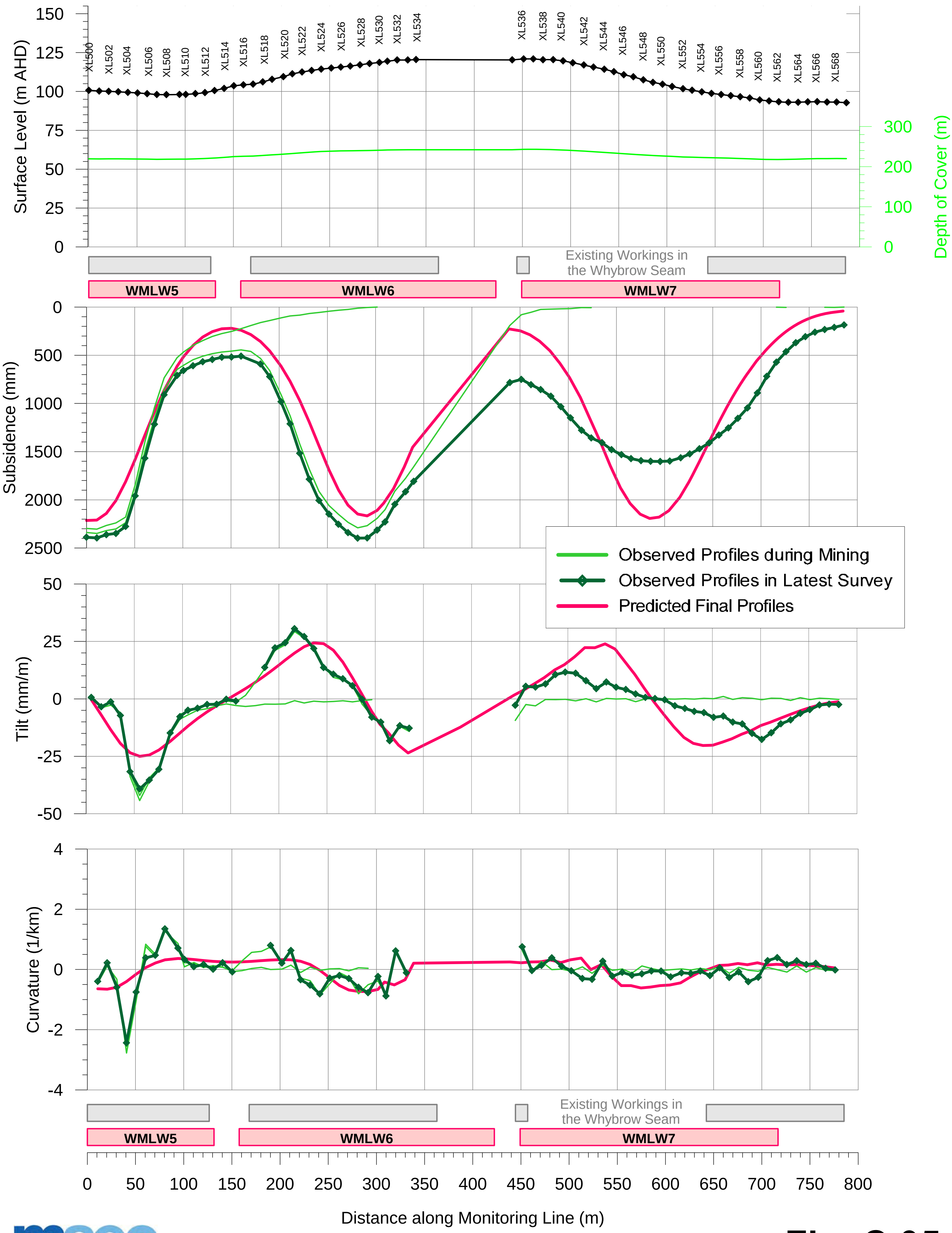

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Fig. C.05

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Profiles of Observed and Back-Predicted Subsidence, Tilt and Curvature along the XL6-Line at the North Wambo Underground Mine

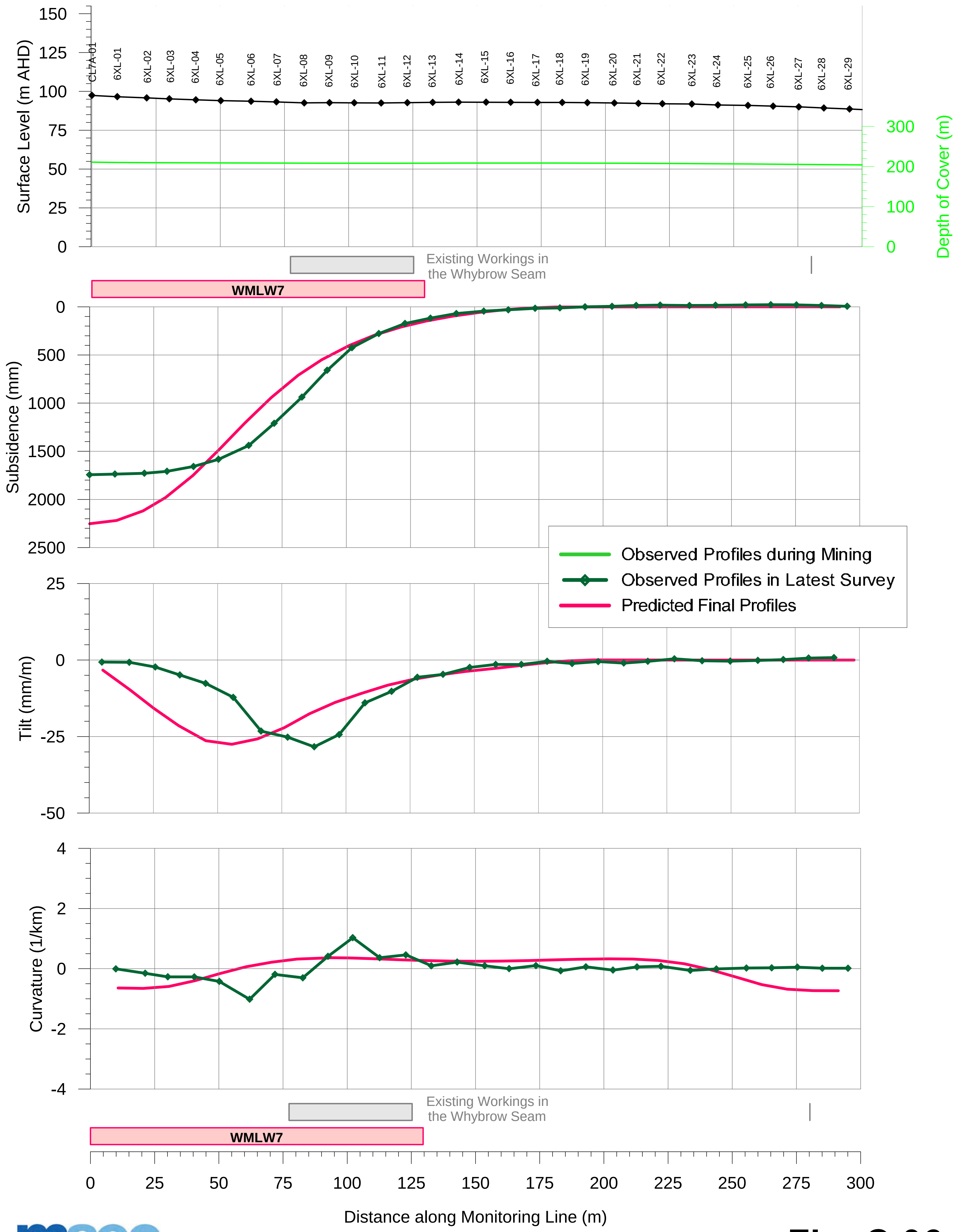

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Fig. C.06

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

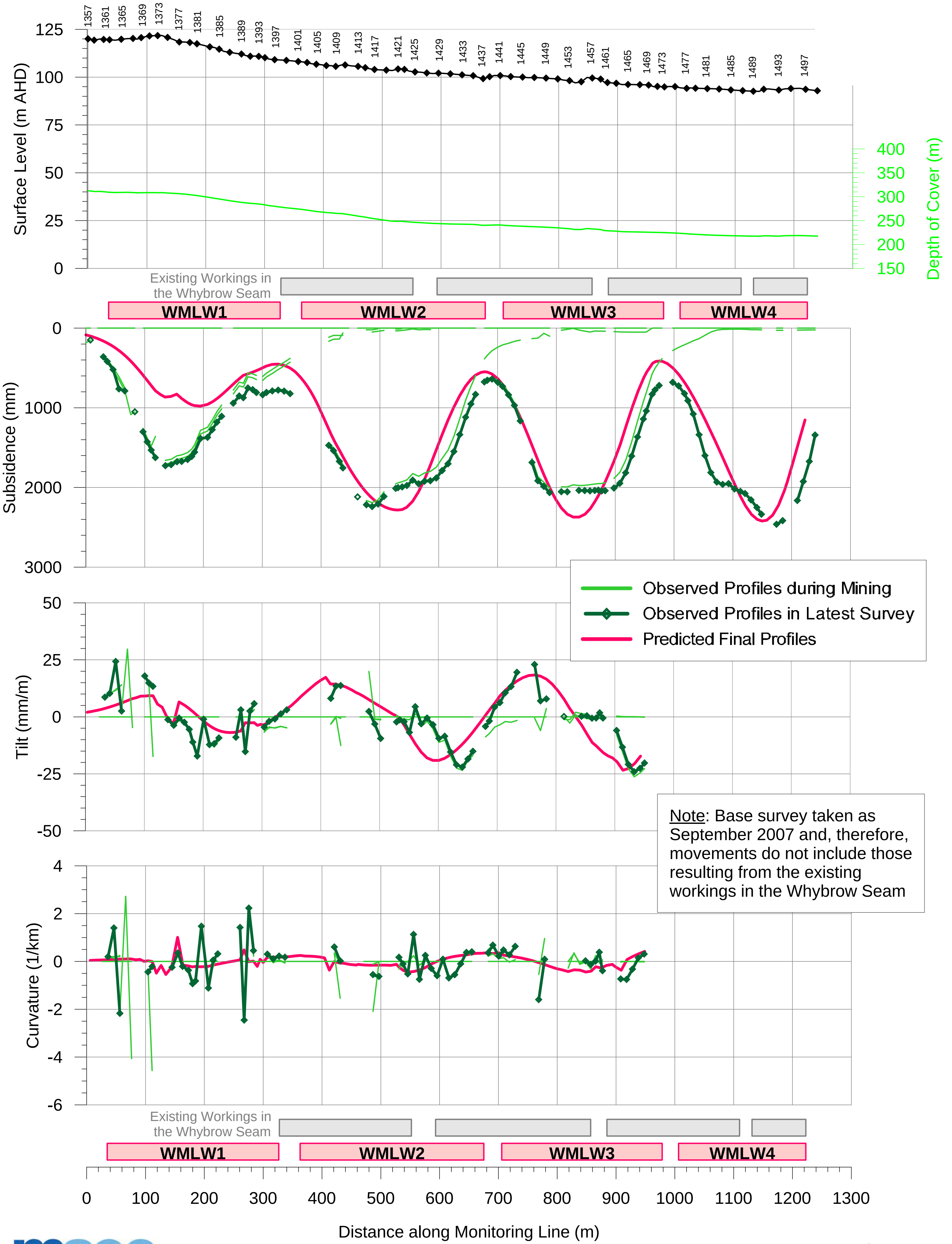

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Fig. C.07

Profiles of Observed and Back-Predicted Subsidence, Tilt and Curvature along the CL5A-Line at the North Wambo Underground Mine

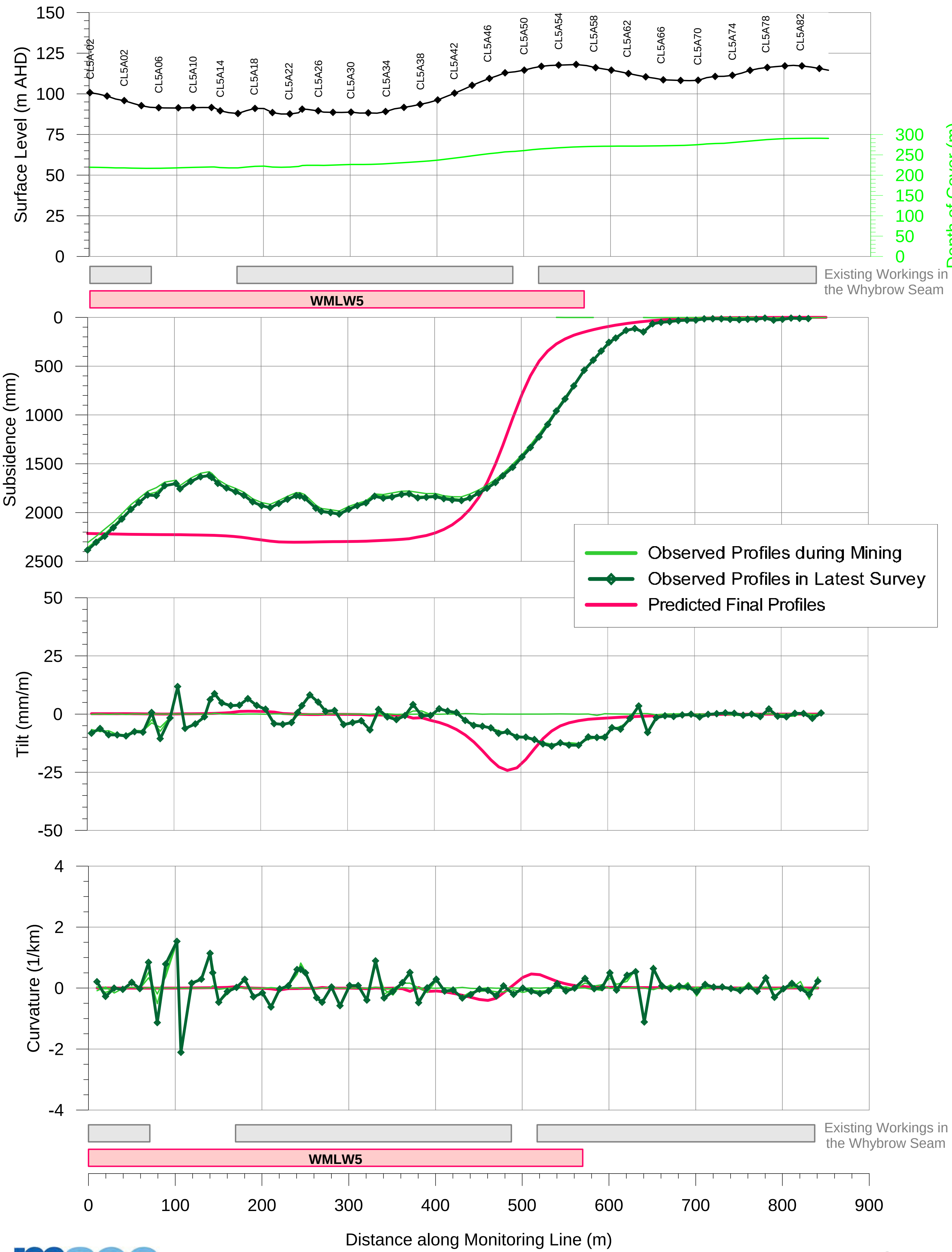

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Fig. C.08

Profiles of Observed and Back-Predicted Subsidence, Tilt and Curvature along the CL7A-Line at the North Wambo Underground Mine

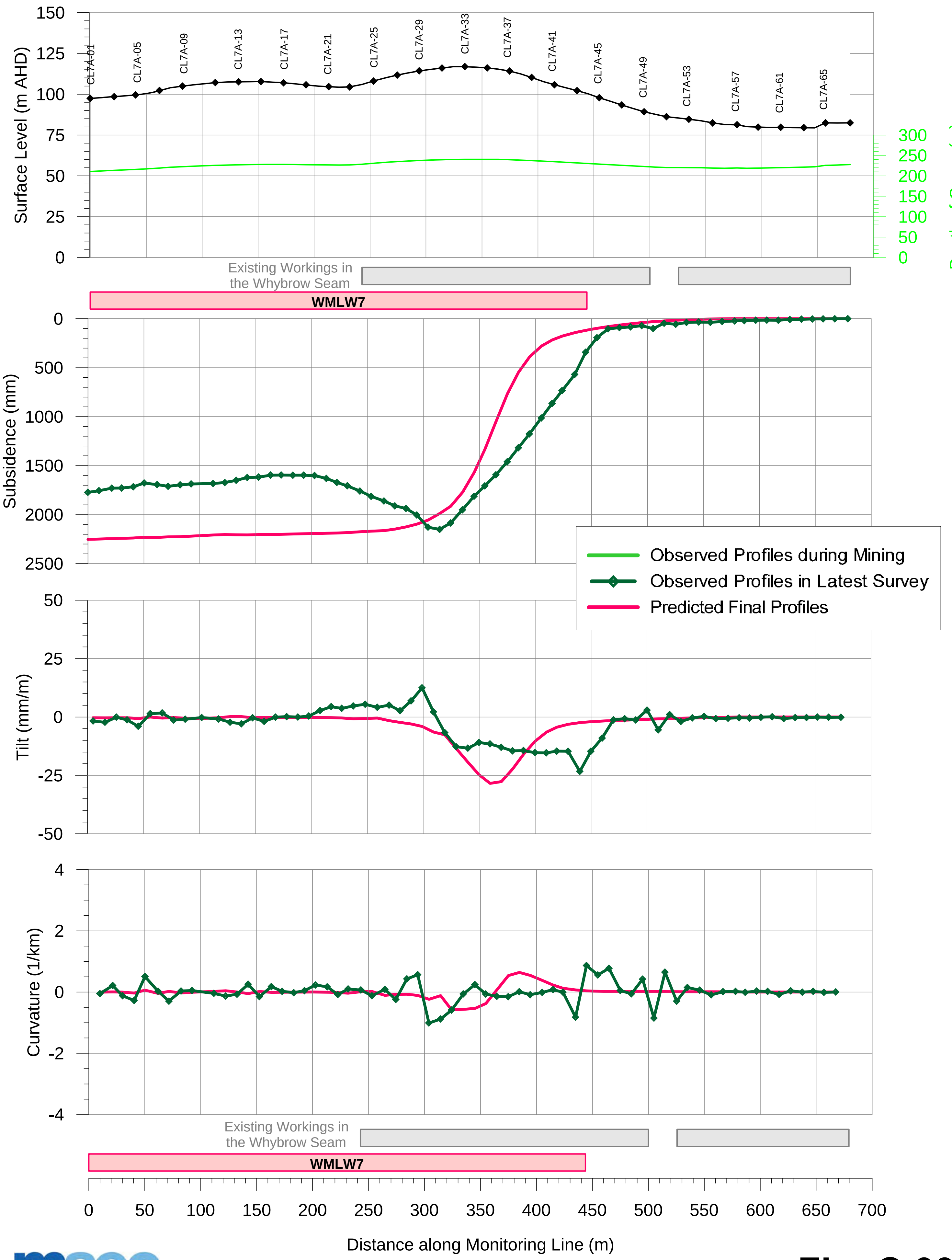

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Fig. C.09

Profiles of Observed and Back-Predicted Subsidence, Tilt and Curvature along the CL7B-Line at the North Wambo Underground Mine

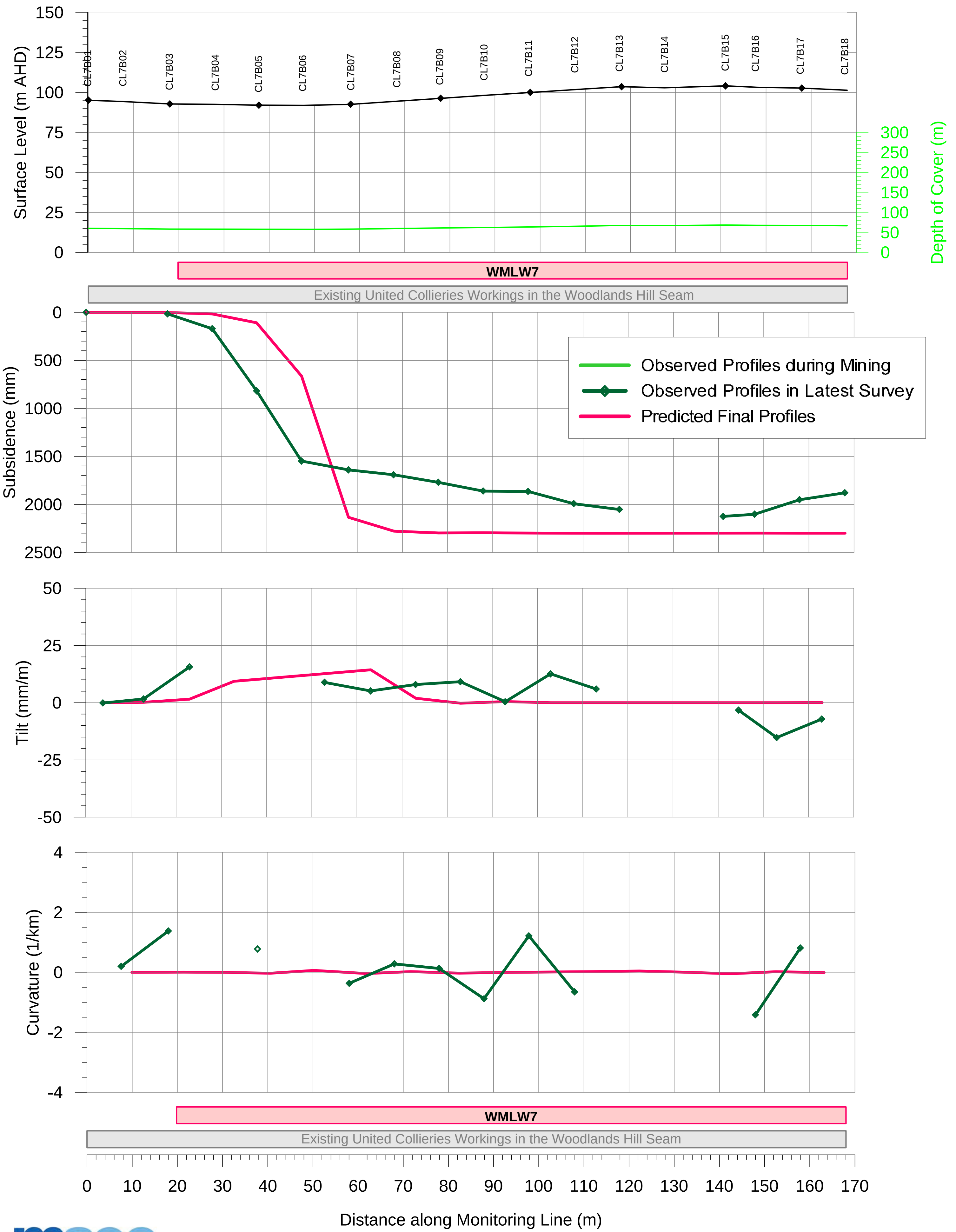

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Fig. C.10

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

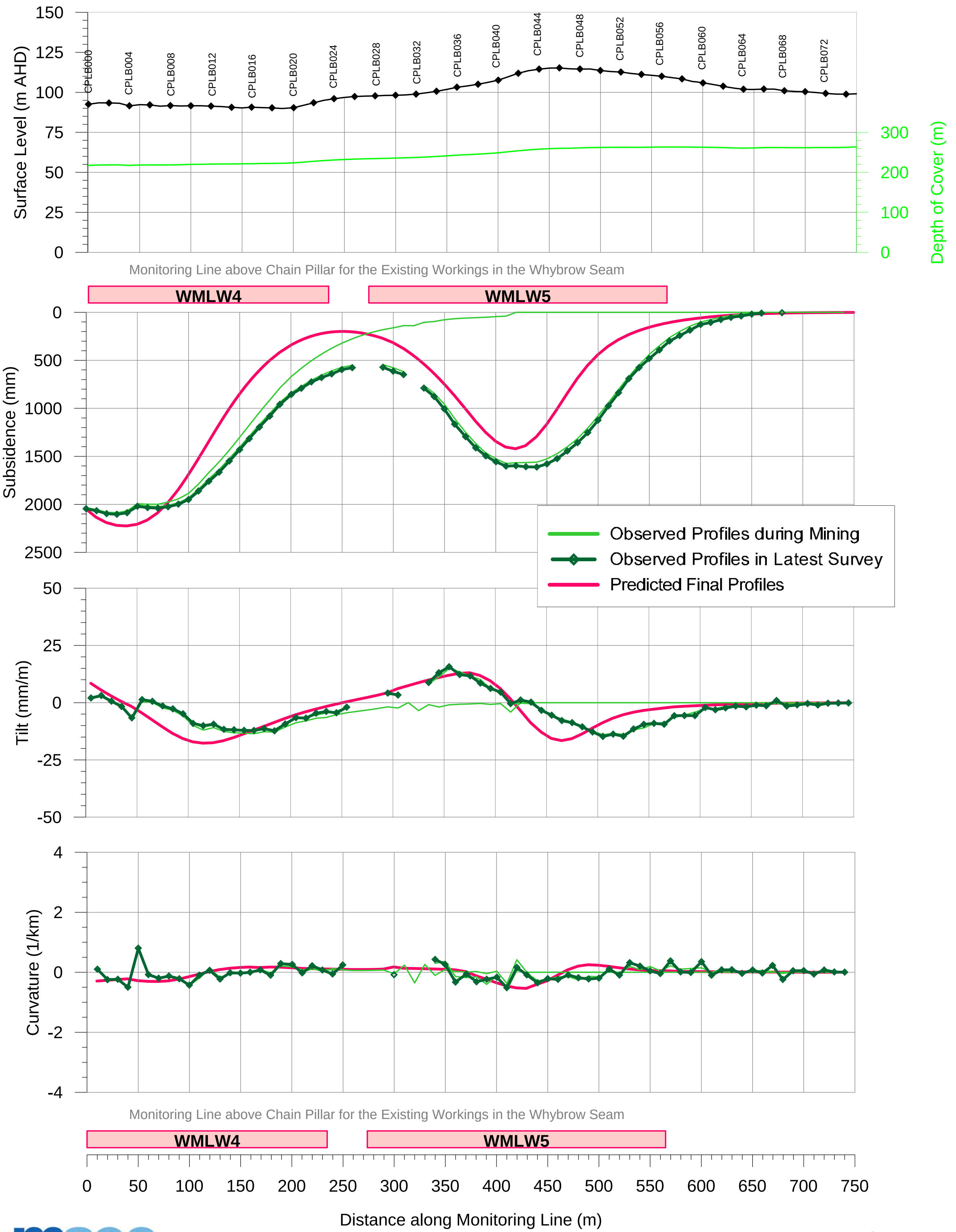

Fig. C.11

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

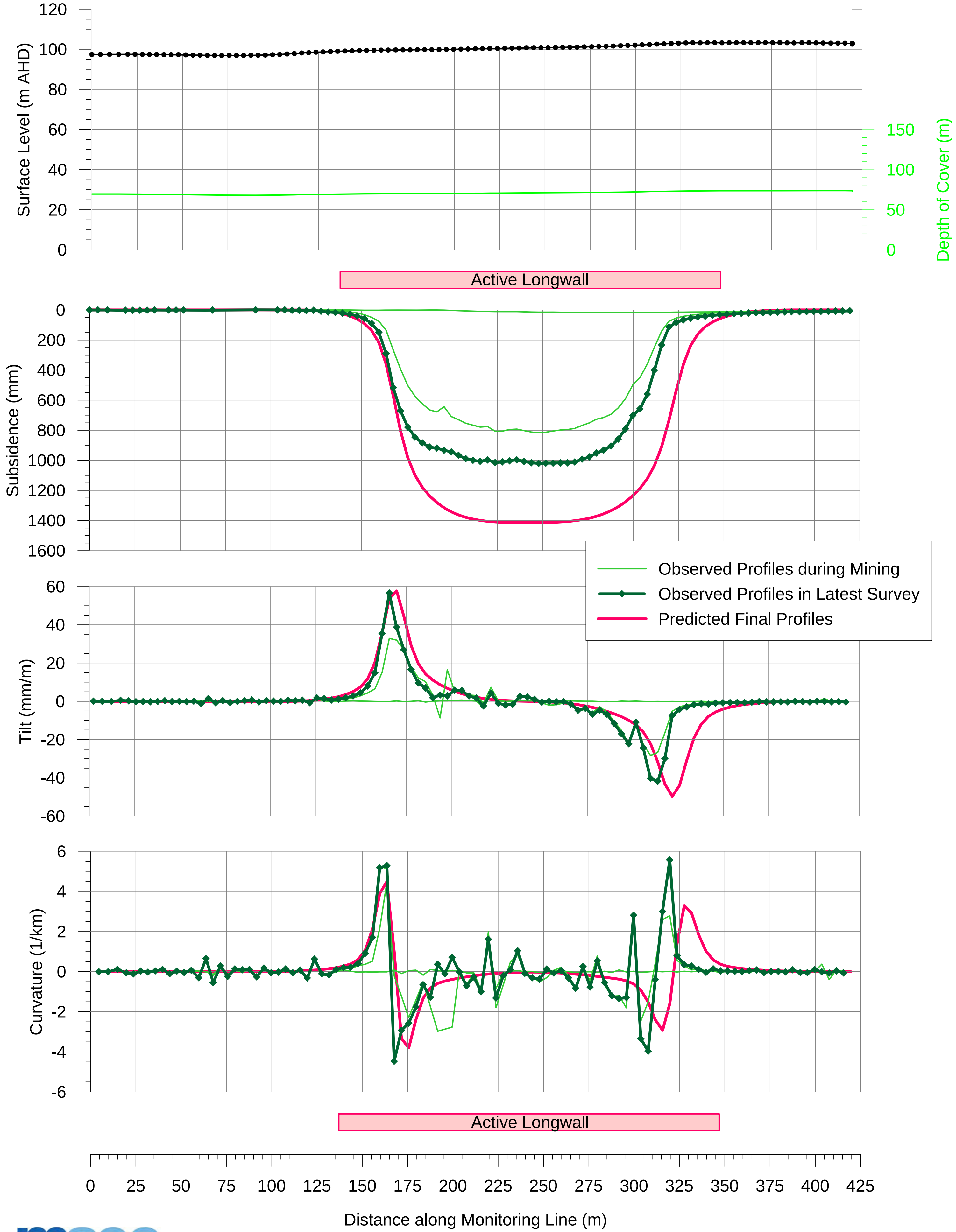

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Fig. C.12

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

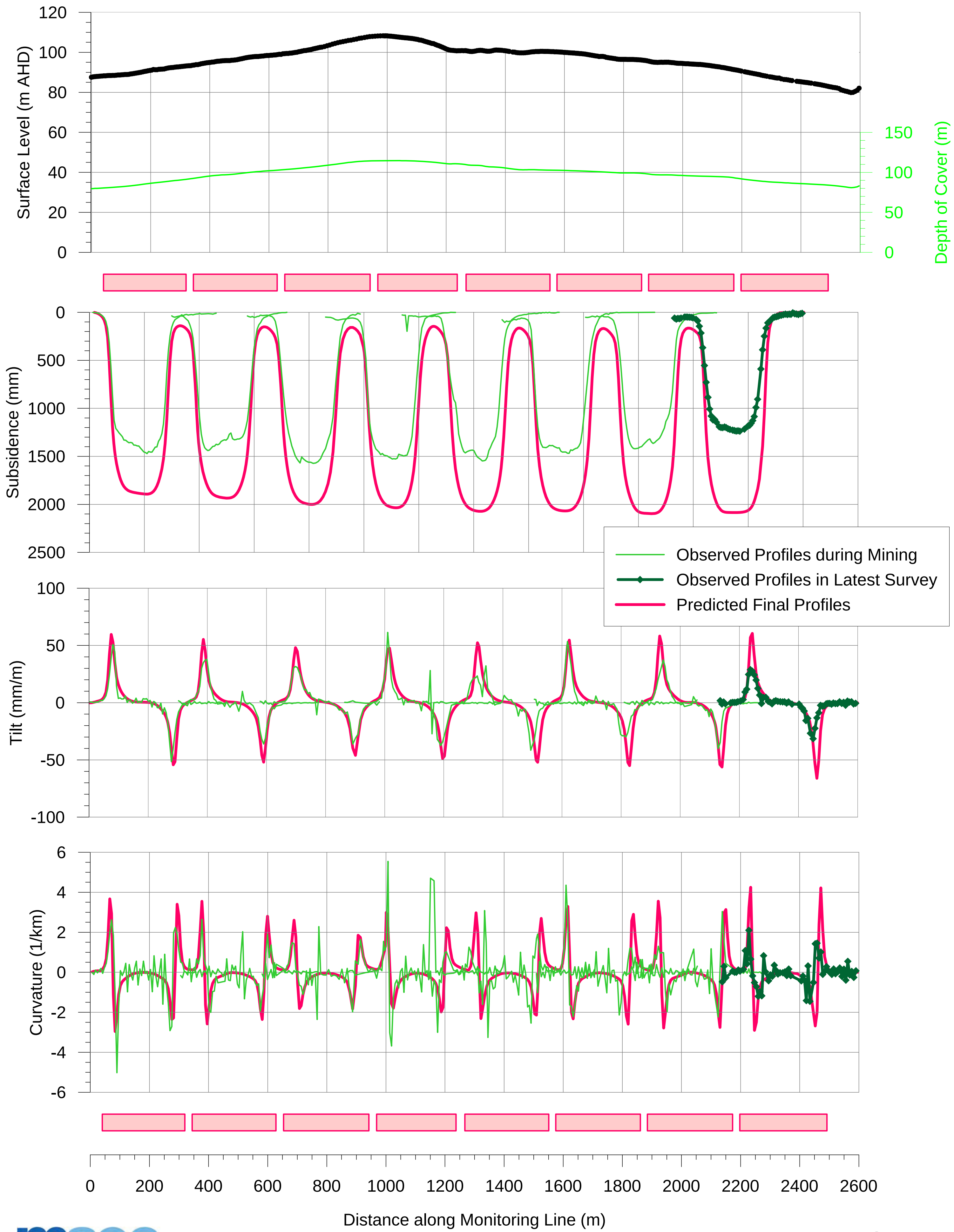

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Fig. C.13

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)
Site 40	Artefact Scatter	550	600	50	6	8	2	0.10	0.10	0.00	0.03	0.10	0.07
Site 41	Artefact Scatter	300	300	0	4	4	0	0.03	0.04	0.01	0.02	0.02	0.00
Site 42	Artefact Scatter	75	75	0	1	1	0	0.01	0.01	0.00	< 0.01	< 0.01	0.00
Site 336	Artefact Scatter	800	900	100	15	20	5	0.50	0.90	0.40	< 0.01	0.50	0.00
Site 363	Artefact Scatter	500	550	50	6	7	1	0.10	0.10	0.00	< 0.01	< 0.01	0.00
Site 371	Isolated Find	2200	3700	1500	20	20	0	0.50	1.50	1.00	0.10	1.50	1.40
Site 372	Isolated Find	2600	4000	1400	30	20	-10	0.50	1.50	1.00	0.10	1.50	1.40
Site 373	Isolated Find	4500	4500	0	35	35	0	0.10	0.10	0.00	1.00	1.00	0.00
Site 374	Isolated Find	1800	3100	1300	25	55	30	0.50	3.00	2.50	0.10	3.00	2.90
Bleached Sand	-	3700	3700	0	50	55	5	0.70	3.00	2.30	0.80	3.00	2.20
Sandstone Outcrops	-	1900	1900	0	40	40	0	0.70	0.70	0.00	0.40	0.40	0.00
	Maximum	**4500**	**4500**	**1500**	**50**	**55**	**30**	**0.70**	**3.00**	**2.50**	**1.00**	**3.00**	**2.90**

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

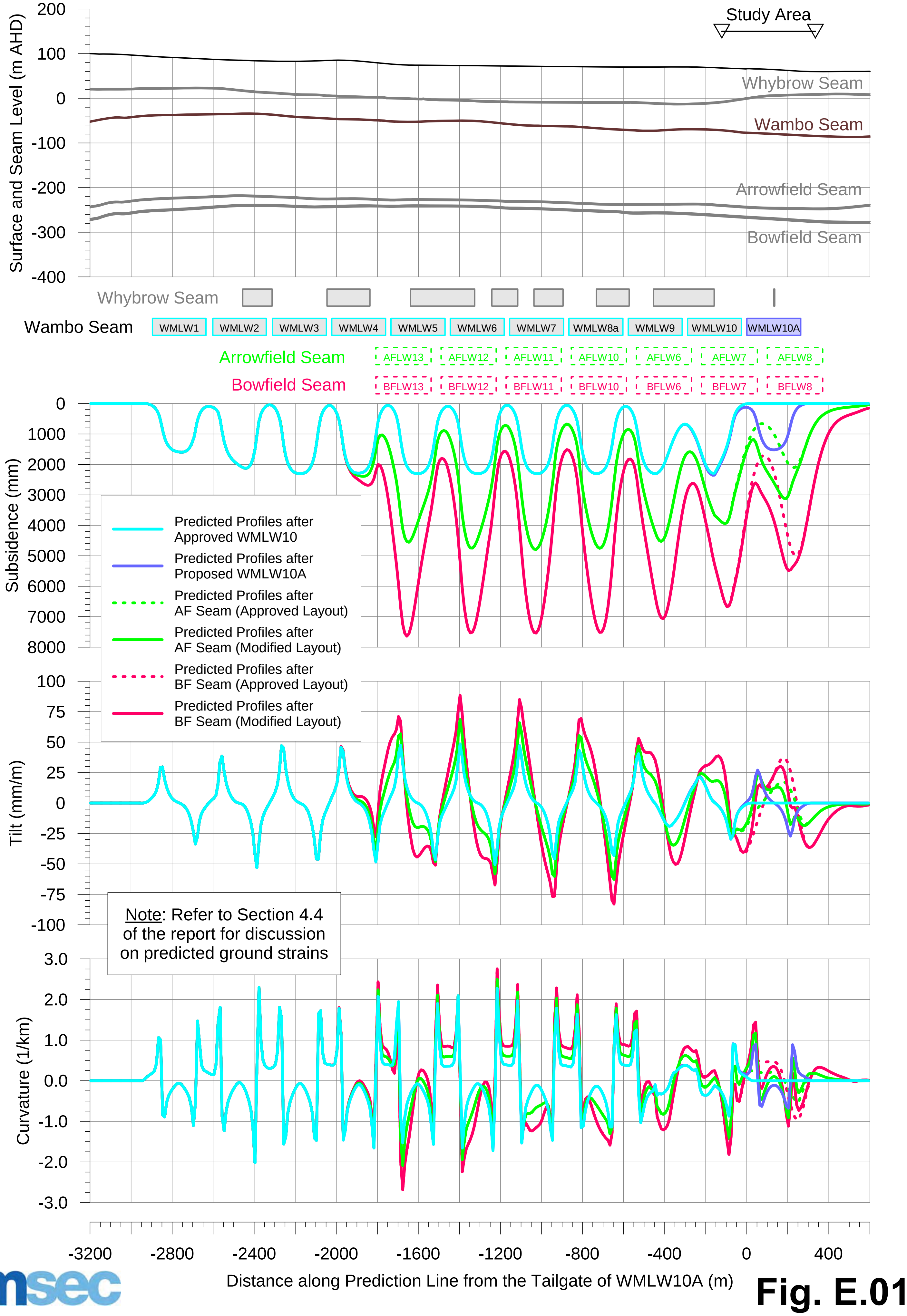

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Fig. E.01

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

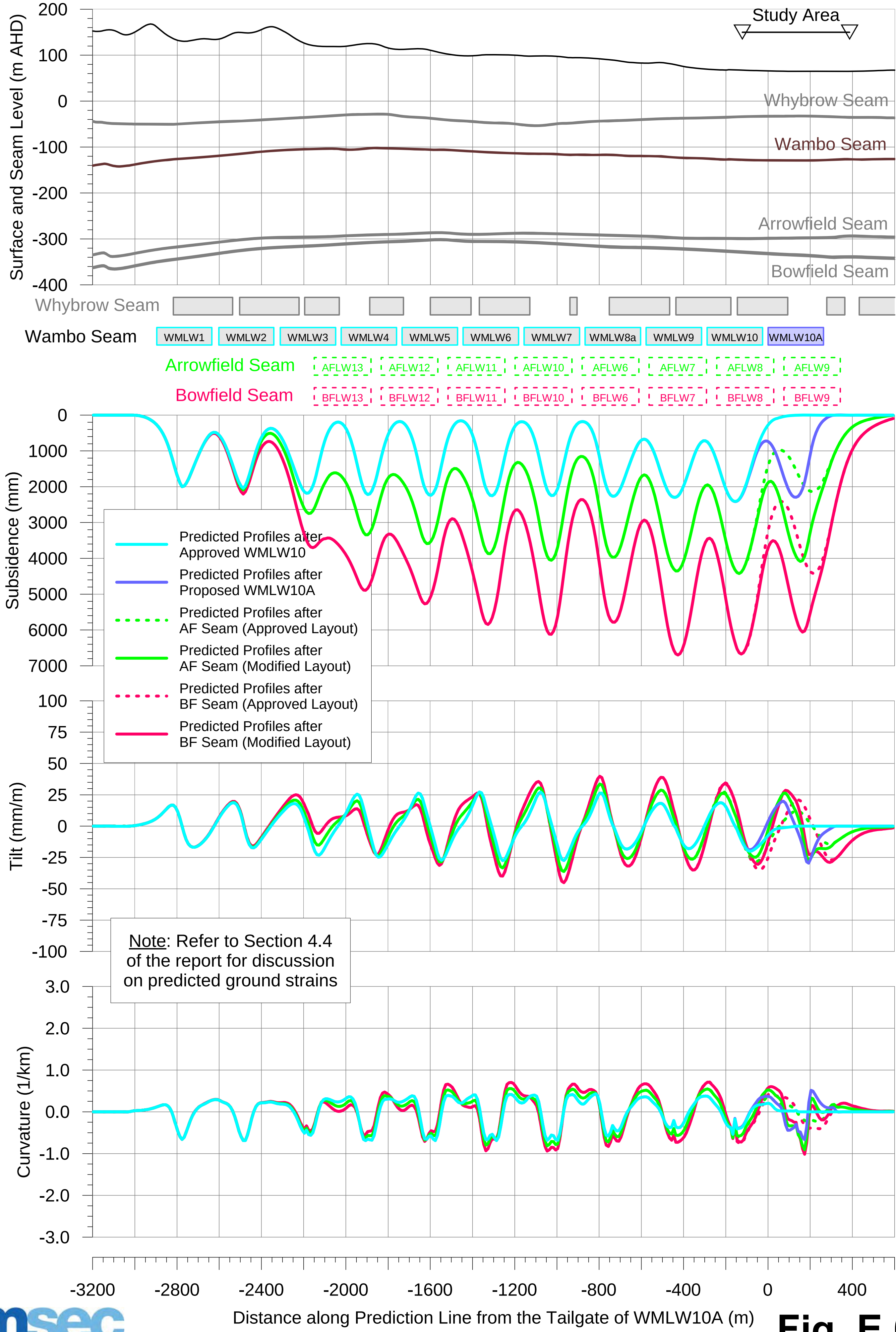

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Fig. E.02

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along the Unsealed Road due to Mining in the Wambo, Arrowfield and Bowfield Seams

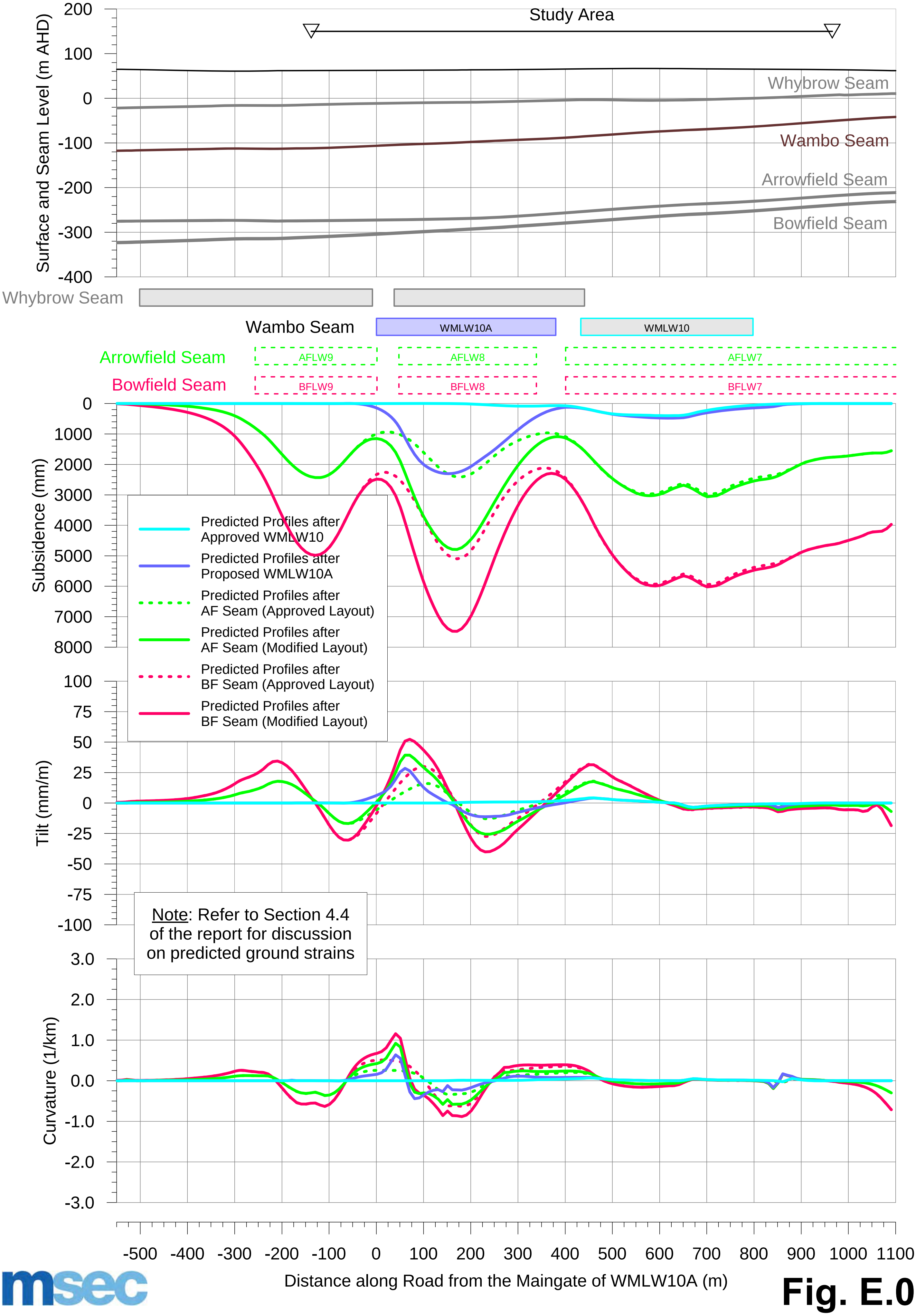

Fig. E.03

APPENDIX F. DRAWINGS

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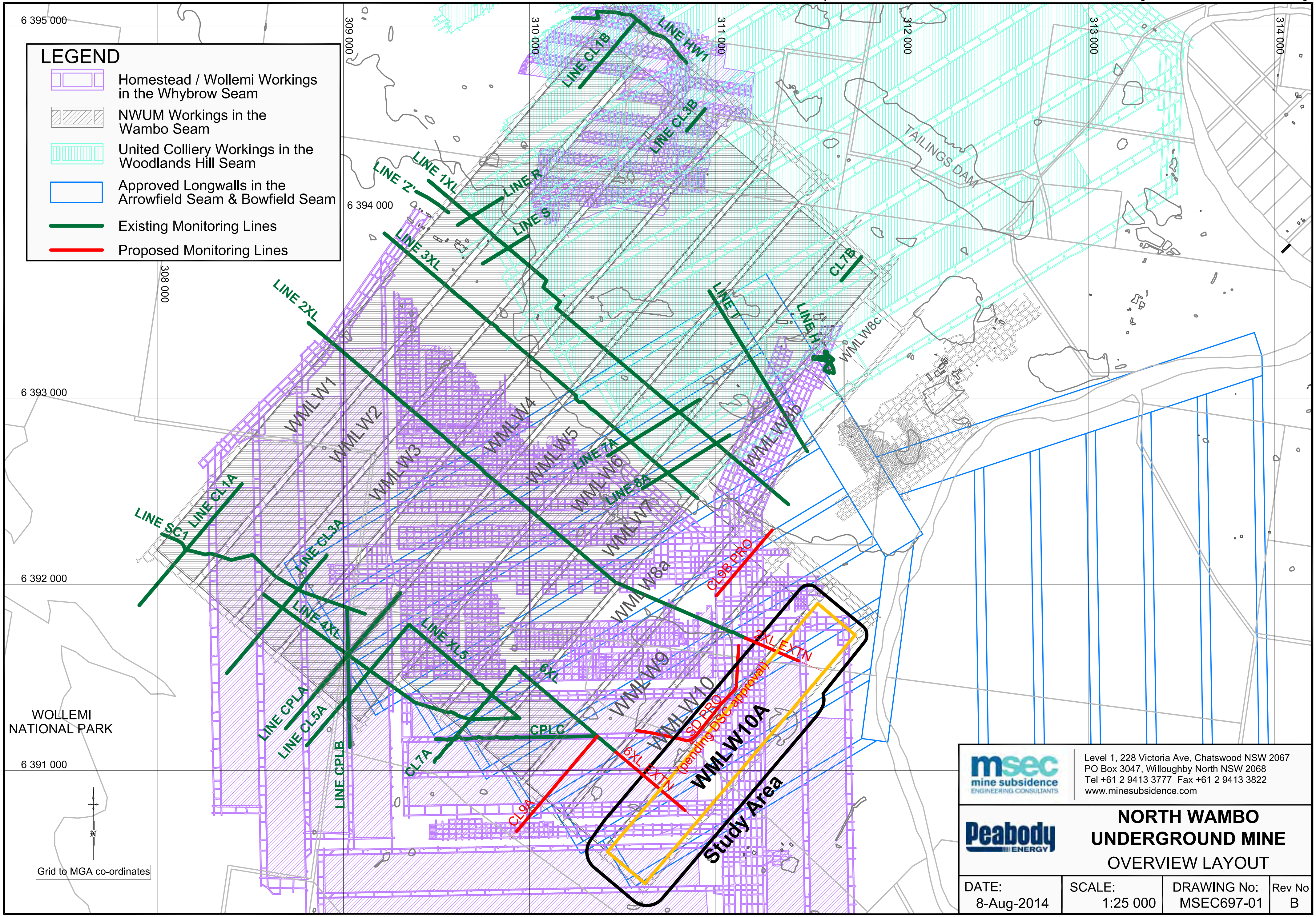

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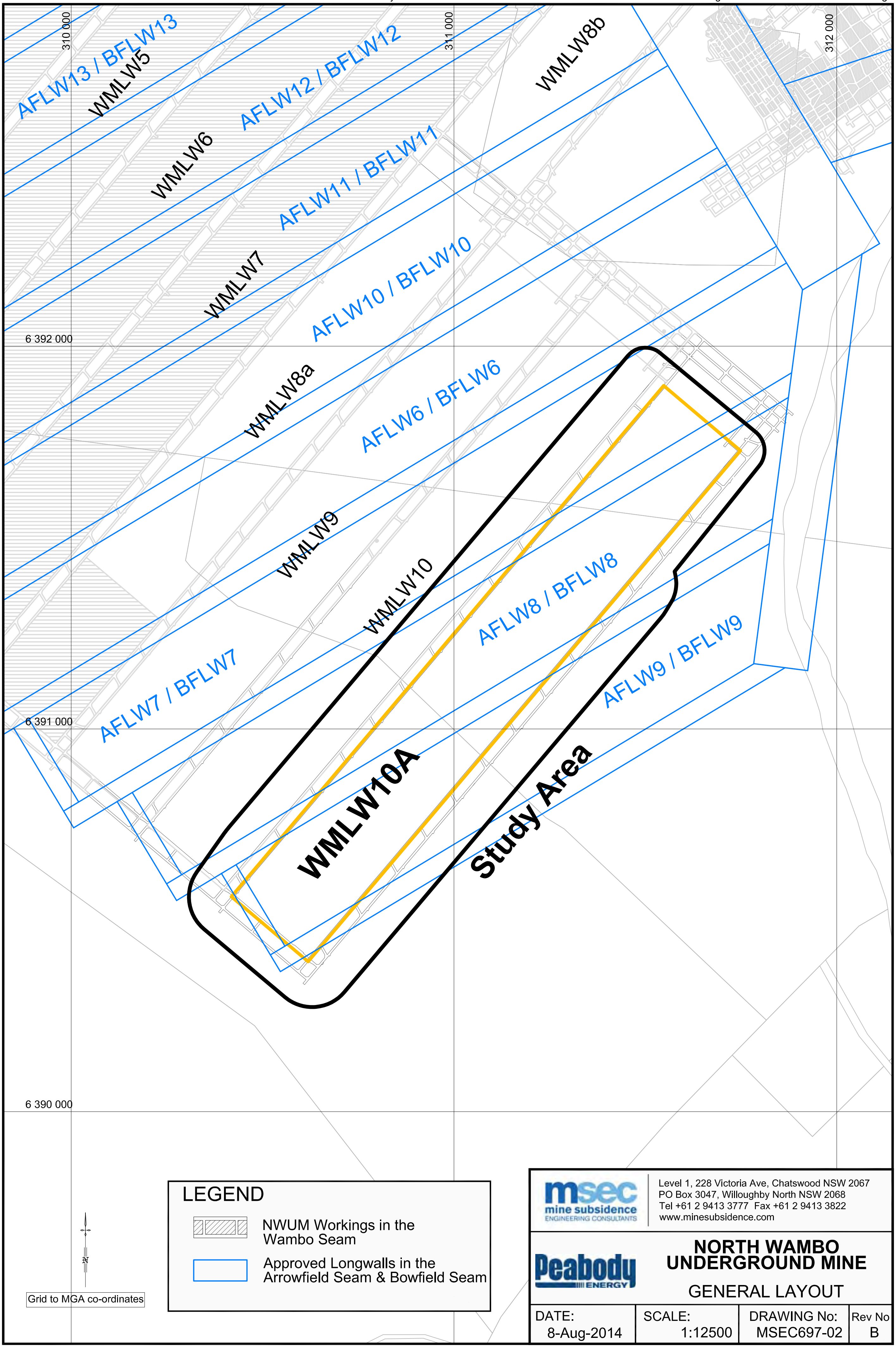

LEGEND

- NWUM Workings in the Wambo Seam
- Approved Longwalls in the Arrowfield Seam & Bowfield Seam

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NORTH WAMBO UNDERGROUND MINE

GENERAL LAYOUT

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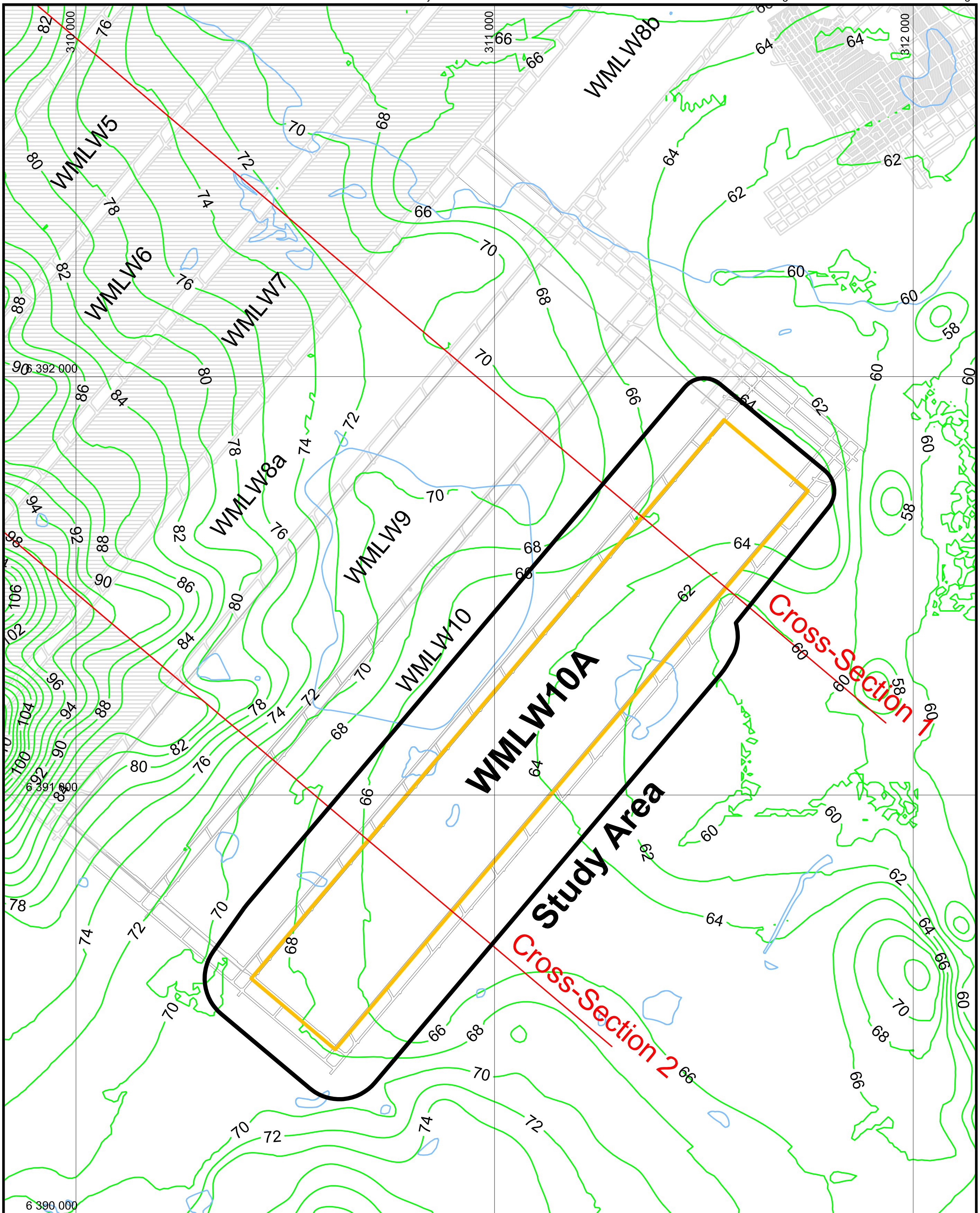

Grid to MGA co-ordinates

SURFACE LEVEL CONTOURS ARE IN m AHD

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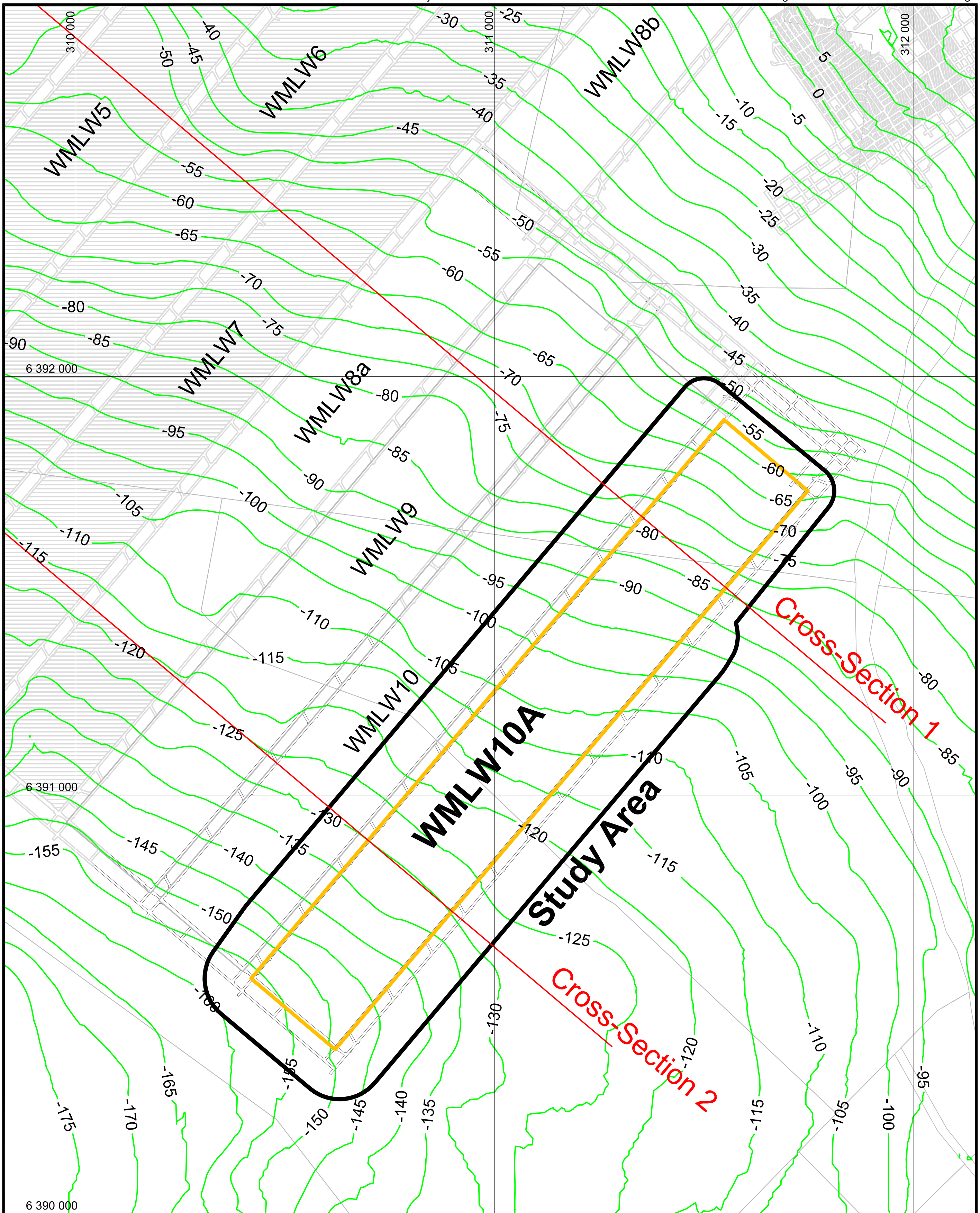

Grid to MGA co-ordinates

SEAM FLOOR CONTOURS ARE IN m AHD

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WAMBO SEAM FLOOR CONTOURS

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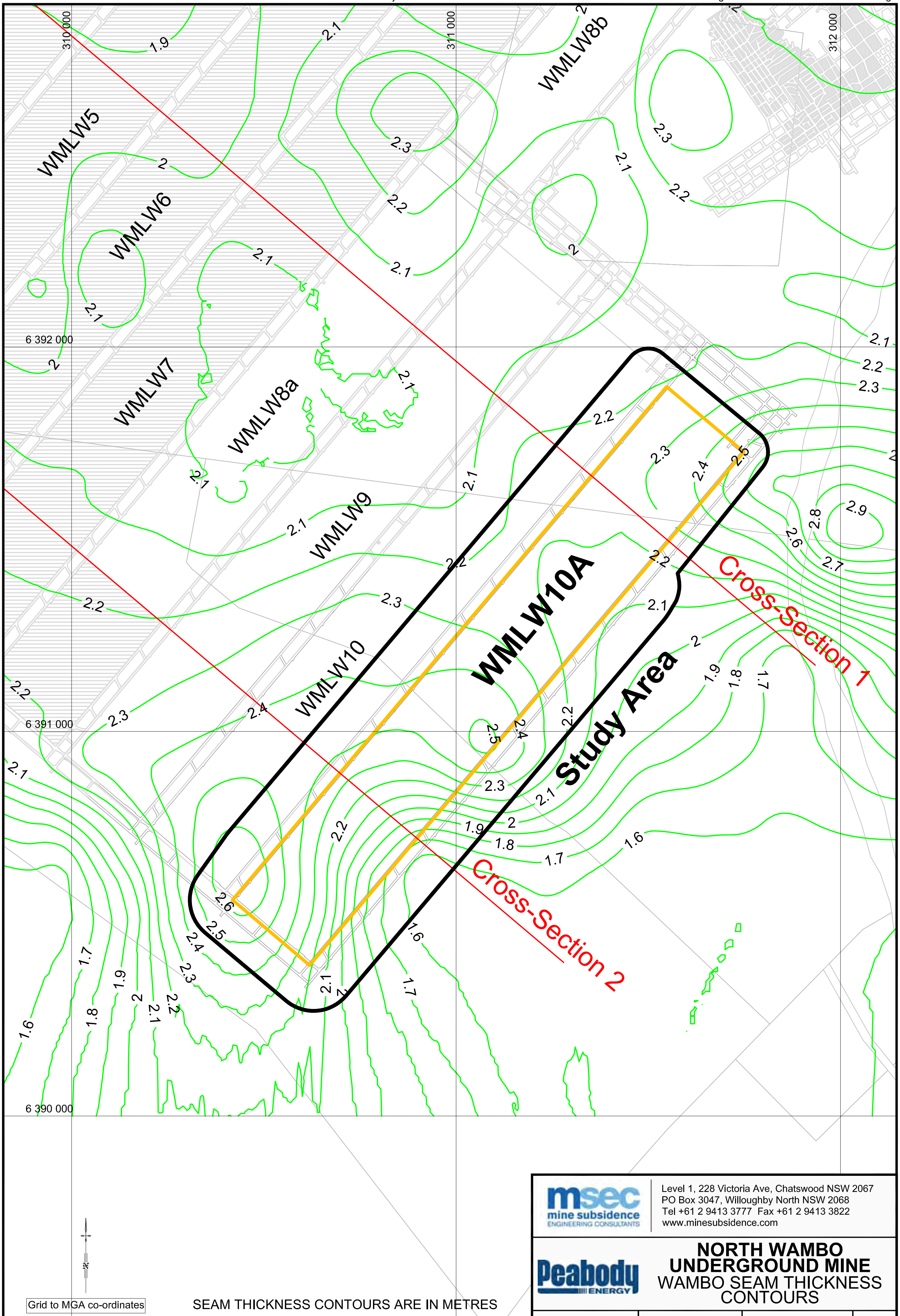

SEAM THICKNESS CONTOURS ARE IN METRES

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WAMBO SEAM THICKNESS CONTOURS

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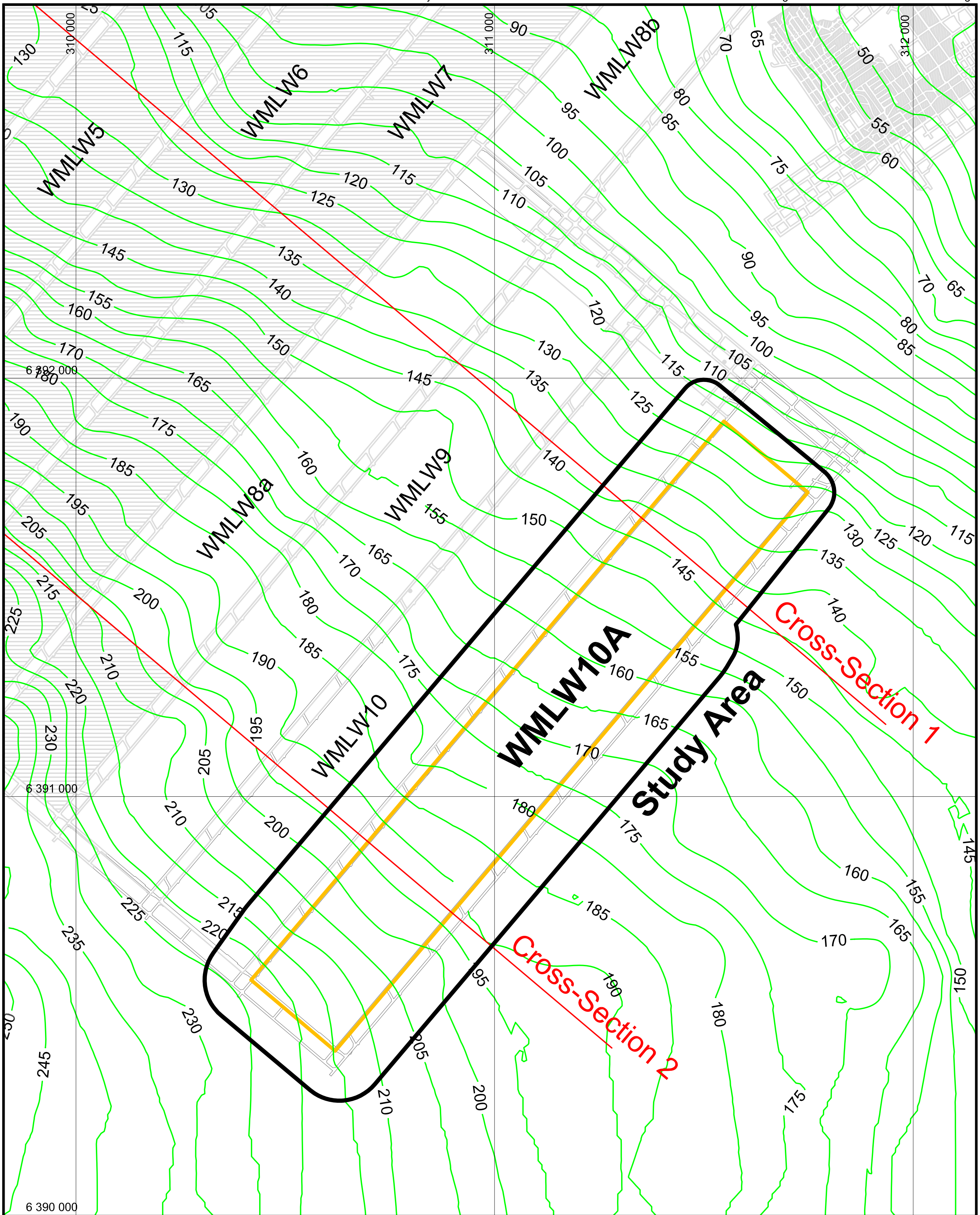

Grid to MGA co-ordinates

DEPTH OF COVER CONTOURS ARE IN METRES

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WAMBO DEPTH OF COVER CONTOURS

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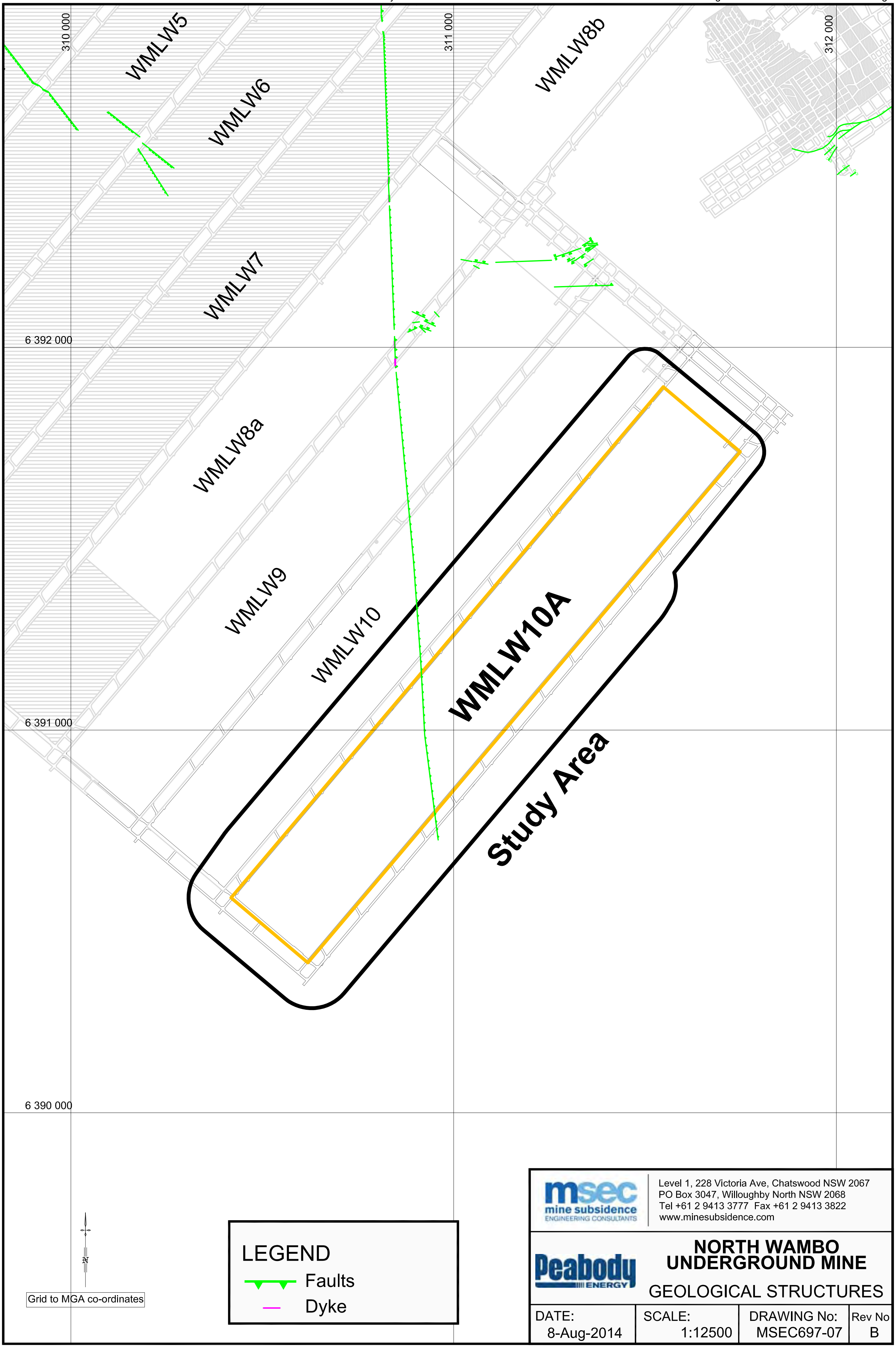

LEGEND
Faults
Dyke

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NORTH WAMBO UNDERGROUND MINE

GEOLOGICAL STRUCTURES

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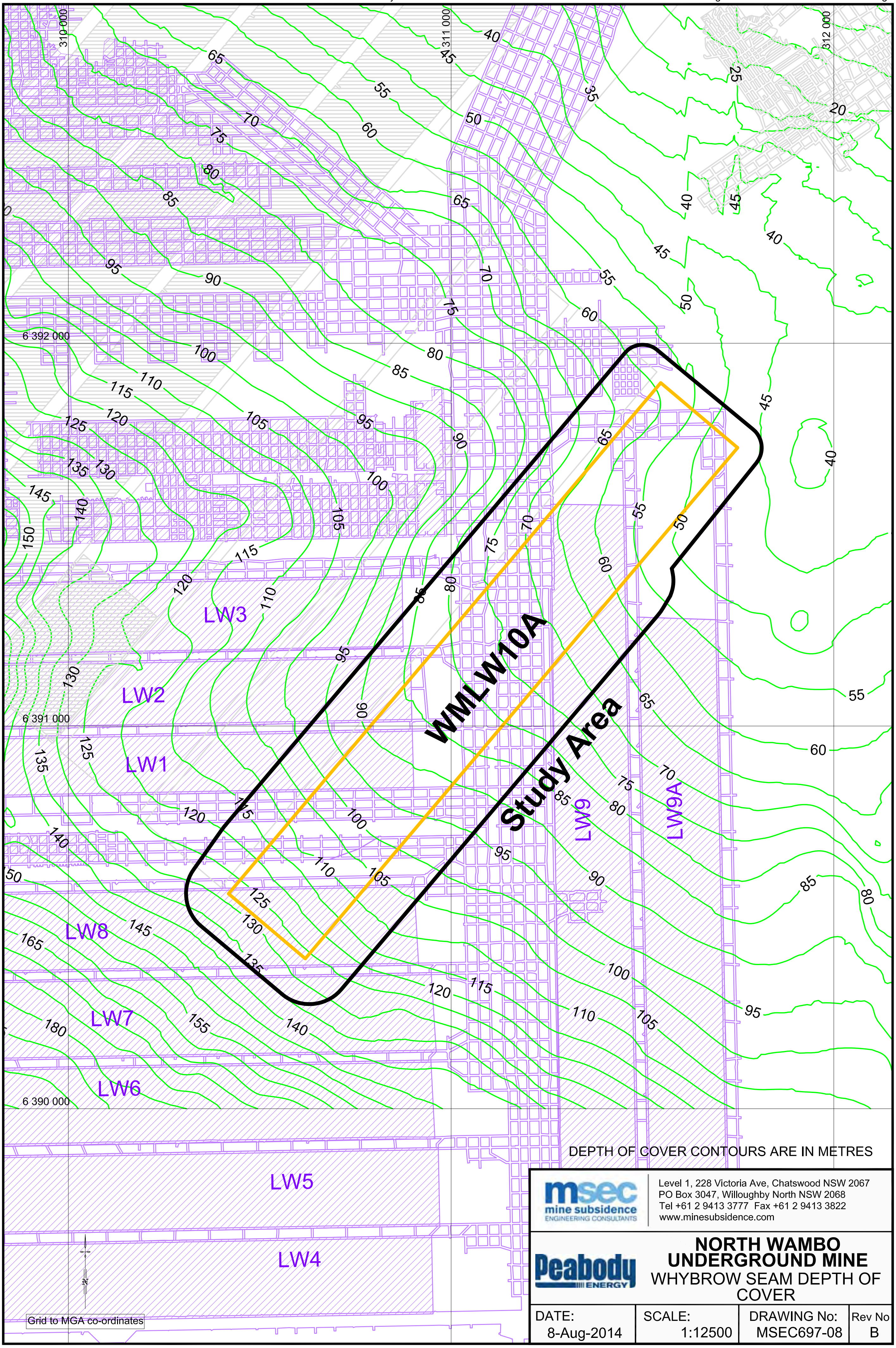

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NORTH WAMBO UNDERGROUND MINE

WHYBROW SEAM DEPTH OF COVER

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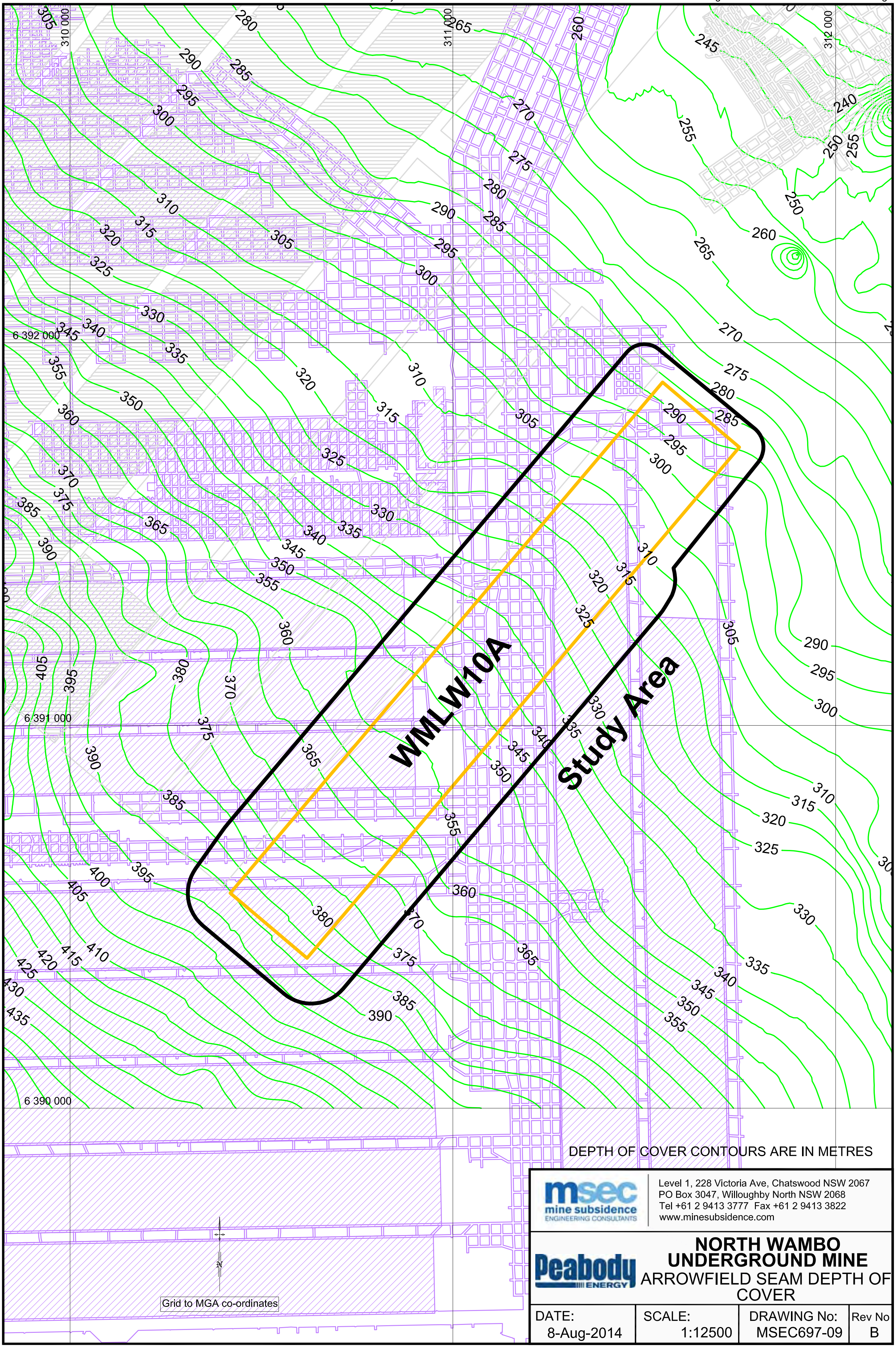

DEPTH OF COVER CONTOURS ARE IN METRES

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NORTH WAMBO UNDERGROUND MINE

ARROWFIELD SEAM DEPTH OF COVER

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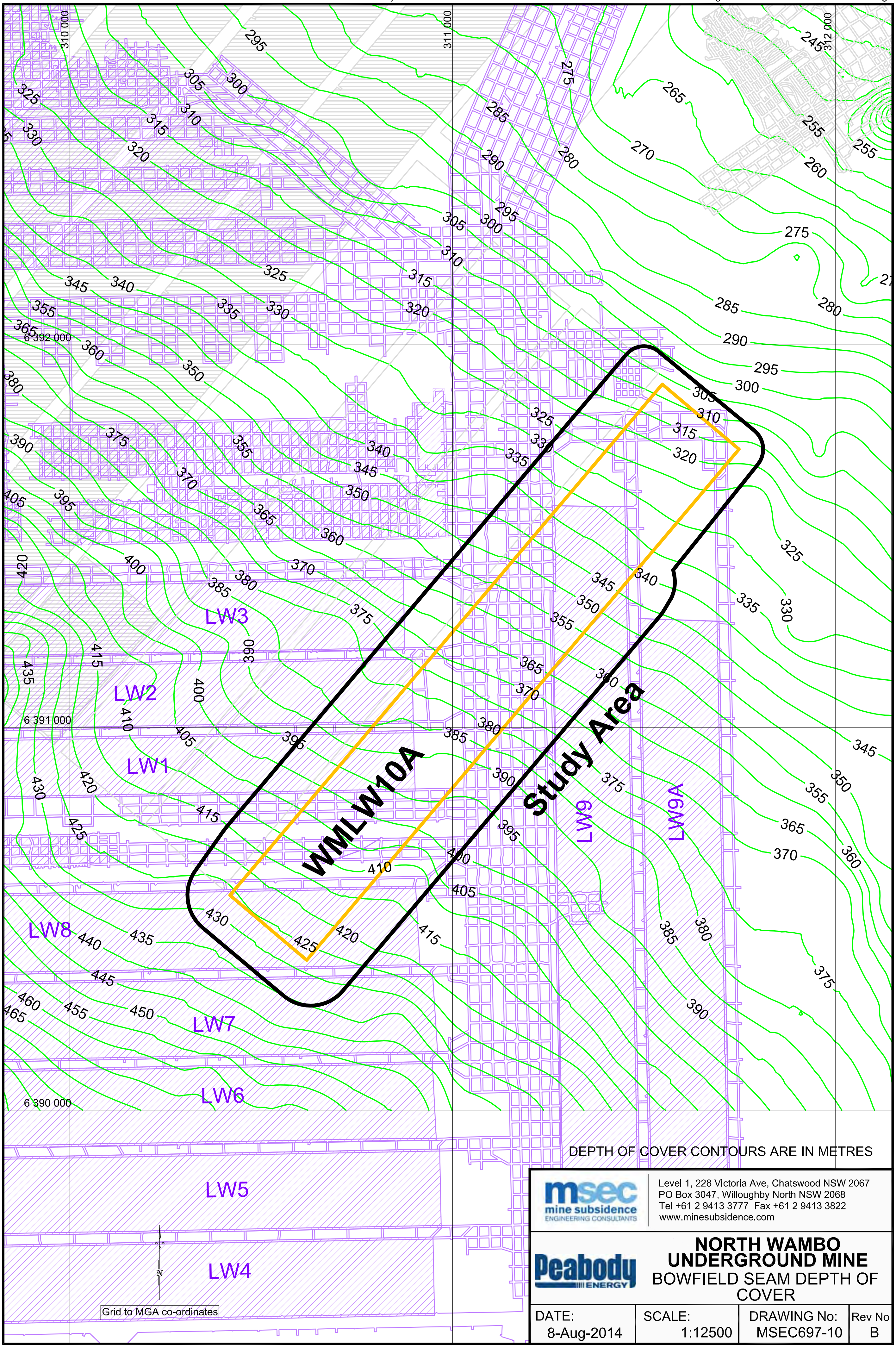

DEPTH OF COVER CONTOURS ARE IN METRES

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BOWFIELD SEAM DEPTH OF COVER

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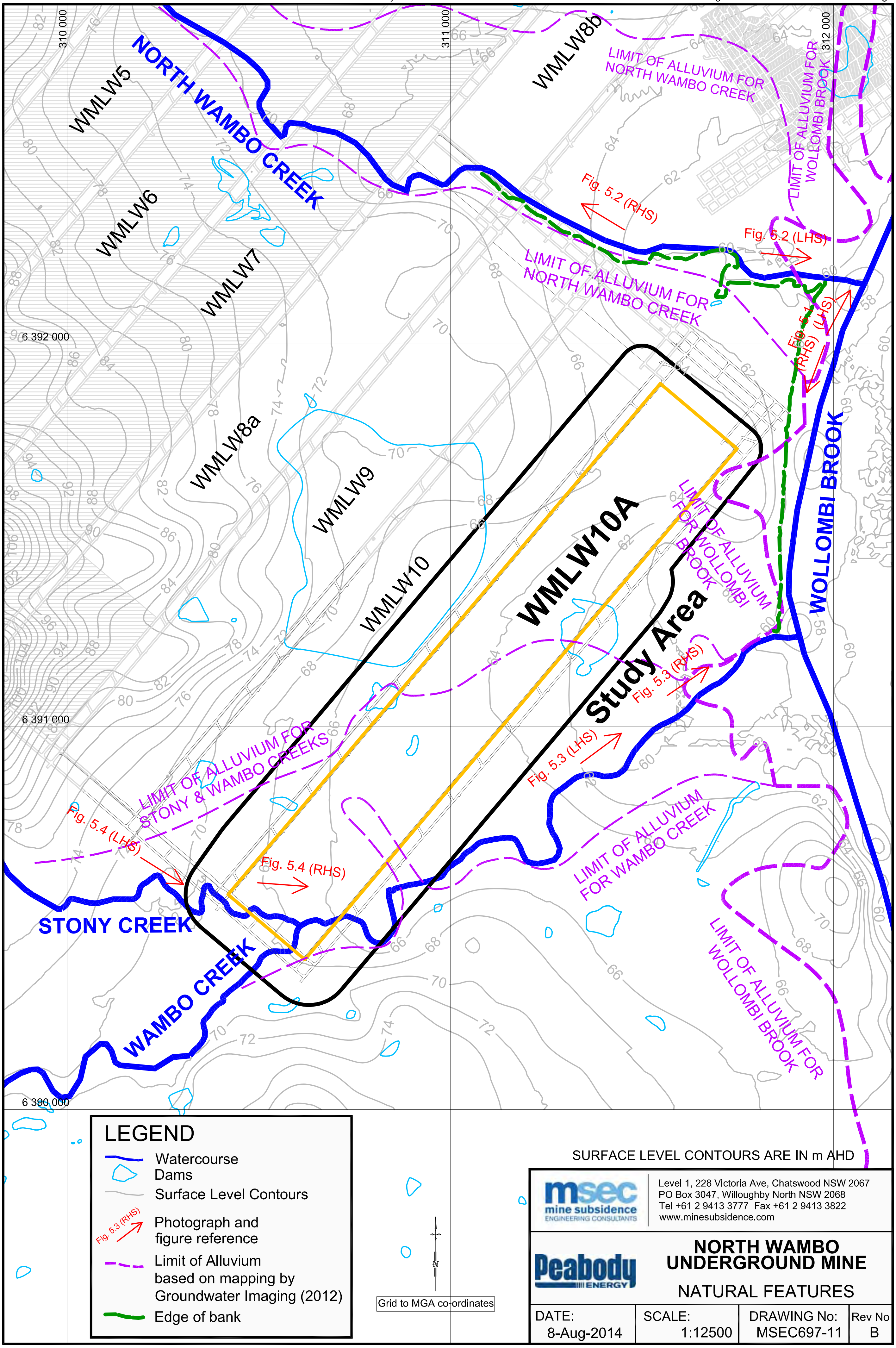

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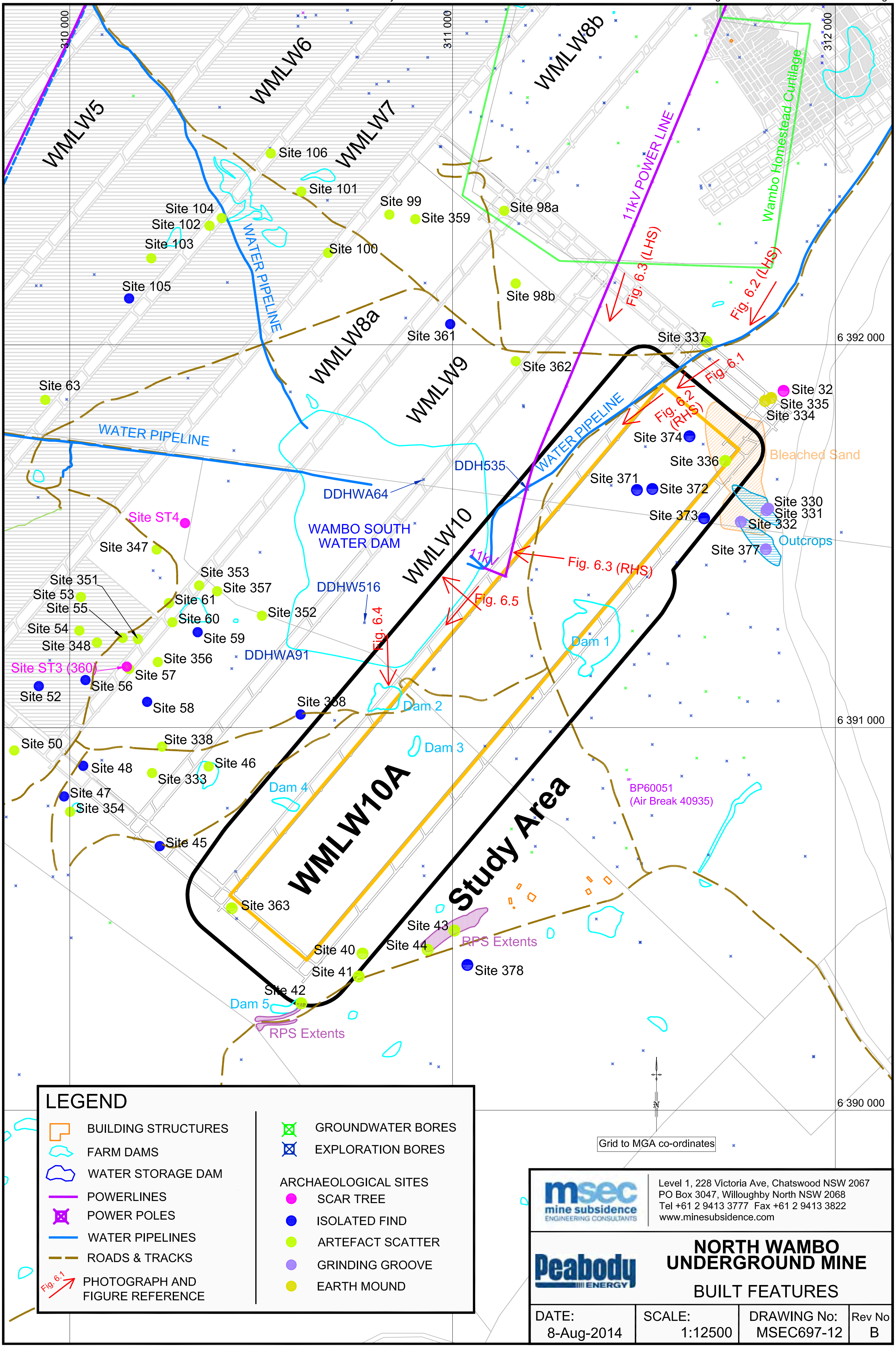

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NORTH WAMBO UNDERGROUND MINE

BUILT FEATURES

DATE:	SCALE:	DRAWING No:	Rev No
8-Aug-2014	1:12500	MSEC697-12	B

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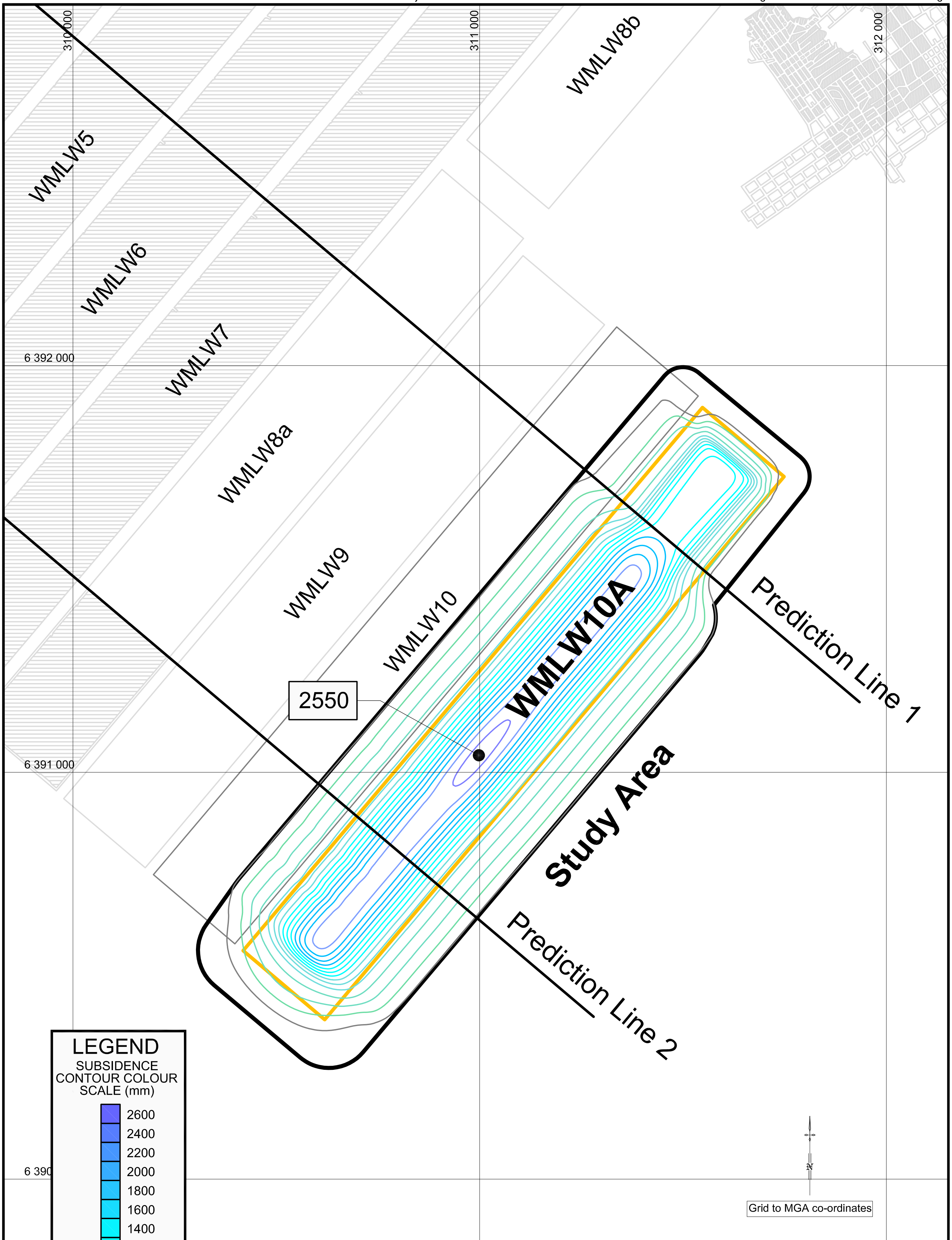

LEGEND
SUBSIDENCE CONTOUR COLOUR SCALE (mm)

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

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. (2400)

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NORTH WAMBO UNDERGROUND MINE

PREDICTED INCREMENTAL CONTOURS BASED ON WMLW10A

DATE:	SCALE:	DRAWING No:	Rev No
8-Aug-2014	1:12500	MSEC697-13	B

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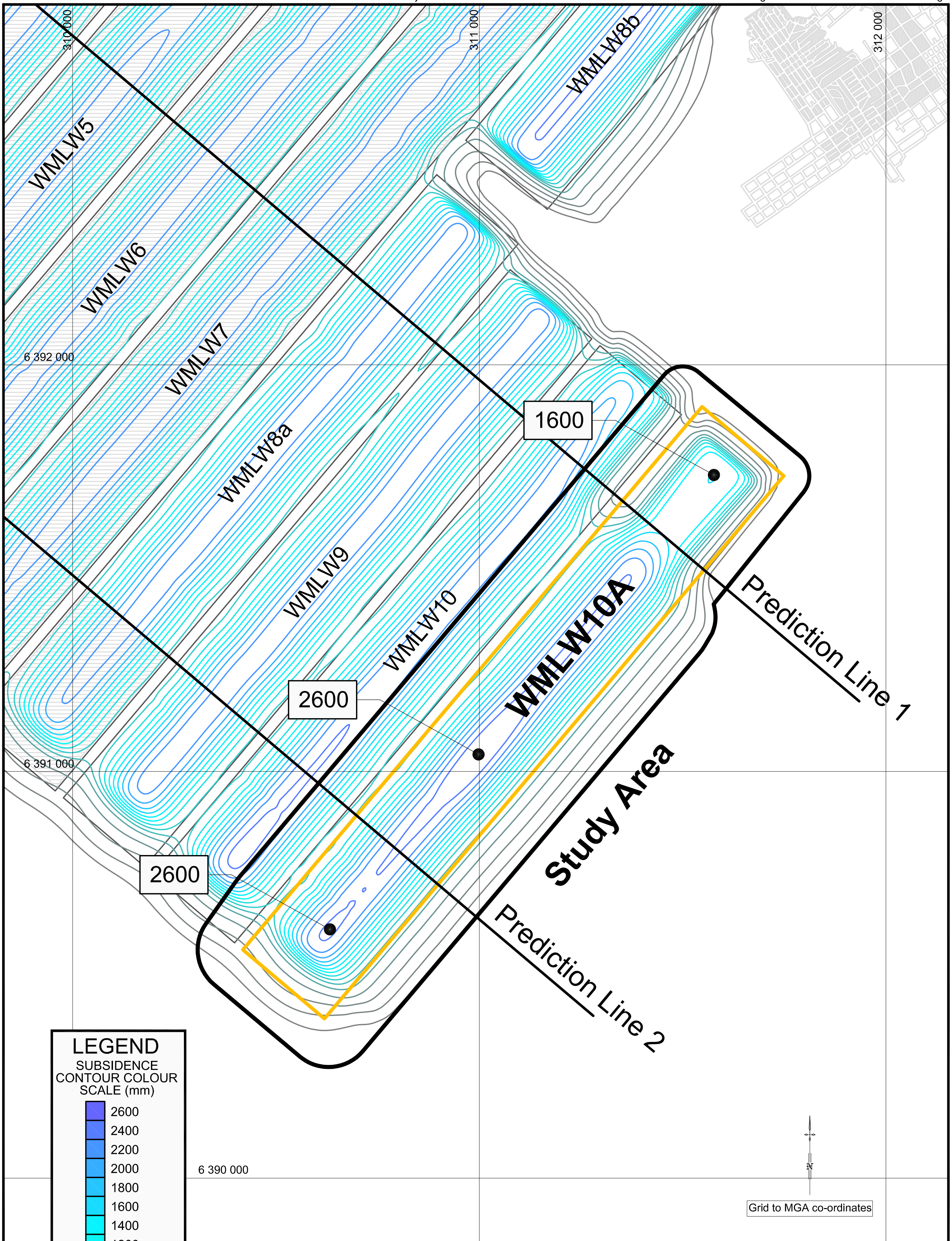

LEGEND

SUBSIDENCE CONTOUR COLOUR SCALE (mm)

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

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. (2400)

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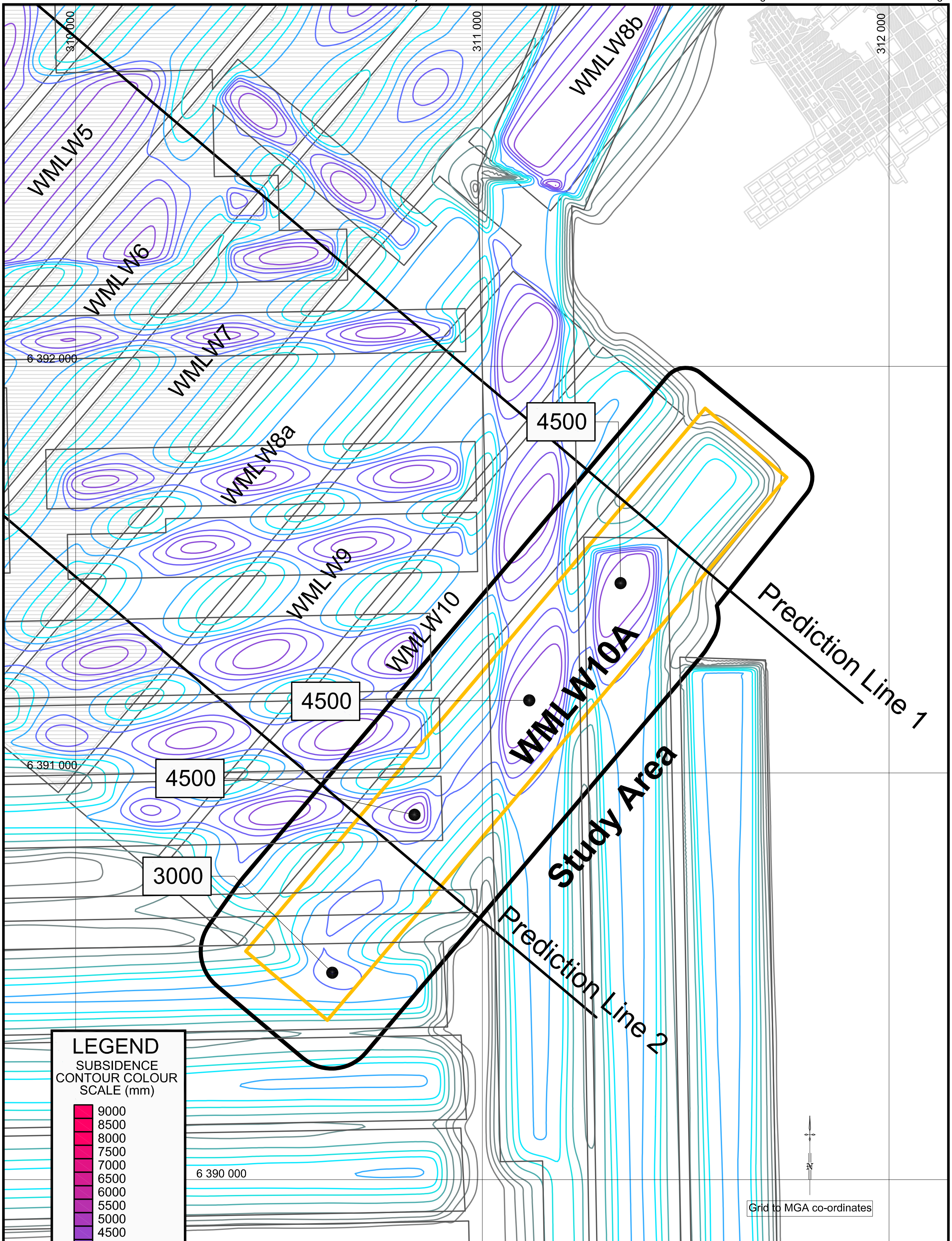
NORTH WAMBO UNDERGROUND MINE

PREDICTED TOTAL CONTOURS BASED ON WMLW1 - WMLW10A

DATE:	SCALE:	DRAWING No:	Rev No
8-Aug-2014	1:12500	MSEC697-14	B

I:\Projects\Wambo\MSEC697 - North Wambo - Modification for Inclusion of Longwall 10A\AcadData\MSEC697-15.dwg



LEGEND

SUBSIDENCE CONTOUR COLOUR SCALE (mm)

9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
200
100
50
20

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. (4000)

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NORTH WAMBO UNDERGROUND MINE

PREDICTED TOTAL CONTOURS BASED ON WHYBROW & WAMBO WORKINGS

DATE:	SCALE:	DRAWING No:	Rev No
8-Aug-2014	1:12500	MSEC697-15	B

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