WAMBO COAL PTY LIMITED

SOUTH BATES EXTENSION UNDERGROUND MINE

EXTRACTION PLAN
LONGWALLS 24 TO 26

REPORT 1
SUBSIDENCE PREDICTIONS AND IMPACT ASSESSMENTS

Peabody

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mine subsidence
ENGINEERING CONSULTANTS

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WAMBO COAL:

South Bates Extension Underground Mine Longwalls 24 to 26 Extraction Plan Subsidence Assessment

Subsidence Predictions and Impact Assessments for the Natural and Built Features
in Support of the Extraction Plan Application for the South Bates Extension Underground Mine
Longwalls 24-26 in the Whybrow Seam

Revision	Description	Author	Checker	Date
01	Draft issue	JB	-	28 Mar 23
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A	Final issue	JB	KK	31 May 23

Report produced to: Support the Extraction Plan Application for the South Bates Extension Longwalls 24-26 in the Whybrow Seam

Previous reports: Report No. MSEC1224 (Rev. A) – South Bates Extension Underground Mine Longwalls 24 to 26 – Modification Subsidence Assessment Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Modification Application for the South Bates Extension Underground Mine Longwalls 24-26 Modification, dated 21 June 2022.

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

Introduction to Longwall Mining and Subsidence (Revision A)

General Discussion of Mine Subsidence Ground Movements (Revision A)

Mine Subsidence Damage to Building Structures (Revision A)

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

Wambo Coal Pty Limited (WCPL) operates the Wambo Coal Mine, which is located in the Hunter Coalfield of New South Wales. The mine was approved under Part 4 of the *Environmental Planning and Assessment Act 1979*, in February 2004, which included the extraction of longwalls in the Whybrow, Wambo, Woodlands Hill and Arrowfield Seams.

The Development Consent (DA 305-7-2003, as modified) allows for the extraction of Longwalls 17 to 26 in the Whybrow Seam (WYLW17 to WYLW26) at the South Bates Extension Underground Mine (SBEUM) mining area of the Wambo Coal Mine.

The SBEUM was originally approved as part of the separate South Bates Extension Modification Application (MOD 17) in 2017. A subsequent Modification Application (MOD 19) was submitted in 2022 to allow for the re-orientation of WYLW24 and WYLW25 and the addition of WYLW26 on the north-western side of the SBEUM mining area. Mine Subsidence Engineering Consultants (MSEC) prepared Report No. MSEC1224 (Rev. A) in support of the Modification Application (MOD 19).

WCPL is preparing an Extraction Plan Application for WYLW24 to WYLW26 at the SBEUM. The layout of these longwalls is the same as that adopted in the Modification Application (MOD 19) and Report No. MSEC1224 apart from the finishing (i.e. southern) end of WYLW24 being shortened by approximately 40 m. There are no other changes to these longwalls.

The predicted subsidence effects for WYLW24 to WYLW26 have been determined using the Incremental Profile Method. The maximum predicted subsidence effects these longwalls are the same as or slightly less than those presented in the Modification Application (MOD 19) and Report No. MSEC1224.

The maximum predicted subsidence effects for WYLW24 to WYLW26 are 1950 mm vertical subsidence (i.e. 65 % of the maximum extraction height of 3.0 m), 75 mm/m tilt (i.e. 7.5 % or 1 in 13) and greater than 3.0 km^{-1} curvature (i.e. a minimum radius of curvature less than 0.3 km). The maximum predicted subsidence effects occur in the eastern part of the SBEUM mining area where the depths of cover are the shallowest.

The Study Area has been defined as the surface area enclosed by the greater of the 26.5° angle of draw line from the extents of WYLW24 to WYLW26 and the predicted total 20 mm subsidence contour due to the mining these longwalls. Other features which could be subjected to far-field or valley-related movements and could be sensitive to such effects have also been assessed in this report.

Several natural and built features have been identified within or near the Study Area including: North Wambo Creek, Waterfall Creek, ephemeral drainage lines, cliffs associated with the Wollemi Escarpment, minor cliffs and pagodas, steep slopes, the Wollemi National Park, unsealed tracks and trails, farm dams, the Montrose Open Cut Pit, Aboriginal heritage sites, survey control marks and unused building structures.

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:

- North Wambo Creek crosses directly above the finishing (i.e. southern) ends of WYLW25 and WYLW26. The upper reaches (i.e. first and second order sections) of Waterfall Creek are located above the northern end of WYLW26 and the third order section is located at a minimum distance of 180 m north of the longwalls. There are also unnamed tributaries to North Wambo Creek and Waterfall Creek located across the mining area.

  The predicted subsidence effects for North Wambo Creek, Waterfall Creek and their tributaries based on the Extraction Plan Layout are the same as those based on the MOD 19 Layout. The assessed impacts for these streams therefore do not change.

  Ponding areas are predicted to develop along North Wambo Creek and its tributaries having depths up to approximately 1.5 m and overall lengths up to approximately 225 m. If adverse impacts were to develop due to the increased ponding, these could be remediated by locally re-grading the stream beds, so as to re-establish the natural gradients.

  Fracturing and compression heaving are expected to develop along the sections of the streams located directly above the mining area. The impacts are expected to be similar to those observed along the streams above the previously extracted WYLW11 to WYLW13 at the South Bates Underground Mine and WYLW17 to WYLW21 at the SBEUM. It may be necessary to remediate the larger surface deformations by infilling with surface soil or other suitable materials, or by locally regrading and recompacting the surface.

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- The Cliffs Associated with the Wollemi Escarpment are located outside the Study Area at a minimum distance of 760 m west of WYLW26. There are also other minor cliffs located at similar distances from these longwalls. Adverse impacts to the cliffs are not anticipated due to their distances from the mining area.

  Steep slopes are located above and near WYLW26 and to a lesser extent WYLW25. The predicted subsidence effects for the steep slopes based on the Extraction Plan Layout are the same as those based on the MOD 19 Layout. The assessed impacts for the steep slopes therefore do not change.

  Surface cracking and compression heaving could develop along the areas of the steep slopes that are located directly above the mining area. Impacts are not anticipated along the steep slopes located outside the mining area. Surface remediation might be required, including infilling of surface cracks with soil or other suitable materials, or by locally regrading and recompacting the surface.

- The Wollemi National Park is located outside and to the west of the mining area. The boundary of the National Park is at a minimum distance of 115 m west of WYLW26.

  The land within the National Park is predicted to experience less than 20 mm vertical subsidence and it is not expected to experience measurable conventional tilts, curvatures or strains. The National Park could experience low-level far-field horizontal movements; however, these bodily movements are not expected to be associated with any measurable strains. It is unlikely, therefore, that the Wollemi National Park would be adversely impacted by the vertical or far-field horizontal movements.

- There are unsealed tracks and trails located across the Study Area which are used for the mining operations and for firefighting activities. It is expected that these roads could be maintained in safe and serviceable conditions using normal road maintenance techniques.

- There are five farm dams located on WCPL owned land above WYLW24 to WYLW26. The predicted subsidence effects for the dams based on the Extraction Plan Layout are the same as those based on the MOD 19 Layout.

  Fracturing and buckling could occur in the uppermost bedrock beneath the farm dams, which could adversely affect the water holding capacities of the farm dams. 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.

- The mining related infrastructure within the Study Area includes the Montrose Open Cut Pit and exploration drill holes. It is recommended that a geotechnical assessment of the highwall be undertaken based on the effects of the existing/approved WYLW17 to WYLW23 and the proposed WYLW24 to WYLW26. It is also recommended that the exploration drill holes are capped (if not already done) prior to being directly mined beneath.

- There are 33 Aboriginal heritage sites that have been identified within the Study Area which all consist of open sites (artefacts or PAD). The predicted subsidence effects for these sites based on the Extraction Plan Layout are the same as those based on the MOD 19 Layout.

  Surface cracking could occur near the open sites that are located directly above the mining area. However, it is unlikely that the artefacts and PADs would be adversely impacted by the mining-induced surface cracking.

- There are two unused sheds located above the southern end of WYLW26. Adverse impacts are not anticipated. It is recommended that these sheds are visually monitored during active subsidence.

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.

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Tables

Table numbers are prefixed by the number of the chapter 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 E at the end of this report.

1.1. Background

Wambo Coal Pty Limited (WCPL) operates the Wambo Coal Mine, which is located in the Hunter Coalfield of New South Wales (NSW). The mine was approved under Part 4 of the *Environmental Planning and Assessment Act 1979*, in February 2004, and through subsequent modifications. WCPL has approval to extract longwalls in the Whybrow, Wambo, Woodlands Hill and Arrowfield Seams.

The Development Consent (DA 305-7-2003, as modified) allows for the extraction of Longwalls 17 to 26 in the Whybrow Seam (WYLW17 to WYLW26) at the South Bates Extension Underground Mine (SBEUM) mining area of the Wambo Coal Mine.

The SBEUM was originally approved as part of the separate South Bates Extension Modification Application (MOD 17) in 2017. A subsequent Modification Application (MOD 19) was submitted in 2022 to allow for the re-orientation of WYLW24 and WYLW25 and the addition of WYLW26 on the north-western side of the SBEUM mining area. Mine Subsidence Engineering Consultants (MSEC) prepared Report No. MSEC1224 (Rev. A) in support of the Modification Application (MOD 19).

The Minister for Planning approved the Modification of the Development Consent (DA 305-7-2003, MOD 19) on 25 January 2023. The layout of WYLW24 to WYLW26 adopted in the Modification Application (MOD 19) and Report No. MSEC1224 is referred to as the *MOD 19 Layout* in this report.

WCPL is preparing an Extraction Plan Application for WYLW24 to WYLW26 at the SBEUM. The layout of these longwalls is the same as that adopted in the Modification Application (MOD 19) and Report No. MSEC1224 apart from the finishing (i.e. southern) end of WYLW24 being shortened by approximately 40 m. There are no other changes to these longwalls.

The layout of the WYLW24 to WYLW26 adopted in the Extraction Application and Report No. MSEC1317 is referred to as the *Extraction Plan Layout* in this report.

MSEC has been engaged by WCPL to:

- provide subsidence predictions for WYLW24 to WYLW26 based on the Extraction Plan Layout including the cumulative subsidence due to the adjacent existing/approved longwalls;
- compare the predictions with the values presented in the Modification Application (MOD 19) and Report No. MSEC1224;
- update the subsidence predictions for the natural and built features located above and near the SBEUM mining area;
- review and update the impact assessments, in conjunction with other specialist consultants, for each of these natural and built features; and
- recommend management strategies and monitoring.

This report has been prepared to support the Extraction Plan Application for WYLW24 to WYLW26 at the SBEUM which will be submitted to the Department of Planning and Environment (DPE).

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

Chapter 3 provides an overview of the methods that have been used to predict the subsidence effects due to the mining of the Extraction Plan Layout.

Chapter 4 provides the maximum predicted subsidence effects due to the mining of the Extraction Plan 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.

1.2. Mining geometry

The layout of WYLW24 to WYLW26 based on the Extraction Plan Layout is the same as that based on the MOD 19 Layout apart from the finishing (i.e. southern) end of WYLW24 being shortened by approximately 40 m.

A summary of the dimensions for WYLW24 to WYLW26 based on the Extraction Plan Layout is provided in Table 1.1.

Table 1.1   Geometry of WYLW24 to WYLW26 based on the Extraction Plan Layout

Layout	Longwall	Overall void length including installation heading (m)	Overall void width including first workings (m)	Overall tailgate chain pillar width (m)
Extraction Plan Layout (MSEC1317)	WYLW24	1540	262	-
	WYLW25	1585	262	25
	WYLW26	1505	262	25

The lengths of longwall extraction (i.e. excluding the installation headings) are approximately 9 m less than the overall void lengths provided in the above table. The widths of the longwall extraction faces (i.e. excluding the first workings) are 250 m. The longwalls will be extracted from the north towards the south, i.e. retreat mining towards the main headings.

1.3. Surface and seam levels

The levels of the natural surface and the Whybrow Seam are illustrated along Sections A and B in Fig. 1.1 to Fig. 1.2 below. The locations of these sections are shown in Drawings Nos. MSEC1317-03 to MSEC1317-06. The existing/approved WYLW17 to WYLW23 are shown as the cyan outlines and the future WYLW24 to WYLW26 are shown as the blue outlines.
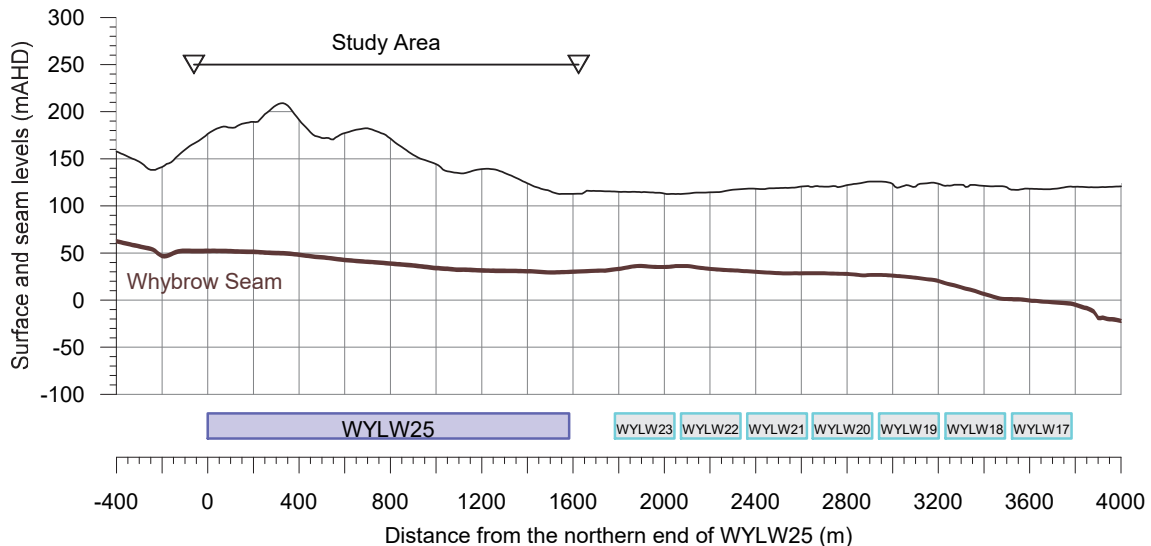
Fig. 1.1   Surface and seam levels along Section A along the centreline of WYLW25 and across WYLW17 to WYLW23
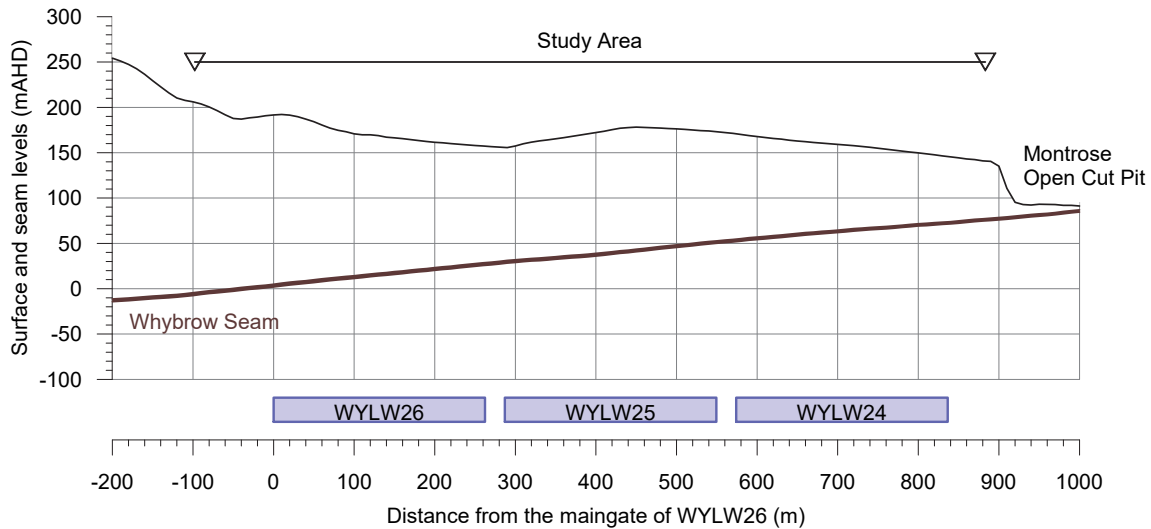
Fig. 1.2 Surface and seam levels along Section B across WYLW24 to WYLW26

The surface level contours are shown in Drawing No. MSEC1317-03. The major natural topographical feature in the area is the Wollemi Escarpment which is located south-west of the SBEUM mining area. Ridgelines cross directly above the existing WYLW17, WYLW18 and WYLW20 and above the proposed WYLW26. The Montrose Open Cut Pit is located north-east of the SBEUM mining area.

The surface levels directly above WYLW24 to WYLW26 vary from a high point of 250 m above Australian Height Datum (mAHD) above the northern end of WYLW26 to a low point of 115 mAHD above the finishing (i.e. southern) ends of WYLW25 and WYLW26. The high point occurs where the ridgeline crosses above WYLW26 and the low points occur along North Wambo Creek.

The seam floor contours, seam thickness contours and depth of cover contours for the Whybrow Seam are shown in Drawings Nos. MSEC1317-04, MSEC1317-05, and MSEC1317-06, respectively. The contours are based on the latest seam information provided by WCPL.

The depths of cover to the Whybrow Seam directly above WYLW24 to WYLW26 vary between a minimum of 60 m above the tailgate of WYLW24 and a maximum of 240 m above the maingate of WYLW26. The shallowest depth of cover occurs along a tributary that crosses WYLW24 and the greatest depth of cover occurs where the ridgeline crosses WYLW26.

The seam floor within the SBEUM mining area generally dips from the north-east towards the south-west. The seam is shallowest and is exposed within the Montrose Open Cut Pit and deepest beneath the Wollemi Escarpment. The average dip of the seam within the extents of WYLW24 to WYLW26 is approximately 8 % or 1 in 12.

The thickness of the Whybrow Seam within the extents of WYLW24 to WYLW26 varies between 2.5 m and 3.5 m. The mining heights for the longwalls are illustrated in Drawing No. MSEC1317-05 and they vary from less than 2.8 up to 3.0 m.

1.4. Geological details

The SBEUM 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 (DMR) *Hunter Coalfield Regional 1:100 000 Geology Map*, is shown in Table 1.2 (DMR, 1993).

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	

The Whybrow Seam lies within the Jerrys Plains Subgroup of the Wittingham Coal Measures. The rocks of the Wittingham Coal Measures mainly comprise frequently interbedded sandstones and siltstones, but also include isolated thinner beds of conglomerate and tuff. The formations are generally less than 10 m 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 Appletree Flat, Horseshoe Creek, Doyles Creek and Glen Gallic Subgroups.

WCPL provided the logs for typical drill holes located within the SBEUM mining area, the locations of which are shown in Drawing No. MSEC1317-09. The geological sections for drill hole UG139 (above the existing/approved WYLW21) and drill hole UG242 (above the future WYLW26) are provided in Table 1.3 and Table 1.4, respectively.

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Table 1.3　Geological section of Drill Hole UG139

Depth (m)	Thickness (m)	Lithology
0 ~ 0.5	0.5	Soil
0.5 ~ 9	8.5	Clay
9 ~ 15.5	6.5	Sandstone
15.5 ~ 17	1.5	Siltstone
17 ~ 18	1	Sandstone
18 ~ 20	2	Sandstone (70 %) and Siltstone (30 %)
20 ~ 21	1	Sandstone (70 %) and Claystone (30 %)
21 ~ 22.5	1.5	Claystone
22.5 ~ 24	1.5	Sandstone (70 %) and Siltstone (30 %)
24 ~ 25	1	Sandstone
25 ~ 26	1	Claystone
26 ~ 49	23	Sandstone
49 ~ 54	5	Sandstone (80 %) and Siltstone (20 %)
54 ~ 57	3	Sandstone
57 ~ 62	5	Siltstone (70 %) and Sandstone (30 %)
62 ~ 64	2	Siltstone
64 ~ 81	17	Sandstone
81 ~ 82	1	Siltstone
82 ~ 87	5	Siltstone (80 %) and Sandstone (20 %)
87 ~ 88.5	1.5	Siltstone
88.5 ~ 110.5	22	Claystone
110.5 ~ 113	2.5	Coal (Whybrow Seam)
113 ~ 114	1	Claystone
114 ~ 115	1	Sandstone (70 %) and Claystone (30 %)
115 ~ 116	1	Sandstone (50 %) and Siderite (50 %)
116 ~ 117	1	Sandstone
117 ~ 122	5	Sandstone (70 %) and Siltstone (30 %)
122 ~ 127	5	Sandstone
127 ~ 130	3	Whybrow Seam

Table 1.4   Geological section of Drill Hole UG242

Depth (m)	Thickness (m)	Lithology
0 ~ 5	5	Clay
5 ~ 6	1	Sandstone
6 ~ 13	7	Siltstone
13 ~ 21	8	Sandstone
21 ~ 24	3	Siltstone
24 ~ 25	1	Sandstone
25 ~ 28	3	Tuff and Coal
28 ~ 36	8	Siltstone with Claystone bands
36 ~ 39	3	Sandstone
39 ~ 42	3	Siltstone
42 ~ 43	1	Coal
43 ~ 50	7	Sandstone
50 ~ 53	3	Siltstone
53 ~ 55	2	Sandstone
55 ~ 57	2	Tuff
57 ~ 58	1	Coal
58 ~ 61	3	Siltstone with Claystone bands
61 ~ 62	1	Coal
62 ~ 69	7	Interbedded Sandstone and Siltstone
69 ~ 70	1	Tuff and Coal
70 ~ 71	1	Sandstone
71 ~ 72	1	Coal
72 ~ 77	5	Sandstone
77 ~ 78	1	Siltstone and Coal
78 ~ 92	14	Conglomerate
92 ~ 95	3	Sandstone
95 ~ 97	2	Siltstone
97 ~ 98	1	Tuff
98 ~ 107	9	Siltstone (60 %) and Sandstone (40 %)
107 ~ 124	17	Sandstone
124 ~ 164	40	Siltstone
164 ~ 165	1	Sandstone
165 ~ 167	2	Siltstone
167 ~ 170	3	Whybrow Seam

The overburden of the Whybrow Seam predominately comprises of interbedded sandstone and siltstone layers, with minor claystone, mudstone, shale, tuffaceous and coal layers. The immediate roof of the Whybrow Seam above the existing longwalls (i.e. drill hole UG139) comprises a 22 m thick claystone layer and above the future WYLW24 to WYLW26 (i.e. drill hole UG242) comprises predominately siltstone with sandstone bands. The immediate floor of the seam comprises interbedded claystone, sandstone, siderite and siltstone.

There are no massive sandstone or conglomerate units within the overburden. The largest unit above the existing longwalls (i.e. drill hole UG139) is the 17 m thick sandstone layer located approximately 30 m above the Whybrow Seam. The largest units above the future WYLW24 to WYLW26 (i.e. drill hole UG242) are the 17 m sandstone layer and 14 m conglomerate layer located approximately 43 m and 75 m, respectively, above the Whybrow Seam. There is a 40 m thick siltstone layer located approximately 3 m above the Whybrow Seam.

Otherwise, the thicknesses of the formations within the overburden are typically less than 10 m. Other boreholes in the vicinity of the modified SBEUM mining area indicate the presence of other larger sandstone units with thicknesses up to 20 m in the lower part of the overburden.

No adjustment factors have been applied in the subsidence prediction model for any massive strata units or for softer floor conditions, as the existing/approved and modified longwalls are supercritical in width and, therefore, they are predicted to achieve the maximum subsidence for single-seam mining conditions.

The geological features that have been identified at seam level are shown in Drawing No. MSEC1317-07.

The largest structure in the area is the *Redmanvale Fault* which is located south-west of the SBEUM mining area. The fault is located more than 1 km from WYLW26 at its closest point to the proposed longwalls. At this distance, the Redmanvale Fault is not expected to affect the predicted subsidence effects or increased potential for adverse impacts.

There are ENE-WSW orientated faults and dykes that cross the middle of WYLW24 to WYLW26. The geological structures within the mining area will be better defined through ongoing investigations and the development of first workings.

No adjustment factors have been applied in the subsidence prediction model for the minor faults and dykes within the SBEUM mining area, as the longwalls are generally supercritical in width and, therefore, they are predicted to achieve the maximum subsidence for single-seam mining conditions. Increased subsidence has not been observed in the locations of similar minor faults during the mining of longwalls at the South Bates Underground Mine and the SBEUM.

The surface lithology in the area can be seen in Fig. 1.3, which shows the longwalls and the Study Area overlaid on *Geological Map of Doyles Creek 9032-1-N*, which was published by the DMR (1988).
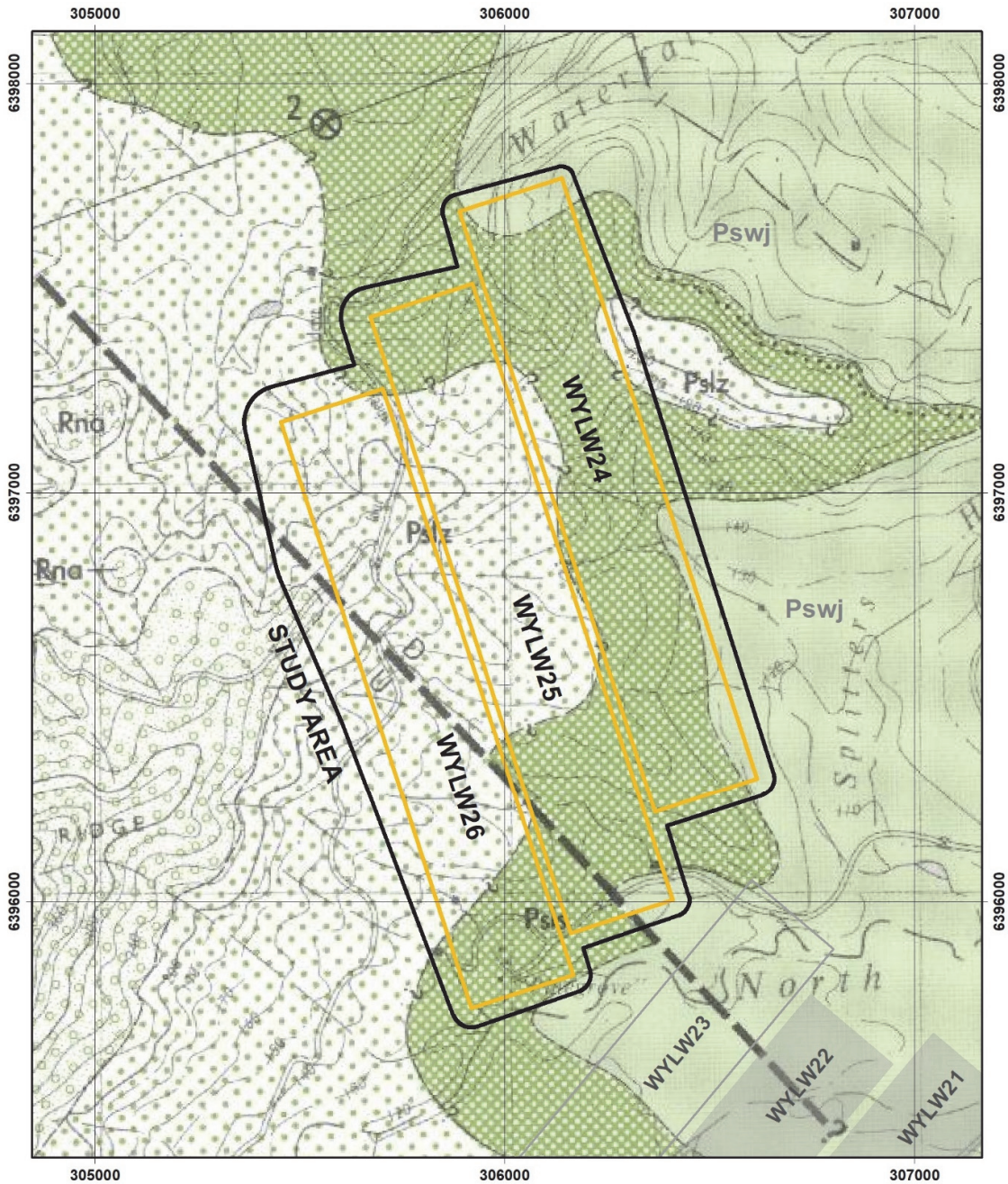
Fig. 1.3   WYLW21 to WYLW24 overlaid on Geological Map Doyles Creek 9032-1-N

The surface lithology generally comprises the Newcastle Coal Measures (Pslz) above the western part of the mining area transitioning to the Watts Sandstone (Psls) and then the Jerrys Plains Subgroup of the Wittingham Coal Measures (Pswj) above the eastern part of the mining area.

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2.1. Definition of the Study Area

The Study Area for this assessment is defined as the surface area that is likely to be affected by the mining of WYLW24 to WYLW26 in the Whybrow Seam. The extent of the Study Area has been calculated by combining the areas bounded by the following limits:

- the 26.5° angle of draw lines from the extents of WYLW24 to WYLW26 based on the Extraction Plan Layout; and

- the predicted limit of vertical subsidence, taken as the 20 mm subsidence contour due to the mining of WYLW24 to WYLW26 based on the Extraction Plan Layout.

The 26.5° 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 depths of cover contours for the Whybrow Seam are shown in Drawing No. MSEC1317-06. As shown in that drawing, the depths of cover directly above WYLW24 to WYLW26 vary between 60 m and 240 m. The 26.5° angle of draw line, therefore, has been determined by drawing a line that is a horizontal distance varying between 30 m and 120 m around the limits of the secondary extraction.

The predicted limit of vertical subsidence, taken as the predicted 20 mm subsidence contour, has been determined using the Incremental Profile Method (IPM) which is described in Chapter 3. The predicted 20 mm subsidence contour based on the Extraction Plan Layout is located inside the combined 26.5° angle of draw.

A line has therefore been drawn defining the Study Area, based upon the 26.5° angle of draw, and it is shown in Drawings Nos. MSEC1317-01 to MSEC1317-09.

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

2.2. Overview of the natural and built features within the Study Area

A number of the natural and built features within the Study Area can be seen in the 1:25,000 Topographic Map of the area, published by the Central Mapping Authority (CMA), numbered *Doyles Creek 9032-1-N*. The longwalls and the Study Area have been overlaid on an extract of this CMA map in Fig. 2.1.
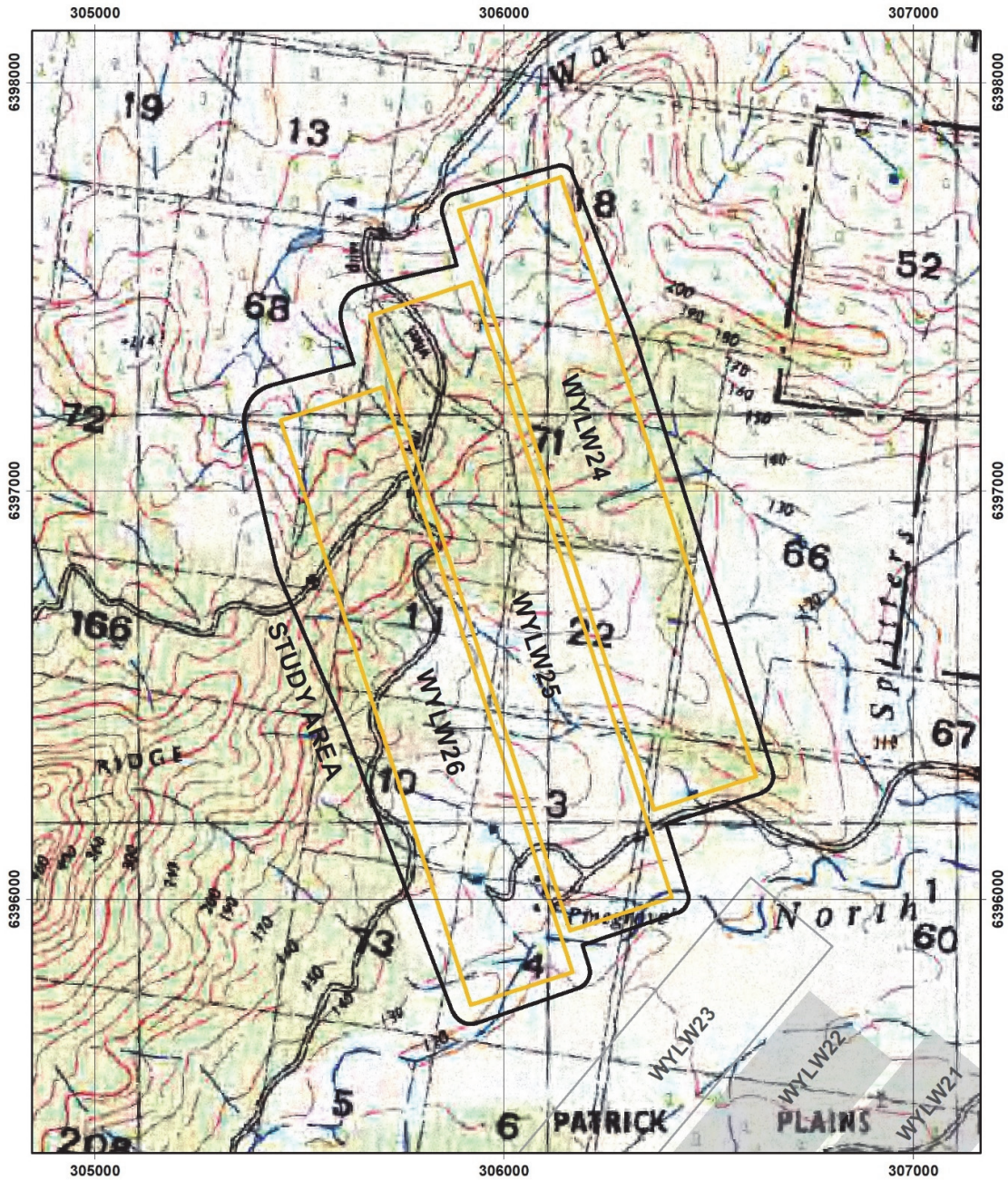
Fig. 2.1   WYLW17 to WYLW26 overlaid on CMA Map No. Doyles Creek 9032-1-N

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. MSEC1317-08 and MSEC1317-09. 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	Item	Within Study Area	Section Number
NATURAL FEATURES			**FARM LAND AND FACILITIES**		
Catchment Areas or Declared Special Areas	✗		Agricultural Utilisation or Agricultural Suitability of Farm Land	✗	6.4.1
Streams	✓	5.2	Farm Buildings or Sheds	✓	6.8
Aquifers or Known Groundwater Resources	✗		Tanks	✓	6.8
Springs or Groundwater Seeps	✗		Gas or Fuel Storages	✗	
Sea or Lake	✗		Poultry Sheds	✗	
Shorelines	✗		Glass Houses	✗	
Natural Dams	✗		Hydroponic Systems	✗	
Cliffs or Pagodas	✓	5.5 & 5.6	Irrigation Systems	✗	
Steep Slopes	✓	5.7	Fences	✓	6.4.2
Escarpments	✗	5.4	Farm Dams	✓	6.4.3
Land Prone to Flooding or Inundation	✓	5.8	Wells or Bores	✓	6.4.4
Swamps or Wetlands	✗		Any Other Farm Features	✗	
Water Related Ecosystems	✓	5.9			
Threatened or Protected Species	✓	5.10	**INDUSTRIAL, COMMERCIAL AND BUSINESS ESTABLISHMENTS**		
Lands Defined as Critical Habitat	✗		Factories	✗	
National Parks	✓	5.11	Workshops	✗	
State Forests	✗		Business or Commercial Establishments or Improvements	✗	
State Recreation or Conservation Areas	✗		Gas or Fuel Storages or Associated Plants	✗	
Natural Vegetation	✓	5.12	Waste Storages or Associated Plants	✗	
Areas of Significant Geological Interest	✗		Buildings, Equipment or Operations that are Sensitive to Surface Movements	✗	
Any Other Natural Features Considered Significant	✗		Surface Mining (Open Cut) Voids or Rehabilitated Areas	✓	6.5.1
			Mine Related Infrastructure Including Exploration Bores and Gas Wells	✓	6.5.2
PUBLIC UTILITIES			Any Other Industrial, Commercial or Business Features	✗	
Railways	✗				
Roads (All Types)	✓	6.2.1	**AREAS OF ARCHAEOLOGICAL SIGNIFICANCE**	✓	6.6
Bridges	✗				
Tunnels	✗		**AREAS OF HISTORICAL SIGNIFICANCE**	✗	
Culverts	✓	6.2.1			
Water, Gas or Sewerage Infrastructure	✗		**ITEMS OF ARCHITECTURAL SIGNIFICANCE**	✗	
Liquid Fuel Pipelines	✗				
Electricity Transmission Lines or Associated Plants	✗		**PERMANENT SURVEY CONTROL MARKS**	✓	6.7
Telecommunication Lines or Associated Plants	✗				
Water Tanks, Water or Sewage Treatment Works	✗		**RESIDENTIAL ESTABLISHMENTS**		
Dams, Reservoirs or Associated Works	✗		Houses	✗	
Air Strips	✗		Flats or Units	✗	
Any Other Public Utilities	✗		Caravan Parks	✗	
			Retirement or Aged Care Villages	✗	
PUBLIC AMENITIES			Associated Structures such as Workshops, Garages, On-Site Waste Water Systems, Water or Gas Tanks, Swimming Pools or Tennis Courts	✗	
Hospitals	✗		Any Other Residential Features	✗	
Places of Worship	✗				
Schools	✗		**ANY OTHER ITEM OF SIGNIFICANCE**	✗	
Shopping Centres	✗				
Community Centres	✗		**ANY KNOWN FUTURE DEVELOPMENTS**	✗	
Office Buildings	✗				
Swimming Pools	✗				
Bowling Greens	✗				
Ovals or Cricket Grounds	✗				
Race Courses	✗				
Golf Courses	✗				
Tennis Courts	✗				
Any Other Public Amenities	✗				

3.1.   Introduction

The following sections provide overviews of conventional and non-conventional mine subsidence effects and the methods that have been used to predict these movements. Further information is also provided in the background reports entitled *Introduction to Longwall Mining and Subsidence* and *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*.

3.2.   Overview of conventional subsidence effects

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.

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

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

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

3.3. Far-field movements

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

Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain. These movements generally do not result in impacts on natural features or built environments, except where they are experienced by large structures which are very sensitive to differential horizontal movements.

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

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

3.4. Overview of non-conventional subsidence movements

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

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

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

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

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

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

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 influence these irregular subsidence movements are the blocky nature of near-surface sedimentary strata layers and the presence of unknown faults, dykes or other geological structures, cross bedded strata, thin and brittle near-surface strata layers and pre-existing natural joints. The presence of these geological features near the surface can result in a bump in an otherwise smooth subsidence profile and these bumps are usually accompanied by locally increased tilts, curvatures and strains.

Even though it may be possible to explain most observed non-conventional ground movements, there remain some observed irregular ground movements that cannot be explained with available 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.

3.4.2. Non-conventional subsidence movements due to steep topography

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

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

3.4.3. Valley-related movements

The streams within the Study Area will be affected by valley-related movements, which are commonly observed in the Southern Coalfield, but less so in the Hunter and Newcastle Coalfields. Valley bulging movements are a natural phenomenon, resulting from the formation and ongoing development of the valley, as illustrated in Fig. 3.1. The potential for these natural movements is influenced by the geomorphology of the valley.
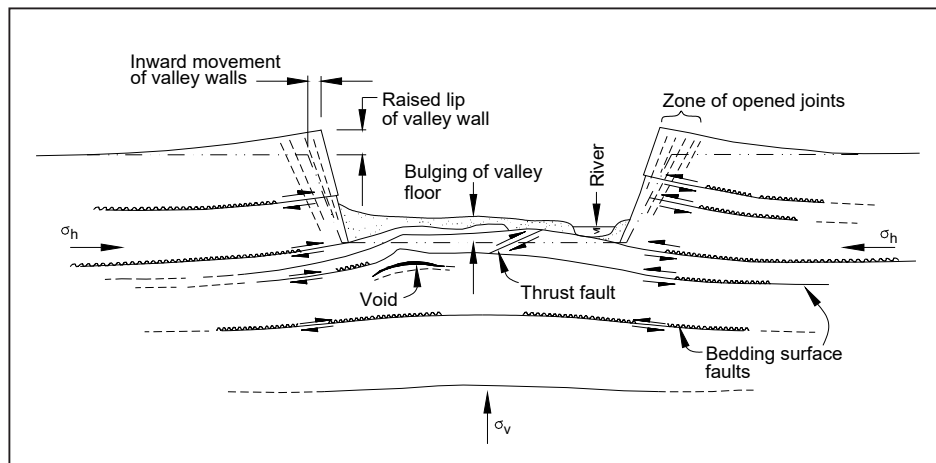
**Fig. 3.1   Valley formation in flat-lying sedimentary rocks
(after Patton and Hendren 1972)**

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

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

- **Closure** is the reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of *millimetres (mm)*, is the greatest reduction in horizontal distance between any two points on the opposing valley sides.

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

The predicted valley-related effects for the streams have been determined using the empirical method outlined in Australian Coal Association Research Program (ACARP) Research Project No. C9067 (Waddington and Kay, 2002), referred to as the 2002 ACARP method. The predicted compressive strains due to these valley-related effects have been determined from the analysis of ground monitoring data from the NSW coalfields.

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

3.5. The Incremental Profile Method

The Incremental Profile Method (IPM) was initially developed by Waddington Kay and Associates, now known as MSEC, as part of a study in 1994. 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 while the final subsidence profiles measured over a series of longwalls were irregular, the observed incremental subsidence profiles due to the mining 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, between 1996 and 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 mines in the Southern, Newcastle, Hunter and Western Coalfields of NSW and from the Bowen Basin in Queensland, including: Airly, 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, Western, Newcastle and Hunter Coalfields. The prediction curves can then be further refined, for the local geology and local conditions, based on the available monitoring data from the area. Discussions on the calibration of the IPM for the longwalls at the SBEUM are provided in Section 3.6.

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

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

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 longwalls at the SBEUM. The profile shapes can be further refined, based on local monitoring data, which is discussed further in Section 3.6.

Finally, the total subsidence profiles resulting from the series of longwalls are derived by adding the predicted incremental profiles from each of the longwalls. Comparisons of the predicted total subsidence profiles, obtained using the IPM, 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 monitoring data is available close to the mining area.

3.6.   Calibration of the IPM

There are no existing workings located above or below the longwalls at the SBEUM (i.e. single-seam mining conditions). The depths of cover to the Whybrow Seam directly above WYLW24 to WYLW26 vary between 60 m and 240 m. The depths of cover are shallowest above the eastern part of the mining area and are greatest above the western part of the mining area.

The longwall width-to-depth ratios vary between 1.1 in the western part of the mining area and greater than 4.0 in the eastern part of the mining area. The magnitudes of subsidence and the shapes of the subsidence profiles, therefore, will vary considerably over the lengths of these longwalls.

In the eastern part of the mining area, the width-to-depth ratios are greater than 1.4 and, therefore, the longwalls are supercritical in width. The maximum predicted subsidence is expected to be the maximum achievable in the Hunter Coalfield for single-seam mining conditions, which has been found to be 60 % to 65 % of the extracted seam thickness. It has been identified, however, that the measured subsidence varies greatly from point to point, at these very shallow depths of cover, as the result of variations in the overburden geology.

In the western part of the mining area, the width-to-depth ratios are less than 1.4 and, therefore, the longwalls are subcritical in width. As a result, the predicted subsidence is expected to be less than the maximum achievable in the Hunter Coalfield and, hence, less than that predicted in the eastern part of the mining area. Similarly, the predicted tilts, curvatures and strains in the western part of the mining area are less than those predicted in the eastern part of the mining area.

The IPM was previously calibrated to local conditions using ground monitoring data from the Wambo Coal Mine and from other nearby collieries. The available monitoring data included that from WYLW11 to WYLW13 (i.e. single-seam mining conditions) at the South Bates Underground Mine. The monitoring comprised three ground survey lines (7XL-Line, CL11B-Line and CL13B-Line) and LiDAR surveys. Comparisons between the measured and predicted movements for WYLW11 to WYLW13 are provided in the subsidence summary reviews in Reports Nos. MSEC866, MSEC886 and MSEC916.

Ground monitoring data have also been gathered during the mining of WYLW17 to WYLW21 at the SBEUM. The monitoring comprises two ground survey lines (8XL-Line and CL17B-Line) and Light Detecting and Ranging (LiDAR) surveys. Comparisons between the measured and predicted movements for WYLW17 to WYLW21 are provided in the subsidence summary review in Report Nos. MSEC1007, MSEC1135, MSEC1198 and MSEC1302.

The measured and predicted vertical subsidence for the combined 7XL-Line and 8XL-Line, due to the mining of WYLW11 to WYLW13 and WYLW17 to WYLW21, are illustrated in Fig. 3.2. The measured profile of vertical subsidence (i.e. green line) reasonably matches the predicted profile (i.e. red line).
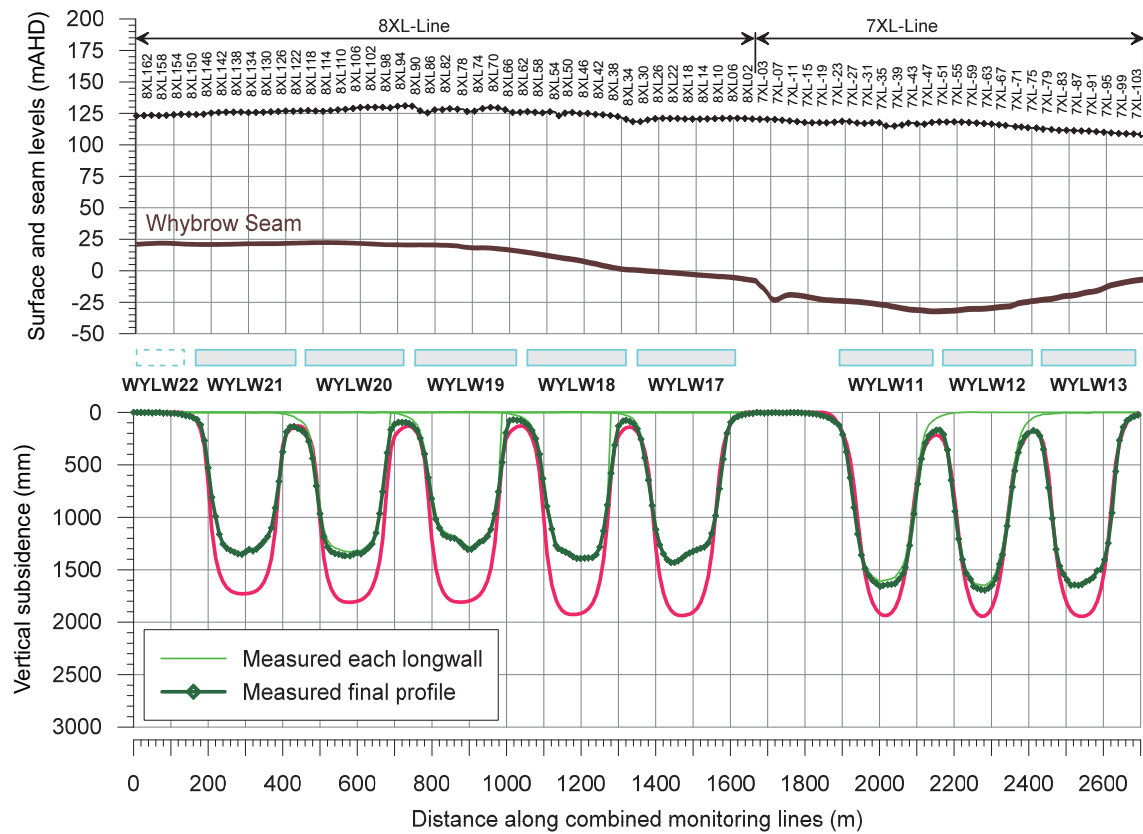
Fig. 3.2   Measured and predicted vertical subsidence along the 7XL-Line and 8XL-Line due to the mining of WYLW11 to WYLW13 at the South Bates Underground Mine and WYLW17 to WYLW21 at the South Bates Extension Underground Mine

The maximum measured values of vertical subsidence along the 7XL-Line and 8XL-Line are less than the maximum predicted values. The ratio of the maximum measured to maximum predicted vertical subsidence above each of the longwalls vary between 0.85 and 0.87 for WYLW11 to WYLW13 and between 0.72 and 0.79 for WYLW17 to WYLW21. The values of the measured vertical subsidence above the chain pillars are similar to the predicted values.

The measured profile of tilt (not shown) reasonably matches the predicted profile. The measured profile of curvature (also not shown) is irregular (i.e. more erratic) due to survey tolerance, localised irregular ground movements and possibly due to disturbed survey marks. The measured zones of hogging curvature and sagging curvature reasonably matched the predicted zones. The maximum measured tilt and curvatures are similar to the maximum predicted values.

The observations for the other ground monitoring lines above WYLW11 to WYLW13 and WYLW17 to WYLW21 are similar to that described above for the 7XL-Line and 8XL-Line. It is considered that the IPM provides predictions that are consistent with the measurements for these existing longwalls.

It is therefore not considered necessary to further calibrate the subsidence model for the proposed WYLW24 to WYLW26 based on the monitoring data for the Whybrow Seam.

4.1. Introduction

This chapter provides the maximum predicted conventional subsidence effects due to the mining of WYLW24 to WYLW26 based on the Extraction Plan Layout. The predicted subsidence effects and the impact assessments for the natural and built features are provided in Chapters 5 and 6.

The predicted values of vertical subsidence, tilt and curvature have been obtained using the standard IPM for the Hunter Coalfield, which is described in Section 3.6. The predicted strains have been determined by analysing the strains measured at the Wambo Coal Mine, and other NSW collieries, where the longwall width-to-depth ratios and extraction heights are similar to those for longwalls based on the Extraction Plan Layout.

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

4.2. Maximum predicted conventional subsidence, tilt and curvature

A summary of the maximum predicted values of incremental conventional vertical subsidence, tilt and curvature due to the mining of WYLW24 to WYLW26 is provided in Table 4.1. The incremental values represent the maximum predicted additional movements due to the mining of each of the longwalls based on the Extraction Plan Layout.

Table 4.1   Maximum predicted incremental vertical subsidence, tilt and curvature due to the mining of each of WYLW24 to WYLW26 based on the Extraction Plan Layout

Due to longwall	Maximum predicted incremental vertical subsidence (mm)	Maximum predicted incremental tilt (mm/m)	Maximum predicted incremental hogging curvature (km^{-1})	Maximum predicted incremental sagging curvature (km^{-1})
WYLW24	1850	70	> 3.0	> 3.0
WYLW25	1850	60	> 3.0	> 3.0
WYLW26	1850	60	> 3.0	> 3.0

The magnitudes of the predicted subsidence effects vary across the mining area due to the wide range of depths of cover above the Whybrow Seam. The maximum predicted subsidence effects occur above the eastern parts of WYLW24 to WYLW26, where the depths of cover are the shallowest.

The maximum predicted incremental curvatures for each of WYLW24 to WYLW26 are greater than 3.0 km^{-1} (i.e. minimum radius of curvature of less than 0.3 km). These curvatures are very localised and therefore do not necessarily represent the overall (i.e. macro) ground movements. The magnitudes of the localised curvatures greater than 3.0 km^{-1} become less meaningful and, therefore, the specific values have not been presented.

The predicted total vertical subsidence after the mining of each of WYLW24 to WYLW26 are shown in Drawings Nos. MSEC1317-10 to MSEC1317-12, respectively. The contours include the accumulated movements due to the mining of the existing/approved WYLW17 to WYLW23 and the future WYLW24 to WYLW26.

A summary of the maximum predicted values of total conventional vertical subsidence, tilt and curvature due to the mining of WYLW24 to WYLW26 is provided in Table 4.2. The total values represent the maximum predicted accumulated movements above the mining area based on the Extraction Plan Layout.

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Table 4.2   Maximum predicted total vertical subsidence, tilt and curvature due to the mining of the modified WYLW24 to WYLW26

After longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
WYLW24	1850	70	> 3.0	> 3.0
WYLW25	1950	75	> 3.0	> 3.0
WYLW26	1950	75	> 3.0	> 3.0

The maximum predicted total vertical subsidence is 1950 mm and it represents 65 % of the maximum mining height of 3.0 m. The maximum predicted subsidence movements occur above the eastern parts of WYLW24 to WYLW26, where the depths of cover are the shallowest.

The maximum predicted total tilt is 75 mm/m (i.e. 7.5 % or 1 in 13). The maximum predicted tilt occurs adjacent to the tailgate of WYLW24 where the depths of cover are the shallowest.

The maximum predicted total hogging and sagging curvatures are greater than 3.0 km^{-1} and they represent minimum radii of curvature of less than 0.3 km. The maximum curvatures are localised and therefore they do not necessarily represent the overall (i.e. macro) ground movements. The magnitudes of the localised curvatures greater than 3.0 km^{-1} become less meaningful and, therefore, the specific values have not been presented.

The predicted conventional subsidence effects vary across the mining area as the result of, amongst other factors, variations in the depths of cover and seam thickness. The predicted vertical subsidence varies between the western and eastern areas above WYLW24 to WYLW26, as shown in Drawings Nos. MSEC1317-10 to MSEC1317-12. It can also be inferred from the spacing of the contours shown in these drawings, that the predicted tilts and curvatures also vary over the lengths of the longwalls.

To illustrate this variation, the predicted profiles of vertical subsidence, tilt and curvature have been determined along three prediction lines. The predicted subsidence effects along Prediction Lines 1 to 3 are shown in Figs. C.01 to C.03, respectively, in Appendix C. The locations of these prediction lines are shown in Drawings Nos. MSEC1317-10 to MSEC1317-12.

4.3.   Comparison of the maximum predicted subsidence effects

The predicted subsidence effects for the MOD 19 Layout are provided in Report No. MSEC1224 which supported the Modification Application for WYLW24 to WYLW26.

A comparison of the maximum predicted total subsidence effects for the MOD 19 Layout and Extraction Plan Layout is provided in Table 4.3. The values represent the maximum predicted accumulated movements anywhere above the mining area.

Table 4.3   Comparison of maximum predicted total subsidence effects

Longwalls	Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
WYLW24 to WYLW26	MOD 19 Layout (MSEC1224)	1950	75	> 3.0	> 3.0
	Extraction Plan Layout (MSEC1317)	1950	75	> 3.0	> 3.0

The maximum predicted vertical subsidence and tilt for WYLW24 to WYLW26, based on the Extraction Plan Layout, are the same as the maximum predicted values based on the MOD 19 Layout. The predicted subsidence effects are the same as the longwall layout does not change apart from the finishing (i.e. southern) end of WYLW24 being shortened by approximately 40 m.

The maximum predicted total hogging and sagging curvatures are greater than 3.0 km^{-1} (i.e. minimum radius of curvature less than 0.3 km) based on both the MOD 19 Layout and Extraction Plan Layout. While specific values have not been presented, the maximum predicted curvatures do not change.

4.4.   Predicted strains

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

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 maximum 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. The maximum predicted strains, therefore, are greater than 30 mm/m above the longwall finishing ends.

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.

The range of strains above the longwalls at the SBEUM has been determined using monitoring data from the previously extracted longwalls in the Hunter and Newcastle Coalfields, where the mining geometry is reasonably similar to those at the SBEUM. The range of strains measured during the mining of these longwalls should, therefore, provide a reasonable indication of the range of potential strains for WYLW24 to WYLW26.

The data used in the analysis of measured strains included those resulting from both conventional and non-conventional anomalous movements, but does not include those resulting from valley-related effects, which are addressed separately in this report. The strains resulting from damaged or disturbed survey marks have also been excluded.

4.4.1.   Existing/approved WYLW17 to WYLW23

The predicted strains for WYLW17 to WYLW23 based on the MOD 19 Layout are provided in Report No. MSEC1224. The depths of cover above the longwall commencing (i.e. south-western) ends are considerably greater than the depths of cover above the longwall finishing (i.e. north-eastern) ends. The strains have therefore been provided separately for each end.

The depths of cover above the longwall commencing (i.e. south-western) ends are typically greater than 200 m. In these locations, the predicted strains are: 5 mm/m tensile and 4 mm/m compressive based on the 95 % confidence level; and 10 mm/m tensile and 7 mm/m compressive based on the 99 % confidence level.

The depths of cover above the longwall finishing (i.e. north-eastern) ends are typically less than 100 m. In these locations, the predicted strains are: 12 mm/m tensile and 17 mm/m compressive based on the 95 % confidence level; and greater than 28 mm/m tensile and greater than 30 mm/m compressive based on the 99 % confidence level.

4.4.2.   Proposed WYLW24 to WYLW26

The depths of cover above WYLW24 to WYLW26 vary between a minimum of 60 m above the tailgate of WYLW24 and a maximum of 240 m above the maingate of WYLW26. The average depths of cover above each of the longwalls are 90 m for WYLW24, 120 m for WYLW25 and 145 m for WYLW26.

The ranges of the depths of cover and seam thicknesses for WYLW24 to WYLW26 are the same as those for the existing/approved WYLW17 to WYLW23. Hence, it follows that, the range of predicted strains is also similar, as described in the previous section, where the depths of cover are less than 100 m and where the depths of cover are greater than 200 m.

msec

The depths of cover in the central part of WYLW24 to WYLW26 are typically between 100 m and 200 m and the corresponding longwall width-to-depth ratios vary between 1.3 and 2.6. The predicted strains for this area have been determined by analysing the measured ground strains for monitoring lines from the Hunter and Newcastle Coalfields, where the width-to-depth ratios are within this range. This should provide a reasonable indication of the range of potential strains in the central part of the SBEUM mining area above WYLW24 to WYLW26.

The available monitoring lines have been analysed to extract the maximum tensile and compressive strains that have been measured at any time during mining, for survey bays that were located directly above goaf or the chain pillars that are located between the extracted longwalls. Several 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.

Histograms of the maximum measured tensile and compressive strains for the survey bays located directly above goaf, for previously extracted longwalls in the Hunter and Newcastle Coalfields having width-to-depth ratios between 1.3 and 2.6, are provided in Fig. 4.1. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.
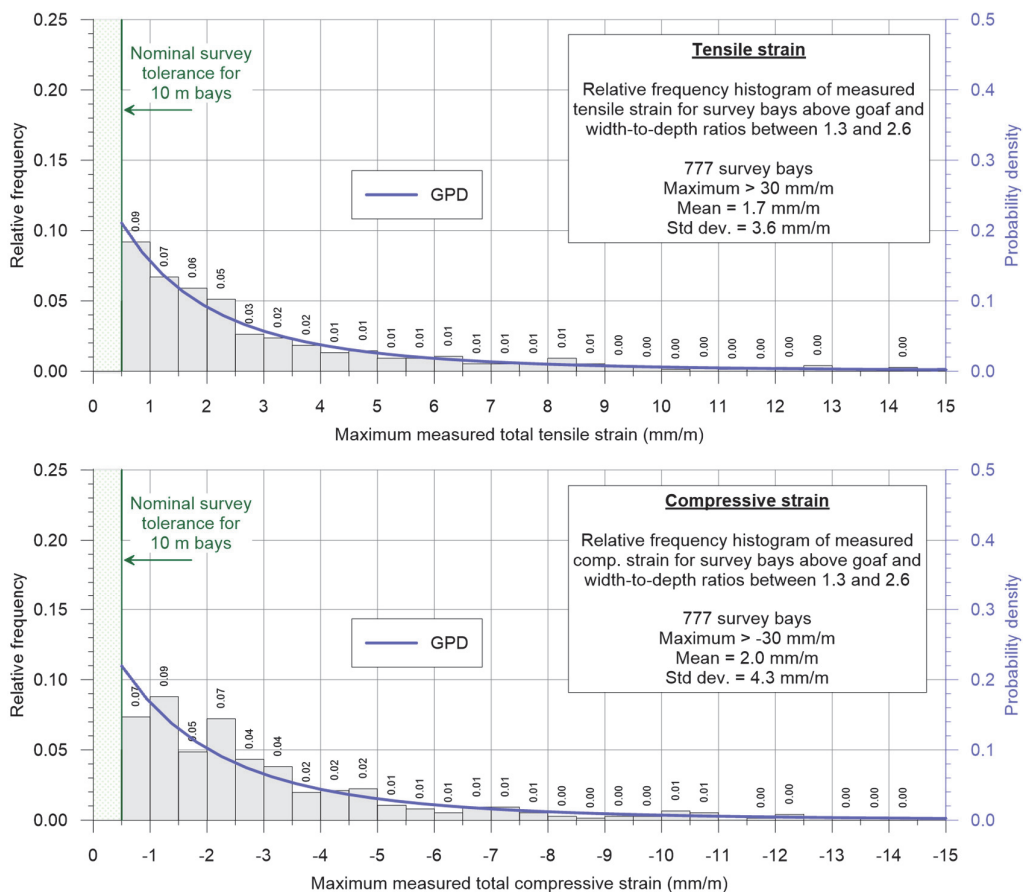
Fig. 4.1   Distributions of the measured maximum tensile and compressive strains for survey bays located above longwalls with width-to-depth ratios between 1.3 and 2.6

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 are 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 are 18 mm/m tensile and 19 mm/m compressive.

msec

A summary of the maximum predicted strains for the Extraction Plan Layout is provided in Table 4.4.

Table 4.4   Maximum predicted strains for the Extraction Plan Layout

Location	Maximum tensile strain (mm/m)		Maximum compressive strain (mm/m)	
	95 % CL	99 % CL	95 % CL	99 % CL
Higher depth of cover (greater than 200 m)	5	10	4	7
Intermediate depth of cover (100 m to 200 m)	8	18	9	19
Lower depth of cover (less than 100 m)	12	> 28	17	> 30

4.5.   Predicted far-field horizontal movements

In addition to the conventional subsidence movements that have been predicted above and adjacent to the SBEUM mining area, and the predicted valley-related effects along the streams, it is also likely that far-field horizontal movements will occur outside of the mining area.

An empirical database of measured incremental far-field horizontal movements has been compiled using monitoring data from the Southern and Western Coalfields. The far-field horizontal movements resulting from mining were generally orientated towards the mined panels. At very low levels of far-field horizontal movements; however, there was a high scatter in the orientation of the observed movements.

There is considerably less 3D monitoring data in the Hunter and Newcastle Coalfields that have stable base points and that extend well beyond the mining areas. Based on the available data, the extents of far-field horizontal movements measured in the Hunter Coalfield are less than those measured in the Southern and Western Coalfields. The reason is that the shallower depths of cover in the Hunter Coalfield result in greater movements above the mining areas but lesser movements outside the mining areas. The data from the Southern and Western Coalfields should therefore provide conservative predictions of the far-field horizontal movements for the Extraction Plan Layout.

The measured total far-field horizontal movements due to longwall mining in the Southern and Western Coalfields are shown in Fig. 4.2. The measured values (y-axis) are the accumulated movements due to the mining in each mining domain. The distances (x-axis) are those of the survey marks from the nearest longwall (active or completed) in the mining domain.

The distributions of far-field horizontal movements in the Southern and Western Coalfields are similar. Confidence levels have therefore been fitted to the data from both these coalfields, as illustrated in Fig. 4.2. The predicted far-field horizontal movement at a distance of 1 km outside the mining area is 80 mm based on the 95 % confidence level.

The Montrose Open Cut Pit is located to the north-east of WYLW24 to WYLW26 as shown in Drawing No. MSEC1317-01. The open cut pit has extracted the overburden material above the Whybrow Seam. The removal of this material would have relieved and redistributed much of the horizontal in situ stress in the overburden strata adjacent to the open cut pit. The potential for far-field horizontal movements in the vicinity of the Montrose Open Cut Pit, therefore, is reduced.

The far-field horizontal movements due to the mining of WYLW24 to WYLW26 are expected to be bodily (i.e. en masse) movements towards the mining area. These movements are associated with very low levels of strain (i.e. differential horizontal movements) that are generally in the order of survey tolerance (i.e. less than 0.3 mm/m).

The potential impacts of far-field horizontal movements on the natural and built features within the vicinity of the longwalls based on the Extraction Plan Layout are not expected to be significant.
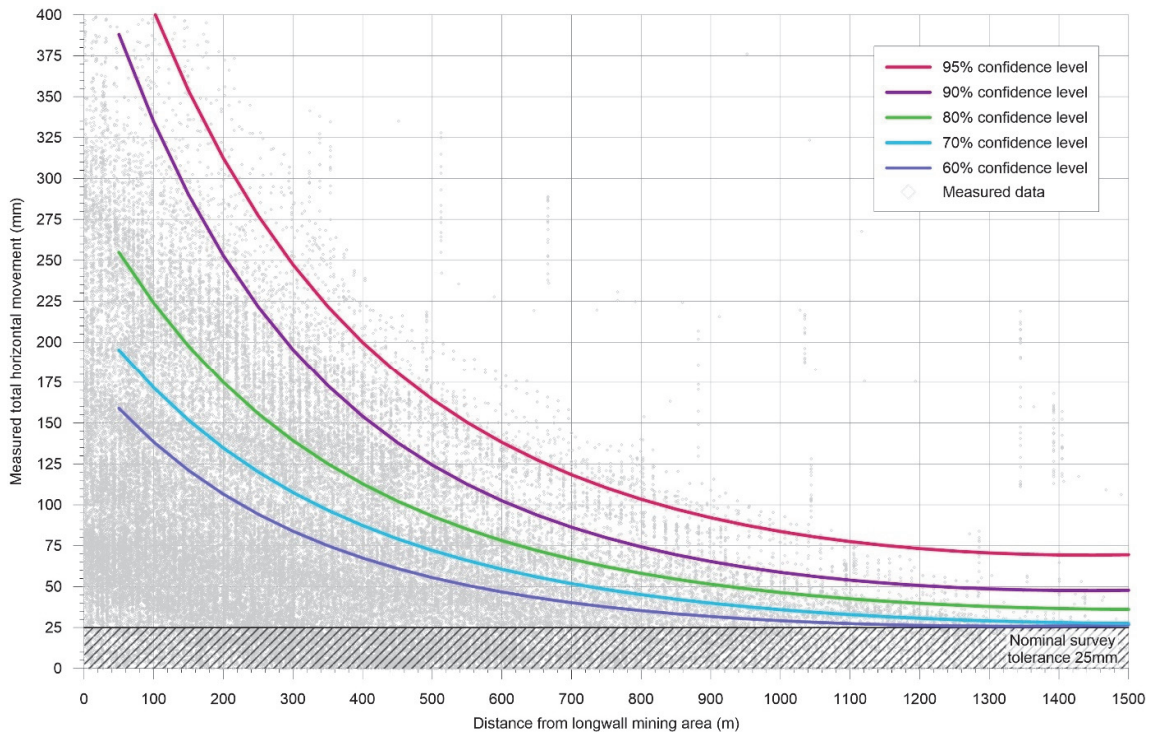
Fig. 4.2   Measured total far-field horizontal movements in the Southern and Western Coalfields

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, steep topography and shallow depths of cover, which are discussed in Section 3.4. These non-conventional movements are often accompanied by elevated tilts, curvatures and strains which are likely to exceed the conventional predictions.

Specific predictions of upsidence, closure and compressive strain due to the valley-related effects are provided for the streams in Section 5.2. The impact assessments for the streams are based on both the conventional and valley-related effects. The potential for non-conventional movements associated with steep topography is discussed in Section 5.7.

There are ENE-WSE orientated faults and dykes that cross the middle of WYLW24 to WYLW26. Increased subsidence is not anticipated as the longwalls are generally supercritical in width and, therefore, they are predicted to achieve the maximum subsidence for single-seam mining conditions. Increased subsidence has not been observed in the locations of similar minor faults during the mining of longwalls at the South Bates Underground Mine and the SBEUM.

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 are discussed in Section 4.4.

4.7.   Surface deformations

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

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

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

Fracturing of bedrock can also occur in the bases of stream valleys due to the compressive strains associated with valley-related upsidence and closure effects. The impact assessments for valley-related movements are provided in Section 5.2.

The surface deformations due to the mining of WYLW17 to WYLW21 have been recorded by WCPL and these were described in Reports Nos. MSEC1007, MSEC1135, MSEC1198 and MSEC1302. The locations of the mapped surface cracking due to the mining of the longwalls in the Whybrow Seam are shown in Fig. 4.3 (Source: WCPL).
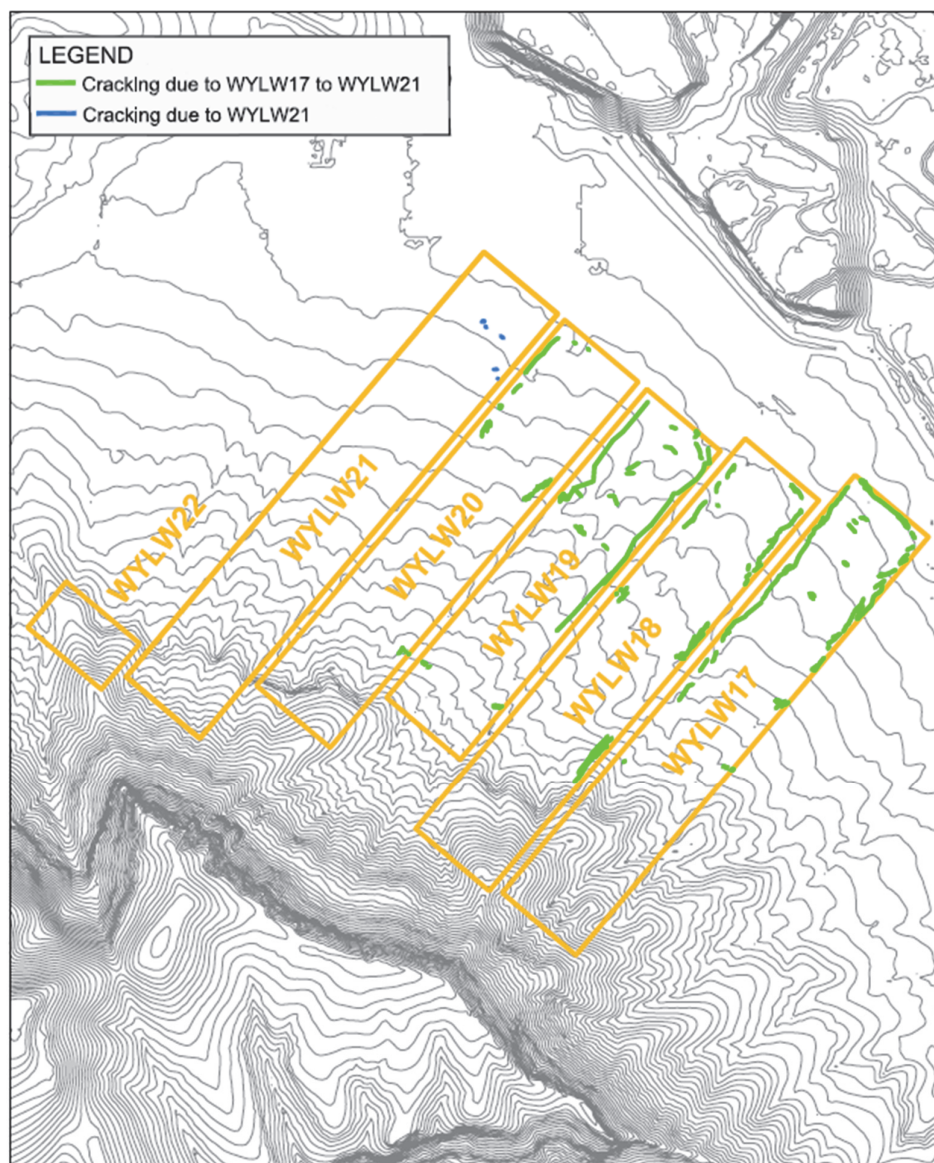
Fig. 4.3   Mapped surface cracking above WYLW17 to WYLW21

The largest surface deformations occurred adjacent to the maingates and tailgates, towards the finishing (i.e. north-eastern) ends of the longwalls, due to the shallower depths of cover. Less extensive cracking was recorded towards the commencing (i.e. south-western) end of the longwalls due to the higher depths of cover and possibly because the less accessible terrain limited inspection and mapping of the surface.

The surface crack widths towards the finishing ends of WYLW17 to WYLW21 were typically between 25 mm and 50 mm, with localised crack widths up to approximately 400 mm. Compression heaving also developed with heights up to approximately 300 mm. Fracturing and spalling of the exposed bedrock developed within the North Wambo Creek Diversion.

More isolated surface cracking developed above the central and south-western ends of WYLW17 to WYLW21. The crack widths were typically between 10 mm and 50 mm, with localised crack widths up to approximately 100 mm. Minor potholes were also observed along the steep slopes near the access tracks.

The total length of the mapped surface cracking directly above WYLW17 to WYLW21 is approximately 3.6 km. The recorded crack widths were generally less than 50 mm (i.e. 89 % of cases). The crack widths were between 50 mm and 100 mm in 7 % of cases and greater than 100 mm in the remaining 4 % of cases. The maximum crack width was approximately 500 mm.

Photographs of the surface deformations that developed above WYLW17 to WYLW21 are provided in Fig. 4.4 to Fig. 4.13.

Fig. 4.4   Surface cracking above north-eastern end of WYLW17

Fig. 4.5   Compression heaving above north-eastern end of WYLW17

Fig. 4.6   Surface cracking along the access tracks above WYLW17

Fig. 4.7   Surface cracking above the middle of WYLW17

Fig. 4.8   Surface cracking on the steep slopes above the south-western end of WYLW17

msec

Fig. 4.9   Surface cracking near the finishing end of WYLW18 (Source: WCPL)

Fig. 4.10   Surface cracking on a steep slope above the south-western end of WYLW18

Fig. 4.11   Surface cracking along an access track above WYLW18 and WYLW19 (Source: WCPL)

Fig. 4.12   **Surface cracking adjacent to the tailgate of WYLW20 (Source: WCPL)**

Fig. 4.13   **Surface cracking near Dam d07 adjacent to the maingate of WYLW20 (Source: WCPL)**

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*.

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

5.1. Natural features

As listed in Table 2.1, the following natural features have not been 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;
- swamps or wetlands;
- lands declared as critical habitat under the *Threatened Species Conservation Act 1995*;
- State Recreation Areas or State Conservation Areas;
- State Forests;
- areas of significant geological interest; and
- other significant natural features not described below.

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

5.2. Streams

5.2.1. Description of the streams

The streams are shown in Drawing No. MSEC1317-08.

The natural streams within the Study Area comprise North Wambo Creek, Waterfall Creek and their associated tributaries. The diverted downstream section of North Wambo Creek (i.e. the North Wambo Creek Diversion) is located outside the Study Area.

North Wambo Creek

North Wambo Creek commences along the Wollemi Escarpment to the west of the SBEUM mining area. The upper section of the creek located outside the Study Area is formed within an incised valley at the base of the escarpment. The creek bed comprises a rounded gravel to sandy base. In some locations there is exposed bedrock that has formed into small cascades with isolated pools. There is also significant debris along this section of the creek, including boulders, tree branches and other vegetation.

The lower section of North Wambo Creek is located within the Study Area. This section of creek is a fifth order ephemeral stream with a shallow incision into the natural surface soils. The total length of North Wambo Creek within the Study Area is approximately 0.7 km.

The natural surface level along the section of North Wambo Creek within the Study Area varies from a high point of 116 mAHD at the upstream end to a low point of 112 mAHD at the downstream end. The average natural grade for this section of creek, therefore, is 7 mm/m (i.e. 0.7 % or 1 in 143).

North Wambo Creek crosses directly above the finishing (i.e. southern) ends of WYLW25 and WYLW26. The length of creek above these two proposed longwalls is 0.3 km. North Wambo Creek also crosses directly above the approved WYLW23. The total length of creek above the mining area (i.e. WYLW23, WYLW25 and WYLW26) is 0.6 km based on both the MOD19 Layout and the Extraction Plan Layout.

Photographs of the upper and lower sections of North Wambo Creek are provided in Fig. 5.1 and Fig. 5.2, respectively. The locations of the photographs are shown in Drawing No. MSEC1317-08.

msec

Fig. 5.1   Upper section of North Wambo Creek located outside the SBEUM mining area (P0649 and P0595)

Fig. 5.2   Lower section of North Wambo Creek located adjacent to the SBEUM mining area (P5458)

The natural section of North Wambo Creek joins the constructed North Wambo Creek Diversion between the SBEUM mining area and the Montrose Open Cut Pit. The creek diversion is located outside the Study Area.

Waterfall Creek

The upper reaches (i.e. first and second order sections) of Waterfall Creek are located within the Study Area. This section of the creek is formed within a shallow valley within the steep slopes. The total length of Waterfall Creek within the Study Area is approximately 0.5 km.

The natural surface level along the section of Waterfall Creek within the Study Area varies from a high point of 246 mAHD at the upstream end to a low point of 169 mAHD at the downstream end. The average natural grade for this section of creek, therefore, is 150 mm/m (i.e. 15 % or 1 in 7).

The upper reaches of Waterfall Creek are located above WYLW26. The total length of creek above the mining area is 0.2 km based on both the MOD19 Layout and the Extraction Plan Layout.

The base of Waterfall Creek is founded in the natural surface soils. However, there is a step with exposed bedrock located approximately 50 m west of the maingate of WYLW26. There is locally exposed bedrock in other locations along the upper reaches of the creek.

msec

Photographs of the section of Waterfall Creek within the Study Area are provided in Fig. 5.3 to Fig. 5.5.

Fig. 5.3   Valley of Waterfall Creek near the maingate of WYLW26 (P5565)

Fig. 5.4   Upper reaches of Waterfall Creek founded in natural surface soils (P5578)

Fig. 5.5   Step and exposed bedrock along Waterfall Creek west of WYLW26 (P5586)

The third order section of Waterfall Creek is located downstream and outside of the Study Area. The start of the third order section of stream is located 180 m north of WYLW26.

Unnamed drainage lines

Ephemeral drainage lines are located across the Study Area. The drainage lines located above the southern ends of WYLW24 to WYLW26 are tributaries to North Wambo Creek and the North Wambo Creek Diversion. The drainage lines located above the northern ends of the proposed longwalls are tributaries to Waterfall Creek.

The drainage lines have shallow incisions into the natural surface soils, with some isolated bedrock outcropping along the upper reaches. A photograph of a typical drainage line located above the SBEUM mining area is provided in Fig. 5.6.

Fig. 5.6   Typical drainage line located above the SBEUM mining area (P5644)

The natural grades of the drainage lines within the Study Area typically vary between 5 mm/m (i.e. 0.5 % or 1 in 200) and 100 mm/m (i.e. 10 % or 1 in 10), with average natural grades of approximately 30 mm/m to 60 mm/m (i.e. 3 % to 6 % or 1 in 33 to 1 in 17).

5.2.2. Predictions for the streams

North Wambo Creek

The predicted profiles of vertical subsidence, tilt and curvature along North Wambo Creek are shown in Fig. C.04, in Appendix C. The predicted profiles after the completion of the existing/approved WYLW17 to WYLW23 are shown as the cyan lines and after the completion of the proposed WYLW24 to WYLW26 are shown as the blue lines.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvature for North Wambo Creek is provided in Table 5.1. The values are the maximum predicted subsidence effects for the section of creek located within the Study Area.

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

Location	Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km⁻¹)	Maximum predicted total sagging curvature (km⁻¹)
North Wambo Creek	After WYLW17 to WYLW23	1800	75	> 3.0	> 3.0
	After WYLW24	1800	75	> 3.0	> 3.0
	After WYLW25	1800	75	> 3.0	> 3.0
	After WYLW26	1800	75	> 3.0	> 3.0

The maximum predicted total tilt for North Wambo Creek is 75 mm/m (i.e. 7.5 % or 1 in 13). The maximum predicted total conventional curvature is greater than 3.0 km^{-1}, which represents a minimum radius of curvature of less than 0.3 km.

The maximum predicted conventional strains for North Wambo Creek, based on applying a factor of 10 to the maximum predicted curvatures, are greater than 30 mm/m tensile and compressive. The distribution of the predicted strains due to the mining of the longwalls is described in Section 4.4. The maximum predicted strains for the section of creek above the finishing (i.e. southern) ends of WYLW25 and WYLW26 are 12 mm/m tensile and 17 mm/m compressive based on the 95 % confidence levels.

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.

The section of North Wambo Creek located directly above the longwalls has a shallow incision into the natural surface soils. The predicted valley-related effects for the creek, therefore, are not significant when compared with the predicted conventional movements.

Waterfall Creek

The predicted profiles of vertical subsidence, tilt and curvature along Waterfall Creek are shown in Fig.C.05, in Appendix C. The predicted profiles after the completion of the proposed WYLW24 to WYLW26 are shown as the blue lines.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvature for Waterfall Creek is provided in Table 5.2. The values are the maximum predicted subsidence effects for the section of creek within the Study Area.

msec

Table 5.2   Maximum predicted total vertical subsidence, tilt and curvature for Waterfall Creek

Location	Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km⁻¹)	Maximum predicted total sagging curvature (km⁻¹)
Waterfall Creek	After WYLW17 to WYLW23	< 20	< 0.5	< 0.01	< 0.01
	After WYLW24	< 20	< 0.5	< 0.01	< 0.01
	After WYLW25	< 20	< 0.5	< 0.01	< 0.01
	After WYLW26	450	13	0.45	0.40

The maximum predicted total tilt for Waterfall Creek is 13 mm/m (i.e. 1.3 % or 1 in 77). The maximum predicted total conventional curvatures are 0.45 km⁻¹ hogging and 0.40 km⁻¹ sagging, which represent minimum radii of curvatures of 2.2 km and 2.5 km, respectively.

The maximum predicted conventional strains for Waterfall Creek, based on applying a factor of 10 to the maximum predicted curvatures, are 4.5 mm/m tensile and 4.0 mm/m compressive. The distribution of the predicted strains due to the mining of the longwalls is described in Section 4.4. The depths of cover for this creek are typically between 100 m and 200 m and, therefore, the maximum predicted strains are 8 mm/m tensile and 9 mm/m compressive based on the 95 % confidence levels.

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.

The predicted valley-related effects for Waterfall Creek are not significant when compared with the predicted conventional movements.

Unnamed drainage lines

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

5.2.3.   Comparison of the predicted subsidence effects for the streams

Comparisons of the maximum predicted total subsidence effects for North Wambo Creek, Waterfall Creek and the drainage lines, based on the MOD 19 Layout and Extraction Plan Layout, are provided in Table 5.3, Table 5.4 and Table 5.5, respectively. The values represent the maximum predicted accumulated movements for the sections of the streams within the Study Area due to the mining of all existing, approved and proposed longwalls.

Table 5.3   Comparison of maximum predicted total subsidence effects for North Wambo Creek

Location	Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km⁻¹)	Maximum predicted total sagging curvature (km⁻¹)
North Wambo Creek	MOD 19 Layout (MSEC1224)	1800	75	> 3.0	> 3.0
	Extraction Plan Layout (MSEC1317)	1800	75	> 3.0	> 3.0

msec

Table 5.4   Comparison of maximum predicted total subsidence effects for Waterfall Creek

Location	Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km⁻¹)	Maximum predicted total sagging curvature (km⁻¹)
Waterfall Creek	MOD 19 Layout (MSEC1224)	450	13	0.45	0.40
	Extraction Plan Layout (MSEC1317)	450	13	0.45	0.40

Table 5.5   Comparison of maximum predicted total subsidence effects for the drainage lines

Location	Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km⁻¹)	Maximum predicted total sagging curvature (km⁻¹)
Drainage lines	MOD 19 Layout (MSEC1224)	1950	75	> 3.0	> 3.0
	Extraction Plan Layout (MSEC1317)	1950	75	> 3.0	> 3.0

The maximum predicted subsidence effects for the streams, based on the Extraction Plan Layout, are the same as the maximum predicted values based on the MOD 19 Layout. The predictions for the streams do not change because the layout of WYLW24 to WYLW26 remains the same apart from the finishing (i.e. southern) end of WYLW24 which has been shortened by approximately 40 m.

5.2.4.   Impact assessments for the streams

The impact assessments for the streams, based on the Extraction Plan Layout, are the same as those based on the MOD19 Layout because the predicted subsidence effects do not change. The assessments have been reproduced in the following sections for completeness. The assessments provided in this report should be read in conjunction with the assessments provided in the reports by the other specialist consultants on the project.

Potential for increased levels of ponding, flooding and scouring due to the mining-induced tilts

Mining can result in increased levels of ponding in locations where the mining-induced tilts oppose and are greater than the natural gradients that exist before mining. Mining can also potentially result in an increased likelihood of scouring of the banks in the locations where the mining-induced tilts considerably increase the natural gradients that exist before mining.

The maximum predicted tilt for North Wambo Creek is 75 mm/m (i.e. 7.5 % or 1 in 13). The predicted mining-induced tilts are greater than the average natural gradient of the creek above the SBEUM mining area of 6 mm/m (i.e. less than 1 %). Similarly, the maximum predicted tilt for the drainage lines of 80 mm/m (i.e. 8.0 % or 1 in 13) is greater than the average natural gradients of these streams which vary between 30 mm/m to 60 mm/m (i.e. 3 % to 6 %).

The natural and the predicted post-mining surface levels and grades along North Wambo Creek and Waterfall Creek are illustrated in Fig. 5.7 and Fig. 5.8, respectively. The profiles shown in these figures are after the completion of all existing, approved and proposed longwalls.
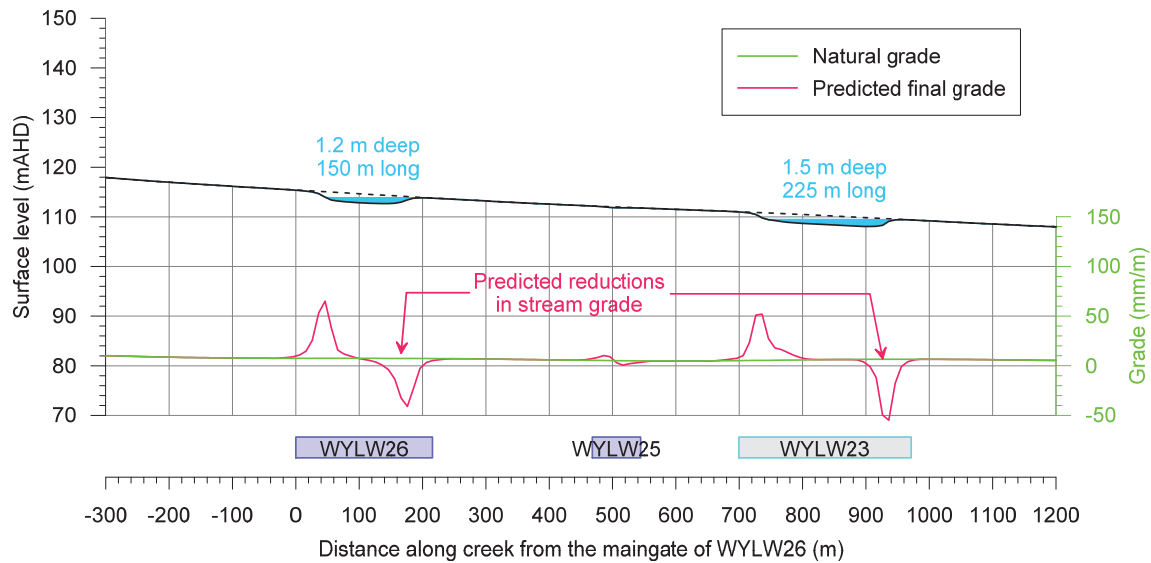
Fig. 5.7   Natural and predicted post-mining surface levels and grades along North Wambo Creek
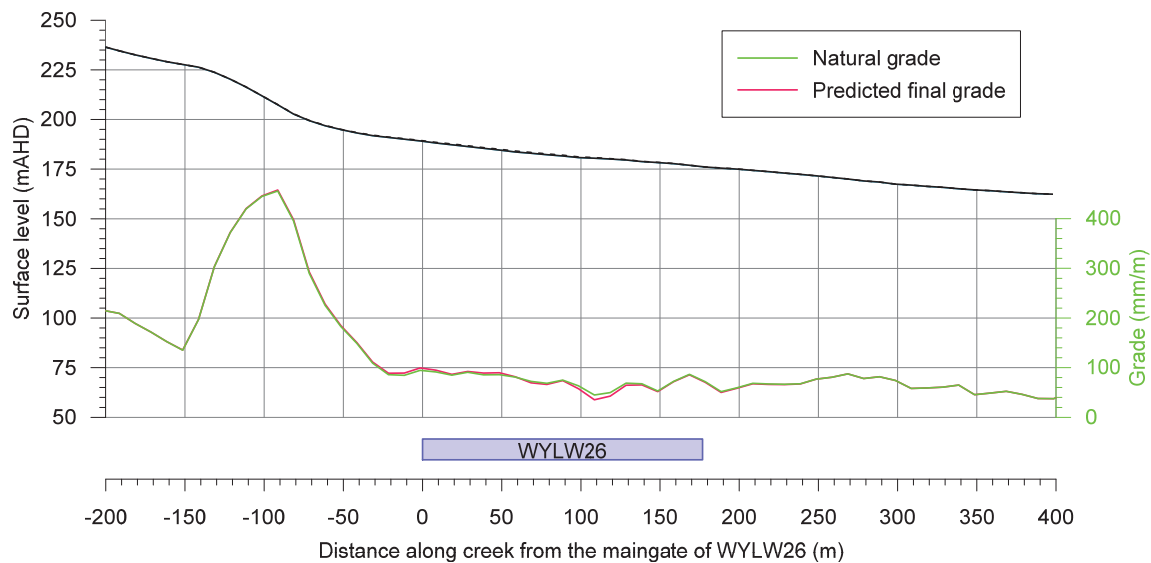
Fig. 5.8   Natural and predicted post-mining surface levels and grades along Waterfall Creek

There are predicted reversals of grade along North Wambo Creek above the approved WYLW23 and the proposed WYLW26. Ponding areas are predicted to develop upstream of the perimeter of the SBEUM mining area along this stream. There are no predicted reversals of grade along Waterfall Creek.

It is noted that the predicted ponding areas along North Wambo Creek differ from the topographical depressions discussed in Section 5.8 and indicated in Fig. 5.15, as they have been based on the predicted changes in surface levels along the original alignment of the creek, i.e. they do not consider the natural grades across the alignment of the creek.

The extraction of the longwalls will result in some changes in the alignment of North Wambo Creek, due to the natural and mining-induced cross-grades and, in consequence, the actual ponding areas are expected to be less than those illustrated in Fig. 5.7. The actual extents and depths of the ponding areas are also dependent on several other factors, including rainfall, catchment sizes, surface water runoff, infiltration and evaporation and, therefore, are expected to be smaller than the topographical depressions.

There are two ponding areas predicted to develop along North Wambo Creek having maximum depths up to 1.5 m and overall lengths up to 225 m. The potential for increased ponding along the creek, based on the Extraction Plan Layout, is the same as that based on the MOD19 Layout.

If adverse impacts were to develop along North Wambo Creek due to increased ponding, these could be remediated by locally re-grading the creek bed so as to re-establish the natural gradients. The creek has a shallow incision in the natural surface soils and, therefore, it is expected that the mining-induced ponding areas could be reduced by locally excavating the channels downstream of these areas. The larger ponding areas may require excavation into the topmost bedrock, depending on the thickness of the overlaying surface soils.

Potential for cracking in the stream beds and fracturing of bedrock

It is expected that fracturing of the topmost bedrock would develop along the sections of the streams located directly above the longwalls. North Wambo Creek, the upper reaches of Waterfall Creek and the drainage lines have shallow incisions into the natural surface soils. Cracking in the beds of the streams would be visible at the surface where the depths of the surface soils are shallow, or where the bedrock is exposed.

The mining-induced compression can also result in dilation and the development of bed separation in the topmost bedrock. The dilation is expected to develop predominately within the top 10 m to 20 m of the bedrock. Compression can also result in buckling of the topmost bedrock resulting in heaving in the overlying surface soils.

North Wambo Creek has been previously mined beneath by Longwalls 1 to 8A in the Wambo Seam (WMLW1 to WMLW8A) at the North Wambo Underground Mine. Surface cracking observed along the creek had widths typically ranging between 10 mm to 50 mm, with localised crack widths up to approximately 100 mm (WCPL, 2014). The North Wambo Creek Diversion has also been previously mined beneath by WYLW11 to WYLW13 (but outside the underlying WMLW14 to WMLW16) and WYLW17. Surface cracking along the creek diversion had widths ranging between 25 mm and 50 mm, with localised crack widths up to approximately 400 mm.

The surface impacts along North Wambo Creek, Waterfall Creek and the drainage lines are expected to be similar to those previously observed at the Wambo Coal Mine. Photographs of the surface deformations above the previously extracted WYLW11 to WYLW13 and WYLW17 to WYLW20 are provided in Section 4.7.

The streams are ephemeral and, therefore, surface water flows only occur during and for short periods after rainfall events. In times of heavy rainfall, the majority of the runoff would flow over the natural surface soil beds and would not be diverted into the dilated strata below. In times of low flow and prior to remediation, however, surface water flows could be diverted into the dilated strata below the beds.

It is expected that fracturing in the underlying bedrock would gradually be filled with surface soils during subsequent flow events, especially during times of heavy rainfall. If the surface cracks were found not to fill naturally, some remedial measures may be required at the completion of mining. Where necessary, any significant surface cracks in the stream beds could be remediated by infilling with surface soil or other suitable materials or by locally regrading and recompacting the surface.

It is not expected that there would be a direct hydraulic connection between the surface and the longwalls, as this has not been previously observed at the Wambo Coal Mine. This includes the extraction of the Homestead/Wollemi workings in the Whybrow Seam directly beneath Stony Creek, WMLW1 to WMLW8A directly beneath North Wambo and Stony Creeks and WYLW11 to WYLW13 and WYLW17 beneath the North Wambo Creek Diversion.

Similar experiences have been found elsewhere in the Hunter and Newcastle Coalfields indicating that mining-induced fracturing and dilation do not have long term adverse impacts on ephemeral streams comprising natural soil beds. For example, the ephemeral drainage lines at South Bulga and the Beltana No. 1 Underground Mine were previously mined beneath by longwalls in the Whybrow Seam, where the depths of cover varied between 40 m and 200 m. Although surface cracking was observed across the mining area, there were no observable surface water flow diversions in the drainage lines, after the remediation of the larger surface cracks had been completed.

It would be necessary to remediate some sections of the streams after the longwalls mine directly beneath them. This would include re-grading the beds and infilling the larger surface cracking. It is expected that there would be no long-term adverse impacts on these streams after the completion of the necessary surface remediation.

Management strategies have previously been developed for the sections of the streams that have already been directly mined beneath at the Wambo Coal Mine. It is recommended that the existing management strategies for the streams be reviewed and, where required, are revised to include the effects of the longwalls based on the Extraction Plan Layout.

5.3.   Aquifers and known ground water resources

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 SLR (2023).

There are no Ground Water Management Areas, as defined by the DPE, within the Study Area. WCPL owns two monitoring bores (Refs. GW200831 and GW200832) which are located outside but near the north-eastern end of the approved WYLW23 and the southern end of the proposed WYLW24. These monitoring bores could be affected due to the mining of the longwalls. There were no other registered groundwater bores identified within the Study Area.

5.4.   Escarpments

The *Wollemi Escarpment* is located to the south-west of the existing/approved WYLW17 to WYLW23. There is no escarpment near the proposed WYLW24 to WYLW26.

The Macquarie Dictionary defines an *escarpment* as *"a long, cliff-like ridge of rock, or the like, commonly formed by faulting or fracturing of the earth's crust"*. The Collins Dictionary of Geology defines an *escarpment* as *"a high, more or less continuous, cliff or long steep slope situated between a lower more gently inclined surface and a higher surface"*. It appears, from these examples, that some definitions of an escarpment include only the cliffs and rock formations, while other definitions also include the steep slopes.

In this report, the escarpment has been defined as the continuous sections of the higher level cliffline along the boundary of the Wollemi National Park. The lower levels of cliffs and minor cliffs, the isolated rock outcrops and the steep slopes have not been included as part of the escarpment. This approach is consistent with that adopted for MOD 19.

The extents of the escarpment and cliffs were determined from detailed site investigations by MSEC and WCPL on the 21 July 2016, as well as from an orthophotograph and surface level contours which were generated from a LiDAR survey of the area. The locations of the cliffs associated with the Wollemi Escarpment are shown in Drawing No. MSEC1317-08.

The impact assessments for the cliffs associated with the Wollemi Escarpment are included in Section 5.5. The impact assessments for the Wollemi National Park are provided in Section 5.11.

5.5.   Cliffs

5.5.1.   Descriptions of the cliffs

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

"*Cliff*   *Continuous rock face, including overhangs, having a minimum length of 20 metres, a minimum height of 10 metres and a minimum slope of 2 to 1 (>63.4°)*

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

The cliffs and minor cliffs were identified using 1 m surface level contours generated from LiDAR surveys and from detailed site investigations. The cliffs associated with the Wollemi Escarpment are shown in Drawing No. MSEC1317-08.

There are no cliffs identified above or adjacent to the proposed WYLW24 to WYLW26. However, there are cliffs located further west of these longwalls and within the Wollemi National Park.

A section has been taken through the Wollemi National Park transverse to the proposed WYLW26 and it is shown in Fig. 5.9. The base of the escarpment and the boundary of the national park are shown in this figure.
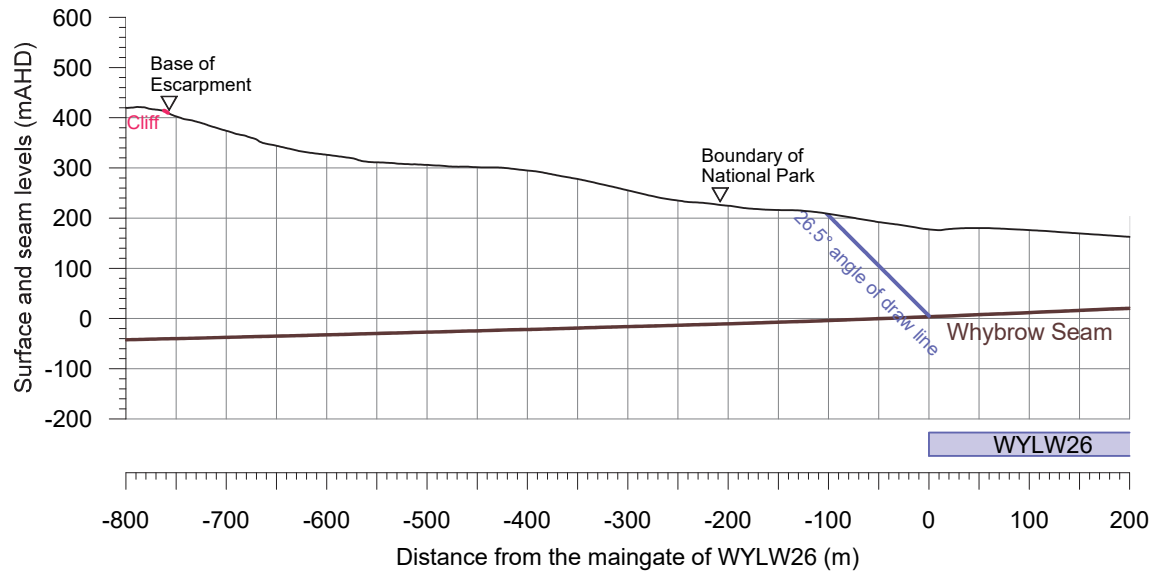
Fig. 5.9   Section through the Wollemi National Park and the proposed WYLW26

The Cliffs Associated with the Wollemi Escarpment are located well outside the angle of draw for the proposed WYLW24 to WYLW26. A summary of the minimum distances of the cliffs from each of the longwalls is provided in Table 5.6.

Table 5.6   Distances of the Cliffs Associated with the Wollemi Escarpment from each of WYLW24 to WYLW26

Feature	Longwall	Minimum distance (m)
Cliffs Associated with the Wollemi Escarpment	WYLW24	> 1000
	WYLW25	> 1000
	WYLW26	760

The Cliffs Associated with the Wollemi Escarpment are located more than 1000 m from WYLW24 and WYLW25 and located 760 m west of WYLW26. There are also other minor cliffs located at similar distances from these longwalls.

The cliffs, minor cliffs and rock outcrops have derived from the Widden Brook Conglomerate of the Narrabeen Group, as can be seen in Fig. 1.3. A photograph of the Cliffs Associated with the Wollemi Escarpment is provided in Fig. 5.10. The location and direction of the photograph are indicated in Drawing No. MSEC1317-08.

Fig. 5.10   Cliffs located south-west of modified WYLW26 (P5557)

5.5.2.   Predictions for the cliffs

A summary of the maximum predicted total vertical subsidence, tilts and curvatures for the Cliffs Associated with the Wollemi Escarpment is provided in Table 5.7. The values represent the maximum predicted accumulated movements within 20 m of the mapped extents of the cliffs due to the mining of the existing, approved and proposed longwalls.

Table 5.7   Maximum predicted total vertical subsidence, tilts and curvatures for the Cliffs Associated with the Wollemi Escarpment
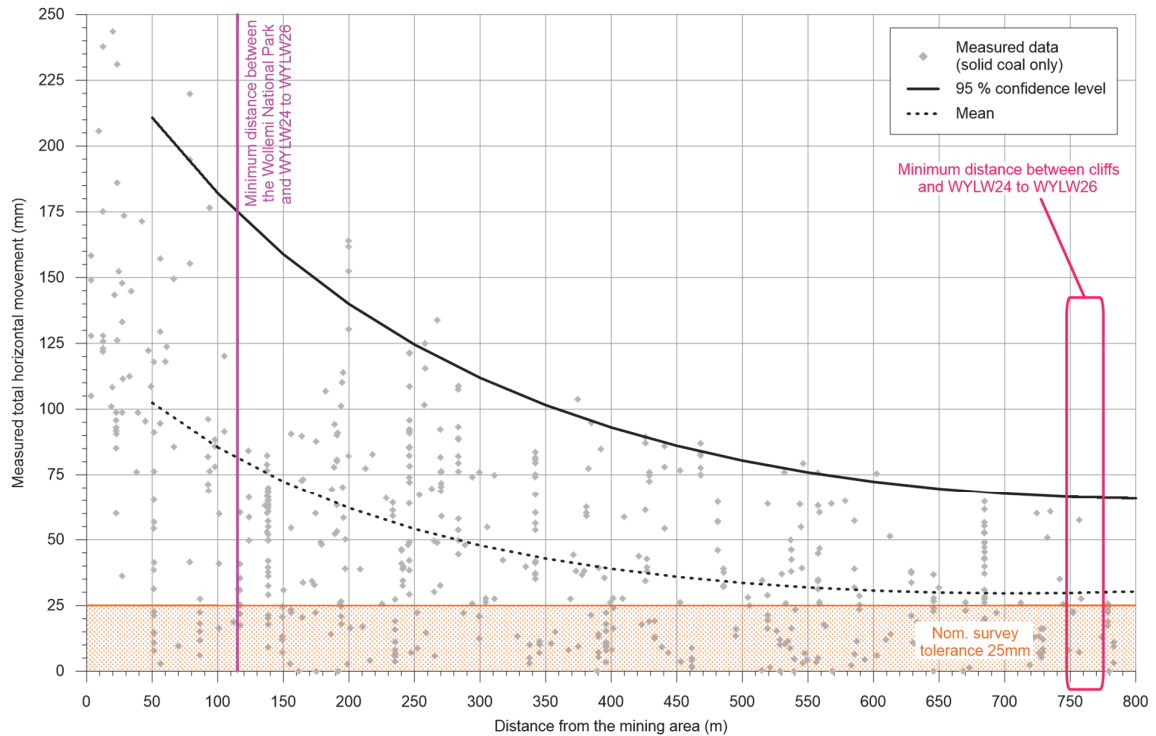
Location	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km⁻¹)	Maximum predicted total sagging curvature (km⁻¹)
Cliffs Associated with the Wollemi Escarpment	< 5	< 0.5	< 0.01	< 0.01

The Cliffs Associated with the Wollemi Escarpment are predicted to experience less than 5 mm vertical subsidence. While these cliffs could experience very low level vertical subsidence, they are not expected to experience measurable tilts, curvatures or strains.

The cliffs could experience far-field horizontal movements. There is no 3D ground monitoring data available at the North Wambo Underground Mine along the steep slopes beneath the Wollemi Escarpment. The predicted far-field horizontal movements, therefore, have been based on the observations at Dendrobium Mine, which has similar or shallower depths of cover and similar natural surface gradients.

Seventeen longwalls have been extracted in Areas 1, 2, 3A and 3B at Dendrobium Mine. The depths of cover vary between 170 m and 320 m in Area 1, 150 m and 310 m in Area 2, 275 m and 385 m in Area 3A and 290 m and 410 m in Area 3B. The longwalls have been extracted in the Wongawilli Seam and had width-to-depth ratios typically ranging between 0.7 and 1.4. Escarpments were located directly above the longwalls in Areas 1 and 2 and the surface was highly undulating in Areas 3A and 3B, with the natural gradients varying between 1 in 3 and 1 in 2 directly above the longwalls.

The measured total 3D horizontal movements at Dendrobium Mine for survey marks located outside the extents of the longwalls (i.e. above solid coal only) are illustrated in Fig. 5.11. The 95 % confidence level for the measured total horizontal movements has been shown as the blue line in this figure.

Fig. 5.11   Measured total 3D horizontal movements above solid coal at Dendrobium Mine

The relative locations of the Cliffs Associated with the Wollemi Escarpment are shown in Fig. 5.11. The maximum predicted total far-field horizontal movement for these cliffs is in the order of 65 mm based on the 95 % confidence level. These movements tend to be bodily movements, towards the extracted longwalls, which are accompanied by very low levels of strain, typically less than the order of survey tolerance.

5.5.3.   Comparison of the predicted subsidence effects for the cliffs

A comparison of the maximum predicted total subsidence effects for Cliffs Associated with the Wollemi Escarpment, based on the MOD 19 Layout and Extraction Plan Layout, are provided in Table 5.8. The values represent the maximum predicted accumulated movements within 20 m of the mapped extents of the cliffs due to the mining of the existing, approved and proposed longwalls.

Table 5.8   Comparison of maximum predicted total subsidence effects for the Cliffs Associated with the Wollemi Escarpment

Location	Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km⁻¹)	Maximum predicted total sagging curvature (km⁻¹)
Cliffs Associated with the Wollemi Escarpment	MOD 19 Layout (MSEC1224)	< 5	< 0.5	< 0.01	< 0.01
	Extraction Plan Layout (MSEC1317)	< 5	< 0.5	< 0.01	< 0.01

The Cliffs Associated with the Wollemi Escarpment are predicted to experience less than 5 mm vertical subsidence based on both the MOD 19 Layout and Extraction Plan Layout. The far-field horizontal movements at these cliffs, based on the Extraction Plan Layout, are the same as those based on the MOD 19 Layout. While the cliffs could experience very low level vertical and horizontal effects, they are not predicted to experience measurable tilts, curvatures or strains.

5.5.4. Impact assessments for the cliffs

The Cliffs Associated with the Wollemi Escarpment are predicted to experience vertical subsidence of less than 5 mm. While these cliffs could experience very low levels of vertical subsidence, they are not expected to experience measurable conventional tilts, curvatures or strains, even if the predicted vertical subsidence was exceeded by a factor of two times.

The Cliffs Associated with the Wollemi Escarpment could also experience far-field horizontal movements in the order of 65 mm based on the 95 % confidence level. These movements are expected to be bodily movements towards the extracted longwalls and are not expected to be associated with any measurable strains. It is unlikely, therefore, that the cliffs would experience adverse impacts due to far-field horizontal movements, even if these predictions were exceeded by a factor of two times.

WYLW11 to WYLW13 at the South Bates Underground Mine and WYLW17 to WYLW21 at the SBEUM have been extracted adjacent to the Wollemi Escarpment. The Cliffs Associated with the Wollemi Escarpment are located at minimum distances of 290 m from WYLW12 and 220 m from WYLW18, at their closest points to the mining areas. There have been no reported mining-related impacts to these cliffs due to the mining at the South Bates Underground Mine and the SBEUM. However, two rockfalls have been observed along the escarpment likely caused by heavy rainfall. Refer to subsidence summary review in Report No. MSEC1302 for further details.

It is not expected, therefore, that there would be adverse impacts on the Cliffs Associated with the Wollemi Escarpment due to the mining of the proposed WYLW24 to WYLW26.

5.5.5. Recommendations for the cliffs

It is recommended that the Cliffs Associated with the Wollemi Escarpment nearest to the proposed WYLW24 to WYLW26 are periodically visually monitored after the mining of each longwall.

5.6. Pagodas

There are no pagoda complexes identified within the Study Area. There are isolated pagodas associated with the Wollemi Escarpment that are located outside the SBEUM mining area, south-west of the proposed WYLW24 to WYLW26. The pagodas have formed from the Widden Brook Conglomerate and have heights typically up to around 3 m to 5 m.

The pagodas are predicted to typically experience vertical subsidence less than 5 mm. While the pagodas could experience very low levels of vertical subsidence, they are not expected to experience measurable tilts, curvatures or strains. It is unlikely, therefore, that the isolated pagodas would experience adverse impacts due to the mining of the proposed WYLW24 to WYLW26.

5.7. Steep slopes

5.7.1. Descriptions of the steep slopes

The definition of a steep slope provided in the *Standard and Model Conditions for Underground Mining* (DPE, 2012) is: "*An area of land having a gradient between 1 in 3 (33% or 18.3°) and 2 in 1 (200% or 63.4°)*". The locations of the steep slopes were identified from 1 m surface level contours which were generated from the LiDAR surveys of the area.

Steep slopes have been identified above the proposed WYLW26 and to a lesser extent the proposed WYLW25 where a ridgeline extends across the northern ends of these longwalls. These steep slopes are located below the boundary of the Wollemi National Park. There are no cliffs identified near the proposed WYLW24 to WYLW26.

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Photographs of the steep slopes located above the proposed WYLW25 and WYLW26 are provided in Fig. 5.12 and Fig. 5.13, respectively.
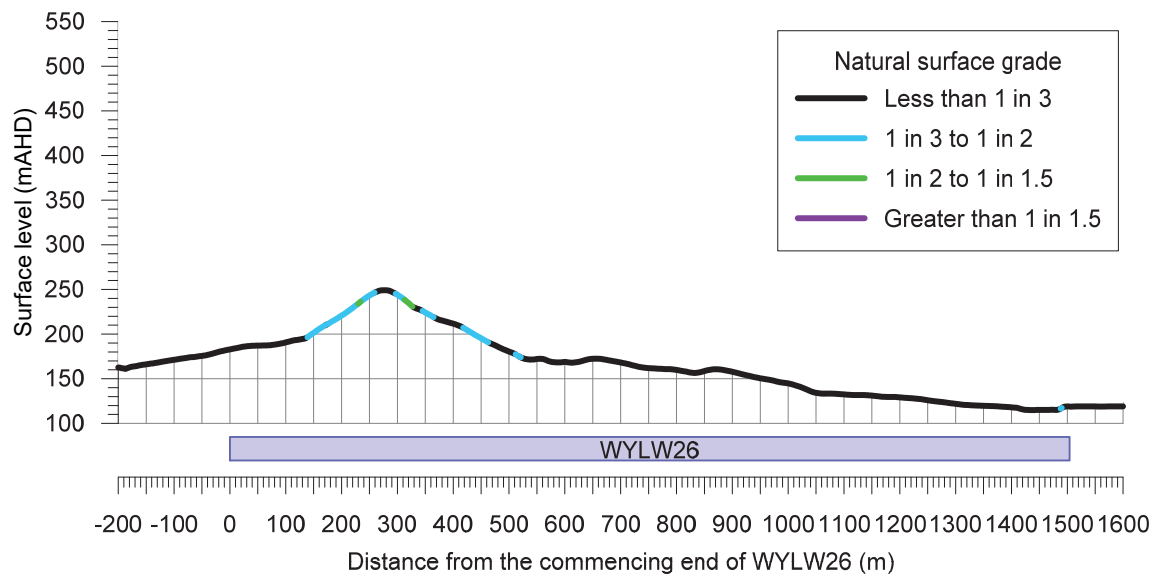

Fig. 5.12   Steep slopes above the modified WYLW25 (P5594)

Fig. 5.13   Steep slopes above the modified WYLW26 (P5519)

The natural slopes along the centreline of the proposed WYLW26 are illustrated in Fig. 5.14.

Fig. 5.14   Section through the steep slopes and the centreline of the proposed WYLW26

The natural surface gradients directly above the proposed WYLW24 to WYLW26 typically range between 1 in 3 and 1 in 2. The slopes are locally steeper on the western side of WYLW26 (i.e. outside the SBEUM mining area) along the upper reaches of Waterfall Creek.

The surface soils along the steep slopes above the longwalls are generally derived from the Widden Brook Conglomerate (Rna), as can be inferred from Fig. 1.3. The slopes are stabilised by the natural vegetation, which can be seen in the aerial photograph in Fig. 5.18.

There are also isolated steep slopes elsewhere above the SBEUM mining area which are generally associated with the banks of the streams.

5.7.2.   Predictions for the steep slopes

A summary of the maximum predicted total subsidence, tilts and curvatures for the steep slopes is provided in Table 5.9. The values represent the maximum predicted accumulated movements for the steep slopes within the Study Area due to the mining of all existing, approved and proposed longwalls.

Table 5.9   Maximum predicted total vertical subsidence, tilts and curvatures for the steep slopes

Location	Longwalls	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Steep slopes	WYLW24 to WYLW26	1950	40	2.0	2.0

The steep slopes above the proposed WYLW24 to WYLW26 are predicted to experience tilts up to 40 mm/m (i.e. 4.0 % or 1 in 25). The maximum predicted curvature for these steep slopes is 2.0 km^{-1} hogging and sagging, which represents a minimum radius of curvature of 0.5 km.

The maximum predicted conventional strains for the steep slopes, based on applying a factor of 10 to the maximum predicted curvatures, are 20 mm/m tensile and compressive. The distribution of the predicted strains due to the mining of the longwalls is described in Section 4.4. The maximum predicted strains for the steep slopes above the proposed WYLW24 to WYLW26 (i.e. depths of cover between 100 m and 200 m) are 8 mm/m tensile and 9 mm/m compressive based on the 95 % confidence levels.

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.

5.7.3. Comparison of the predicted subsidence effects for the steep slopes

A comparison of the maximum predicted total subsidence effects for the steep slopes located above the proposed WYLW24 to WYLW26, based on the MOD 19 Layout and Extraction Plan Layout, are provided in Table 5.10. The values represent the maximum predicted accumulated movements for the steep slopes within the Study Area due to the mining of the existing, approved and proposed longwalls.

Table 5.10   Comparison of maximum predicted total subsidence effects for the steep slopes located above the proposed WYLW24 to WYLW26

Location	Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Steep slopes above WYLW24 to WYLW26	MOD 19 Layout (MSEC1224)	1950	40	2.0	2.0
	Extraction Plan Layout (MSEC1317)	1950	40	2.0	2.0

The maximum predicted subsidence effects for the steep slopes above the proposed WYLW24 to WYLW26, based on the Extraction Plan Layout, are the same as the maximum predicted values based on the MOD 19 Layout. The predictions for the steep slopes do not change because the layout of WYLW24 to WYLW26 remains the same apart from the finishing (i.e. southern) end of WYLW24 which has been shortened by approximately 40 m.

5.7.4. Impact assessments for the steep slopes

The maximum predicted tilt for the steep slopes of 40 mm/m (i.e. 4.0 % or 1 in 25) is small when compared to the natural surface grades, which are greater than 1 in 3. It is unlikely, therefore, that the mining-induced tilts themselves would result in any adverse impact on the stability of the steep slopes.

The steep slopes are more likely to be impacted by curvature and ground strain, rather than tilt. The potential impacts would generally result from the movement of the natural surface in the downslope direction, resulting in tension cracks appearing at the tops and on the sides of the steep slopes and compression ridges forming at the bottoms of the steep slopes.

The south-western ends of WYLW11 to WYLW13 at the South Bates Underground Mine and the existing/approved WYLW17 to WYLW21 at the SBEUM have previously mined beneath the steep slopes. Surface cracking recorded due to the mining of these longwalls is described in Section 4.7. It is noted, however, that the visual inspections above the south-western ends of these longwalls were limited due to the steep terrain and heavy vegetation.

Surface cracking recorded on the steep slopes had widths typically ranging between 25 mm and 50 mm, with localised crack widths up to approximately 400 mm. Photographs of cracking on the steep slopes are provided in Fig. 4.8 and Fig. 4.10. Similar surface deformations are expected where the proposed WYLW26 is mined beneath the steep slopes.

The steep slopes are heavily vegetated and natural erosion due to soil instability (i.e. natural downslope movements) was not readily apparent from the site investigations undertaken. If tension cracks were to develop, due to the mining of the longwalls based on the Extraction Plan Layout, it is possible that soil erosion could occur if these cracks were left untreated.

It is possible, therefore, that some remediation might be required, including infilling of surface cracks with soil or other suitable materials, or by locally regrading and recompacting the surface. In some cases, erosion protection measures may be needed, such as the planting of additional vegetation in order to stabilise the surface soils in the longer term.

5.7.5. Recommendations for the steep slopes

It is recommended that periodic visual inspections of the steep slopes are carried out during and after the mining of each longwall. The larger surface cracking that restricts the passage of vehicles along the tracks and fire trails or could cause ongoing erosion should be remediated in the same way for the cracking above the existing longwalls at the SBEUM.

5.8. Land prone to flooding or inundation

The land within the Study Area generally falls in a north-easterly direction from the Wollemi Escarpment and steep slopes towards the North Wambo Creek and the creek diversion. The natural surface level contours (grey lines) and the predicted post-mining surface level contours (green lines) above WYLW24 to WYLW26 are illustrated in Fig. 5.15. The alignment of North Wambo Creek and the creek diversion is shown as the blue line in this figure.
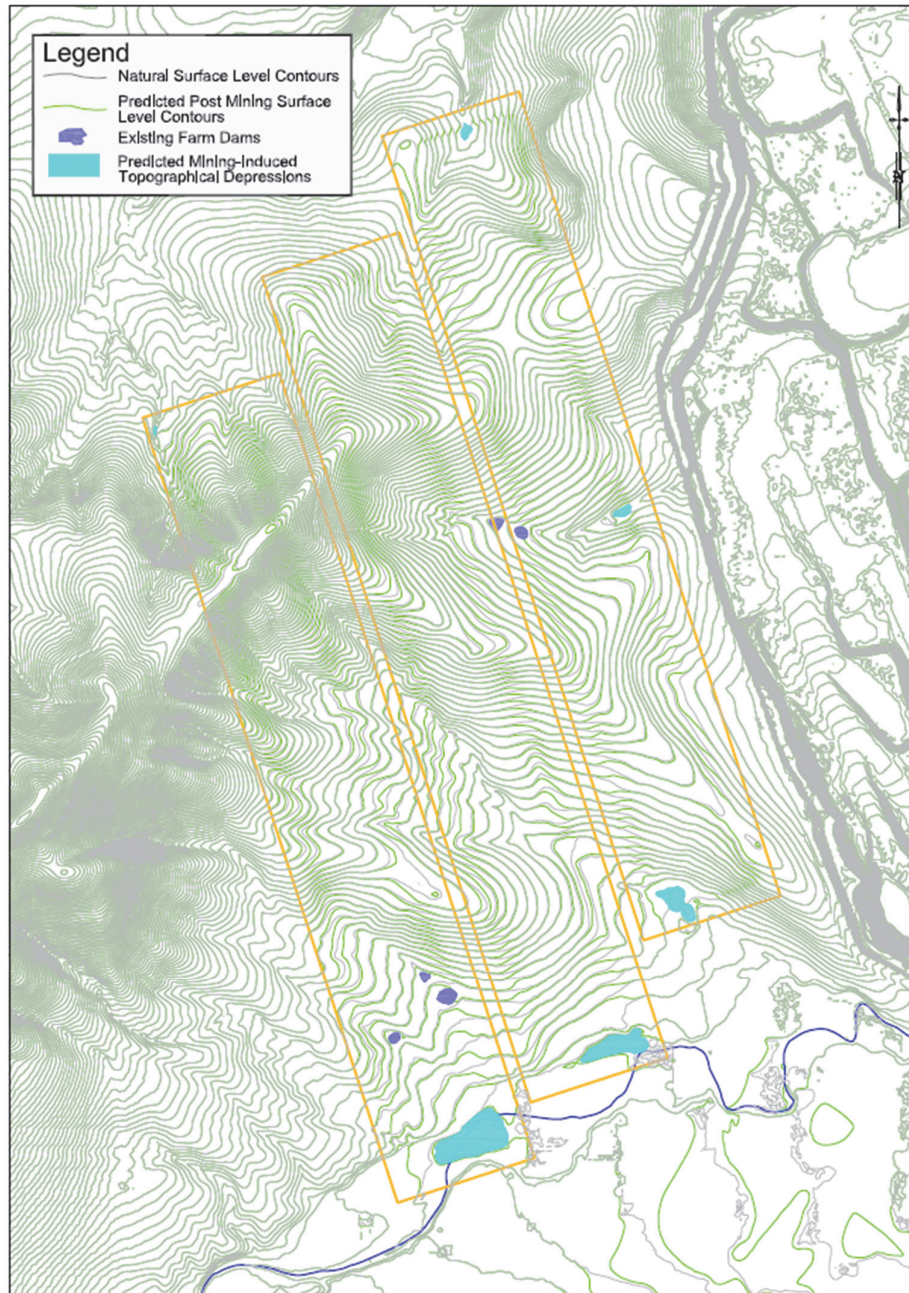
Fig. 5.15   Natural and predicted subsided surface levels and predicted mining-induced topographical depressions due to the mining of WYLW24 to WYLW26

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The predicted extents of the mining-induced topographical depressions are also illustrated in Fig. 5.15, as the cyan hatching, based on the predicted post-mining surface level contours. The actual extents and depths of increased ponding in these locations are dependent on a number of other factors, including rainfall, catchment sizes, surface water runoff, infiltration and evaporation and, therefore, these are expected to be smaller than the topographical depressions.

The mining-induced topographical depressions (i.e. cyan hatching) are predicted to develop above the finishing (i.e. southern ends) of the modified WYLW24 to WYLW26. The topographical depressions are predicted to have depths up to approximately 1.4 m and surface areas up to approximately 0.8 ha.

The extents and depths of the mining-induced topographical depressions, based on the Extraction Plan Layout, are the same as those predicted based on the MOD 19 Layout. The ponding does not change because the layout of WYLW24 to WYLW26 remains the same apart from the finishing (i.e. southern) end of WYLW24 which has been shortened by approximately 40 m.

The actual depths and extents of increased ponding in these locations are expected to be less than the predicted topographical depressions due to the various other factors described previously. The potential for increased ponding along the alignments of North Wambo Creek and typical drainage lines are discussed further in Section 5.2.4.

There are no predicted topographical depressions (i.e. areas of increased ponding) away from the finishing ends of the longwalls apart from the isolated locations along the drainage lines. It is not considered, therefore, that the land across the Study Area is naturally susceptible to flooding or inundation.

5.9. 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 Eco Logical Australia (2022).

5.10. 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 Eco Logical Australia (2022).

5.11. National Parks or wilderness areas

The *Wollemi National Park* is shown in Drawings Nos. MSEC1317-01, MSEC1317-02, MSEC1317-08 and MSEC1317-09.
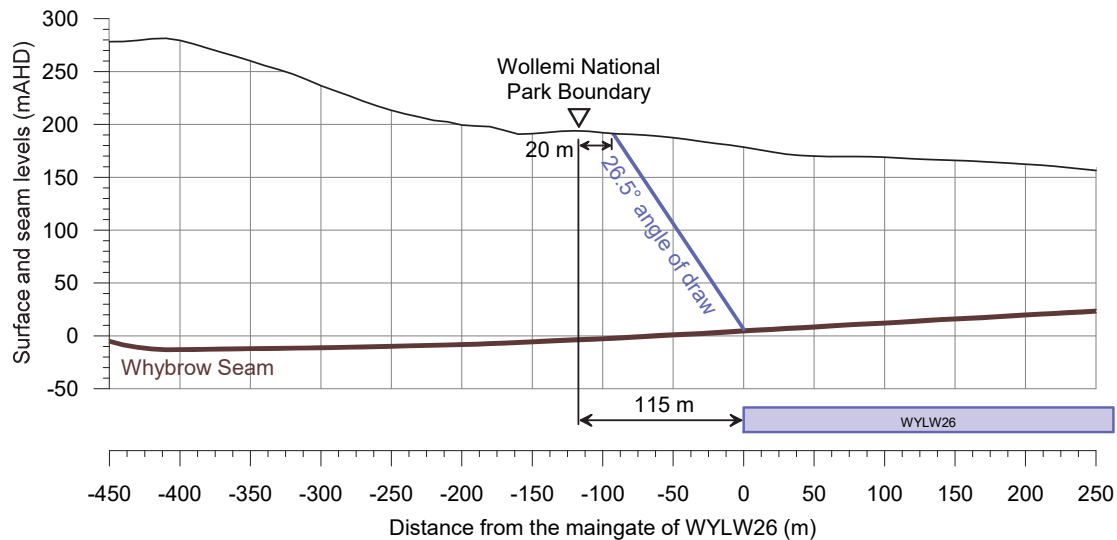
The National Park is located south-west of the proposed WYLW24 to WYLW26. A summary of the minimum distances of the longwalls from the boundary of the National Park is provided in Table 5.11.

Table 5.11   Minimum distances between WYLW24 to WYLW26 and the boundary of the Wollemi National Park

Feature	Longwall	Minimum distance between the longwalls and the Wollemi National Park (m)
Wollemi National Park	WYLW24	690
	WYLW25	400
	WYLW26	115

The distances of the Wollemi National Park from WYLW24 to WYLW26, based on the Extraction Plan Layout, are the same as those based on the MOD 19 Layout. The distances do not change because the layout of WYLW24 to WYLW26 remains the same apart from the finishing (i.e. southern) end of WYLW24 which has been shortened by approximately 40 m.

A section through the Wollemi National Park and the proposed WYLW26 is shown in Fig. 5.16. This section has been taken where the National Park is located closest to the longwalls.

Fig. 5.16   Section through the Wollemi National Park and the proposed WYLW26

The boundary of the National Park is located 115 m south-west of the maingate of the proposed WYLW26. The boundary is also located outside the 26.5° angle of draw line, as shown in Fig. 5.16, at a minimum distance of approximately 20 m. While the National Park is located outside the 26.5° angle of draw line, it has been included as part of the Study Area as it could experience far-field horizontal movements or valley closure effects.

The land within the National Park is predicted to experience less than 20 mm vertical subsidence due to the mining of WYLW24 to WYLW26, i.e. the boundary is located outside of the limit of vertical subsidence. The magnitude of the predicted vertical subsidence is similar to the natural movements that occur due to the wetting and drying of the surface soils. While the National Park could experience very low levels of vertical subsidence, it is not expected to experience measurable tilts, curvatures or strains.

The Wollemi National Park could experience low level far-field horizontal movements. There is no 3D ground monitoring data available at the North Wambo Underground Mine along the steep slopes beneath the Wollemi National Parks. The predicted far-field horizontal movements, therefore, have been based on the measurements at Dendrobium Mine which has similar or shallower depths of cover and similar natural surface gradients.

The measured total 3D horizontal movements at Dendrobium Mine for survey marks located outside the extents of the longwalls (i.e. above solid coal only) are illustrated in Fig. 5.17. The fitted mean and 95 % confidence level for the measured total horizontal movements have been shown in this figure.
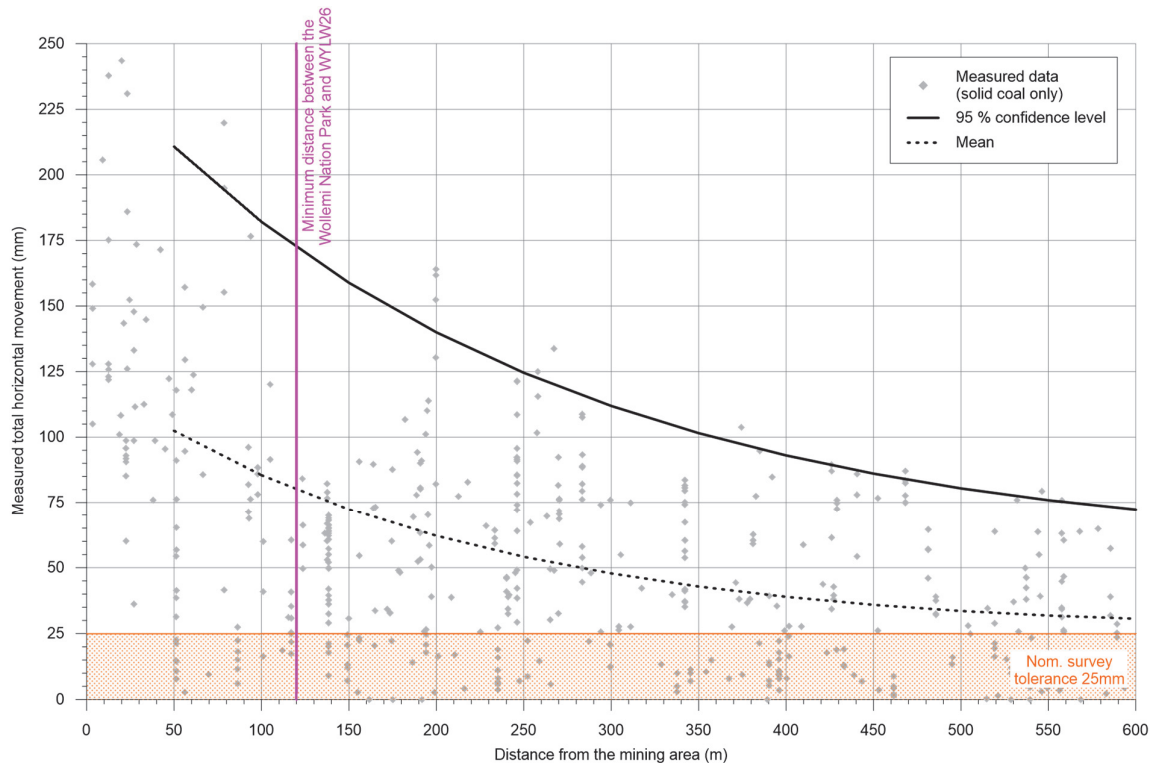
Fig. 5.17   Measured total 3D horizontal movements at Dendrobium Mine

The predicted total far-field horizontal movements at the boundary of the Wollemi Nation Park is approximately 175 mm based on the 95 % confidence level. These movements tend to be bodily movements, towards the extracted longwalls, which are accompanied by very low levels of strain, typically less than the order of survey tolerance.

It is unlikely, therefore, that the Wollemi National Park would experience adverse impacts due to the vertical or far-field horizontal movements, even if these predictions were exceeded by a factor of two times. The predictions and impact assessments for the Wollemi Escarpment (i.e. the cliffs along the boundary of the National Park) are provided in Section 5.5.

The drainage lines within the National Park are generally located at distances greater than 200 m from the modified longwalls. There are small sections of drainage lines (total length of approximately 0.4 km) that are located at distances between 200 m and 400 m from the maingate of the modified WYLW26.

While minor and isolated fracturing have been observed up to around 400 m from longwall mining in the NSW coalfields, these have occurred within very incised river valleys within the Southern Coalfield and have had no adverse impacts on the streams. The drainage lines within the National Park are on top of the steep slopes (i.e. small valley heights) and, therefore, it is unlikely that mining-induced fracturing would occur at these distances from the longwalls.

It is unlikely that there would be any adverse impacts to the Wollemi National Park, even if the predictions were exceeded by a factor of two times.

5.12.   Natural vegetation

There is natural vegetation within the Study Area which can be seen in the aerial photograph provided in Fig. 5.18.
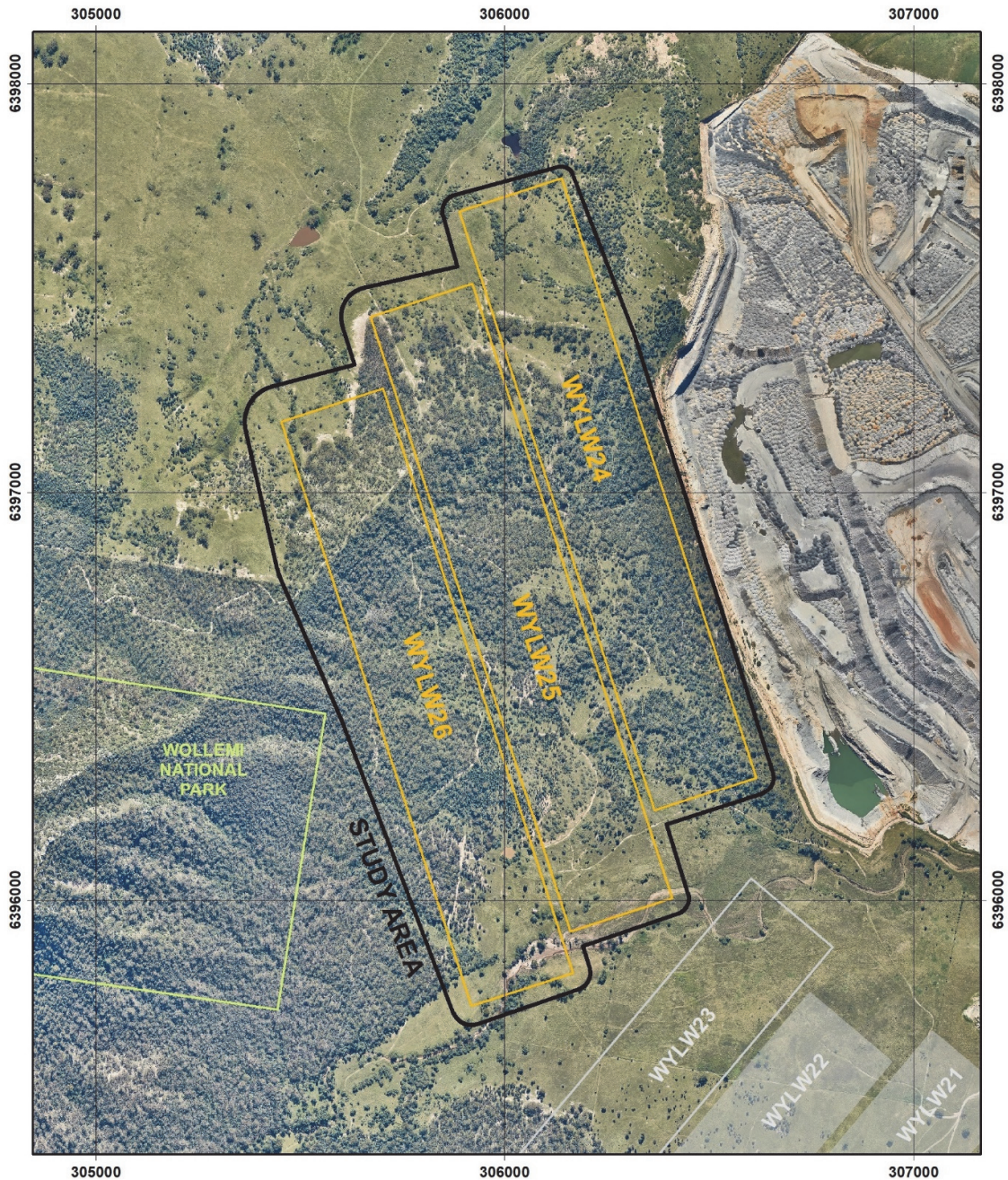
Source: Nearmap

Fig. 5.18   WYLW24 to WYLW26 and the Study Area

There is natural vegetation located above a large part of the proposed WYLW24 to WYLW26. However, the land has been cleared above the northern and southern ends of these longwalls.

The maximum predicted subsidence effects for WYLW24 to WYLW26 are similar to those predicted for the existing/approved WYLW17 to WYLW23. The potential impacts to the natural vegetation for WYLW24 to WYLW26 are therefore similar to those for the existing/approved WYLW17 to WYLW23.

A detailed survey of the natural vegetation has been undertaken and is described and assessed in the report prepared by Eco Logical Australia (2022). Further discussions are provided by the specialist ecology consultant on the project.

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

6.1.   The North Wambo Creek Diversion

The North Wambo Creek Diversion is partially located above the finishing (i.e. north-eastern) end of the existing/approved WYLW17. Surface cracking occurred along the diversion where this longwall mined directly beneath it. Descriptions of these impacts are provided in the subsidence summary review in Report No. MSEC1017.

The North Wambo Creek Diversion is located at distances greater than 600 m from the proposed WYLW24 to WYLW26. Further impacts are not anticipated due to the mining of these future longwalls due to their distances from the creek diversion.

6.2.   Public utilities

As listed in Table 2.1, there were no public utilities identified within the Study Area, apart from the unsealed roads and the associated drainage culverts, which are described below.

6.2.1.   Unsealed roads

There are unsealed tracks and fire trails located within the Study Area. The locations of these roads are shown in Drawing No. MSEC1317-09. The unsealed roads are used for the mining operations and for firefighting activities. Circular concrete culverts have been constructed, in some locations, where the roads cross the drainage lines.

Photographs of typical unsealed tracks located above the modified WYLW24 to WYLW26 are provided in Fig. 6.1.

Fig. 6.1   Typical unsealed tracks (P5490 and P5492)

The unsealed tracks and trails are located across WYLW24 to WYLW26 and, therefore, could experience the full range of predicted subsidence effects. A summary of the maximum predicted mine subsidence effects within the Study Area was provided in Chapter 4.

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

It is expected that cracking, rippling and stepping of the unsealed road surfaces would occur as each of the longwalls mine beneath them. The largest impacts will occur in the eastern part of the SBEUM mining area where the depths of cover are the shallowest. Examples of impacts observed along the tracks located above WYLW11 to WYLW13 and WYLW17 to WYLW20 are provided in Section 4.7. The crack widths above these longwalls typically varied between 25 mm and 50 mm, with localised crack widths up to approximately 400 mm.

The impacts on the unsealed tracks and fire trails due to the mining of WYLW24 to WYLW26 are expected to be similar to those observed due to the mining of WYLW11 to WYLW13 and WYLW17 to WYLW21. It is expected that the 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 effects. 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.

There are existing management strategies for maintaining the unsealed roads that are located above the previously extracted longwalls at the Wambo Coal Mine. It is expected that these same strategies could be used to maintain the unsealed roads which are located directly above the proposed WYLW24 to WYLW26. It is recommended that these roads are periodically visually inspected during active subsidence.

6.3.   Public amenities

As listed in Table 2.1, there were no public amenities identified within the Study Area.

6.4.   Farm land and facilities

6.4.1.   Agricultural utilisation

There is no major farm land or agricultural utilisation identified within the Study Area. The land has been cleared above the southern ends of the proposed WYLW24 to WYLW26, as shown in Fig. 5.18, and it is used for light grazing. There are also some farm features located within the Study Area which are described in the following sections.

6.4.2.   Fences

Fences are located across the Study Area and, therefore, they are expected to experience the full range of predicted subsidence effects. A summary of the maximum predicted conventional subsidence effects 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 WYLW24 to WYLW26. 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 strategies for the fences should be incorporated into the Built Features Management Plan.

6.4.3.   Farm dams

The farm dams are shown in Drawing No. MSEC1317-09.

There are five farm dams (Refs. d11 to d15) located above the proposed WYLW24 to WYLW26. The surface areas of the farm dams vary between 227 m^2 and 720 m^2 and the maximum lengths vary between 20 m and 36 m.

The farm dams are typically of earthen construction and have been established by localised cut and fill operations within the natural drainage lines. The dams within the Study Area are all located on WCPL owned land.

A photograph of a typical farm dam is provided in Fig. 6.2.

Fig. 6.2   Typical farm located above the southern end of WYLW26

A summary of the maximum predicted total vertical subsidence, tilt and curvatures for the farm dams is provided in Table 6.1. The values represent the maximum predicted accumulated movements within 20 m of the perimeters of the dams due to the mining of the existing, approved and proposed longwalls.

Table 6.1   Maximum predicted total vertical subsidence, tilt and curvatures for the farm dams

Location	Ref.	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Farm dams	d11	1800	15	> 3.0	> 3.0
	d12	1800	50	3.0	> 3.0
	d13	1800	30	2.5	3.0
	d14	350	30	> 3.0	1.5
	d15	1600	55	> 3.0	> 3.0

The farm dams are predicted to experience tilts up to 55 mm/m (i.e. 5.5 % or 1 in 18) and curvatures greater than 3.0 km^{-1} (i.e. minimum radius of curvature less than 0.3 km).

The maximum predicted conventional strains for the farm dams, based on applying a factor of 10 to the maximum predicted curvatures, are greater than 30 mm/m tensile and compressive. The distribution of the predicted strains due to the mining of the longwalls is described in Section 4.4. The maximum predicted strains for the farm dams (i.e. minimum depths of cover less than 100 m) are 12 mm/m tensile and 17 mm/m compressive based on the 95 % confidence levels.

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.

The maximum predicted subsidence effects for the farm dams, based on the Extraction Plan Layout, are the same as the maximum predicted values based on the MOD 19 Layout. The predictions for the dams do not change because the layout of WYLW24 to WYLW26 remains the same apart from the finishing (i.e. southern) end of WYLW24 which has been shortened by approximately 40 m.

The predicted final tilts for the farm dams vary between 15 mm/m (i.e. 1.5 % or 1 in 67) and 55 mm/m (i.e. 5.5 % or 1 in 18). Mining-induced tilts can affect the water levels around the perimeters of farm dams, with the freeboard increasing on one side and decreasing on the other. The predicted final changes in freeboard for the farm dams vary from less than 0.1 m to 0.5 m. It is unlikely, therefore, that the predicted tilts would adversely impact on the water storage capacities of the farm dams.

It is expected, at the magnitudes of predicted curvatures and strains, that fracturing and buckling would occur in the uppermost bedrock beneath the natural surface soils. Surface cracking could also occur in the cohesive soils forming the bases and walls of the dams, especially where the depths to 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.

It is recommended that the farm dams are visually inspected during active subsidence.

6.4.4. Registered groundwater bores

The registered groundwater bores within the Study Area are shown in Drawing No. MSEC1317-09. The locations and details of these bores were obtained from the Australian Groundwater Explorer, which is publicly available online (BoM, 2021).

WCPL owns two monitoring bores (Refs. GW200831 and GW200832) which are located outside but near the north-eastern end of the approved WYLW23 and the southern end of the proposed WYLW24. These two bores could be adversely impacted due to the mining of the longwalls. Impacts could include temporary lowering of the piezometric surface, blockage of the bore due to differential horizontal displacements at different horizons within the strata and changes to groundwater quality.

There were no other registered groundwater bores identified within the Study Area.

6.5. 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 the mine related infrastructure, which are described below.

6.5.1. Montrose Open Cut Pit

The Montrose Open Cut Pit is located to the north-east of the SBEUM mining area. The current extent of the pit is shown in Drawing No. MSEC1317-01. It is recommended that a geotechnical assessment of the highwall be undertaken based on the effects of the existing/approved WYLW17 to WYLW23 and the proposed WYLW24 to WYLW26.

6.5.2. Exploration drill holes

The locations of the exploration drill holes within the Study Area are shown in Drawing No. MSEC1317-09. The drill holes are located directly above and adjacent to the SBEUM mining area and, therefore, could experience the full range of predicted subsidence effects, which were described in Chapter 4. It is likely, therefore, that fracturing and shearing would occur in the drill holes as the result of mining. It is recommended that the exploration drill holes are capped (if not already completed) prior to being directly mined beneath.

6.6. Aboriginal heritage sites

6.6.1. Descriptions of the Aboriginal heritage sites

The known Aboriginal heritage sites are shown in Drawing No. MSEC1317-09.

There are 33 Aboriginal heritage sites that have been identified within the Study Area which all consist of open sites (artefacts or PAD). The site references are 37-5-0359, 37-5-0360, 37-5-0605, 37-5-0659, 37-5-0661, 37-5-0662, 37-5-0663, 37-5-0664, 37-5-0668, 37-5-0692, 37-5-0767, 37-5-0782, 37-5-0783 and 37-5-0807, 37-5-0786, 37-5-0787, 37-5-0788, 37-5-0789, 37-5-0790, 37-5-0791, Wambo Site 483, Wambo Site 513, Wambo Site 514, Wambo Site 515, Wambo Site 519, Wambo Site 520, Wambo Site 521, Wambo Site 522, Wambo Site 523, Wambo Site 524, Wambo Site 525, Wambo Site 526, Wambo Site 527 and Wambo Site 528.

Further descriptions of these sites are provided by South East Archaeology (2022).

6.6.2. Predictions for the Aboriginal heritage sites

The maximum predicted total subsidence effects for each of the Aboriginal heritage sites located within the Study Area are provided in Table D.01, in Appendix D. The values are the maximum predicted values within 20 m of the identified locations of each of the sites.

A summary of the maximum predicted total subsidence effects for the Aboriginal heritage sites is provided in Table 6.2. The values are the maximum predicted values within 20 m of the identified locations of each of the sites.

Table 6.2   Maximum predicted total subsidence, tilts and curvatures for the Aboriginal heritage sites within the Study Area

Site type	Maximum predicted total subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Open sites	1950	75	> 3.0	> 3.0

The maximum predicted total tilt for the Aboriginal heritage sites is 75 mm/m (i.e. 7.5 %, or 1 in 13). The maximum predicted total curvatures are greater than 3.0 km^{-1} hogging and sagging, which represents a minimum radius of curvature of less than 0.3 km.

The maximum predicted conventional strains for the Aboriginal heritage sites, based on applying a factor of 10 to the maximum predicted curvatures, are greater than 30 mm/m tensile and compressive.

The range of strains will vary considerably across the mining area due to, amongst other factors, variation in the depth of cover. The greatest strains are predicted to occur where the depths of cover are shallowest and lesser strains where the depths of cover are higher.

The distribution of the predicted strains due to the mining of the longwalls is described in Section 4.4. The maximum predicted strains for the Aboriginal heritage sites located above the mining area (i.e. minimum depths of cover less than 100 m) are 12 mm/m tensile and 17 mm/m compressive based on the 95 % confidence levels. The predicted strains are less where the depths of cover are greater above the mining area.

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.

The maximum predicted subsidence effects for the Aboriginal heritage sites, based on based on the Extraction Plan Layout, are the same as the maximum predicted values based on the MOD 19 Layout. The predictions for the sites do not change because the layout of WYLW24 to WYLW26 remains the same apart from the finishing (i.e. southern) end of WYLW24 which has been shortened by approximately 40 m.

The mining-induced curvatures and strains could cause surface cracking in the vicinity of the open sites, where they are located directly above the mining area. It is unlikely that the artefacts and deposits themselves would be impacted by surface cracking. It is possible, however, that if remediation of the surface were required after mining, that these works could potentially impact the open sites.

It is recommended that WCPL develop appropriate protocols and seek the required approvals from the appropriate authorities in the event that remediation of the surface is required in the locations of the open sites. Further assessments of the potential impacts on these sites are provided by South East Archaeology (2022).

6.7.   State survey control marks

The state survey control marks are shown in Drawing No. MSEC1317-09. The locations and details of the survey control marks were obtained from the *Land and Property Management Authority* using the *SCIMS Online* website (SCIMS, 2022).

There are no state survey control marks within the Study Area. However, there are state survey control marks identified further afield including within the Montrose Open Cut Pit.

The survey control marks located in the area could be affected by far-field horizontal movements, up to 3 km outside the extents of the mining area. Far-field horizontal movements and the methods used to predict such movements are described further in Sections 3.3 and 4.5.

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 Spatial Services will be required to ensure that these survey control marks are reinstated at the appropriate time, as required.

6.8.   Building structures

There are two sheds located above the southern end of the proposed WYLW26. The sheds are timber framed with metal sheet cladding. These structures are unused.

Photographs of the two unused sheds are provided in Fig. 6.3.

Fig. 6.3   Unused sheds located above the southern end of the proposed WYLW26

A summary of the maximum predicted total vertical subsidence, tilt and curvatures for the unused sheds is provided in Table 6.3. The values represent the maximum predicted accumulated movements within 20 m of the perimeters of the sheds due to the mining of the proposed longwalls.

Table 6.3   Maximum predicted total vertical subsidence, tilt and curvatures for the unused sheds

Location	Longwalls	Ref.	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Unused sheds	WYLW24 to WYLW26	r10 and r11	1800	60	> 3.0	> 3.0

The unused sheds could experience tilts up to 60 mm/m (i.e. 6 % or 1 in 17), curvatures greater than 3.0 km^{-1} (i.e. minimum radius of curvature less than 0.3 km) and strains greater than 30 mm/m. The predicted subsidence effects for these sheds, based on the Extraction Plan Layout, are the same as the maximum predicted values based on the MOD 19 Layout.

The predicted ground movements could result in the distortion of the timber frames and it is possible that these structures could become unsafe due to their existing poor conditions.

It is recommended that the unused sheds located above the southern end of WYLW26 are visually monitored during active subsidence as the longwall face mines directly beneath them. If either structure is identified as unstable or unsafe during monitoring, then measures should be undertaken to stabilise it, such as the provision of temporary bracing, or prevent access to it with the installation of fencing. Alternatively, the structures could be removed prior to active subsidence.

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APPENDIX A. GLOSSARY OF TERMS AND DEFINITIONS

Glossary of terms and definitions

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

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

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

APPENDIX B.   REFERENCES

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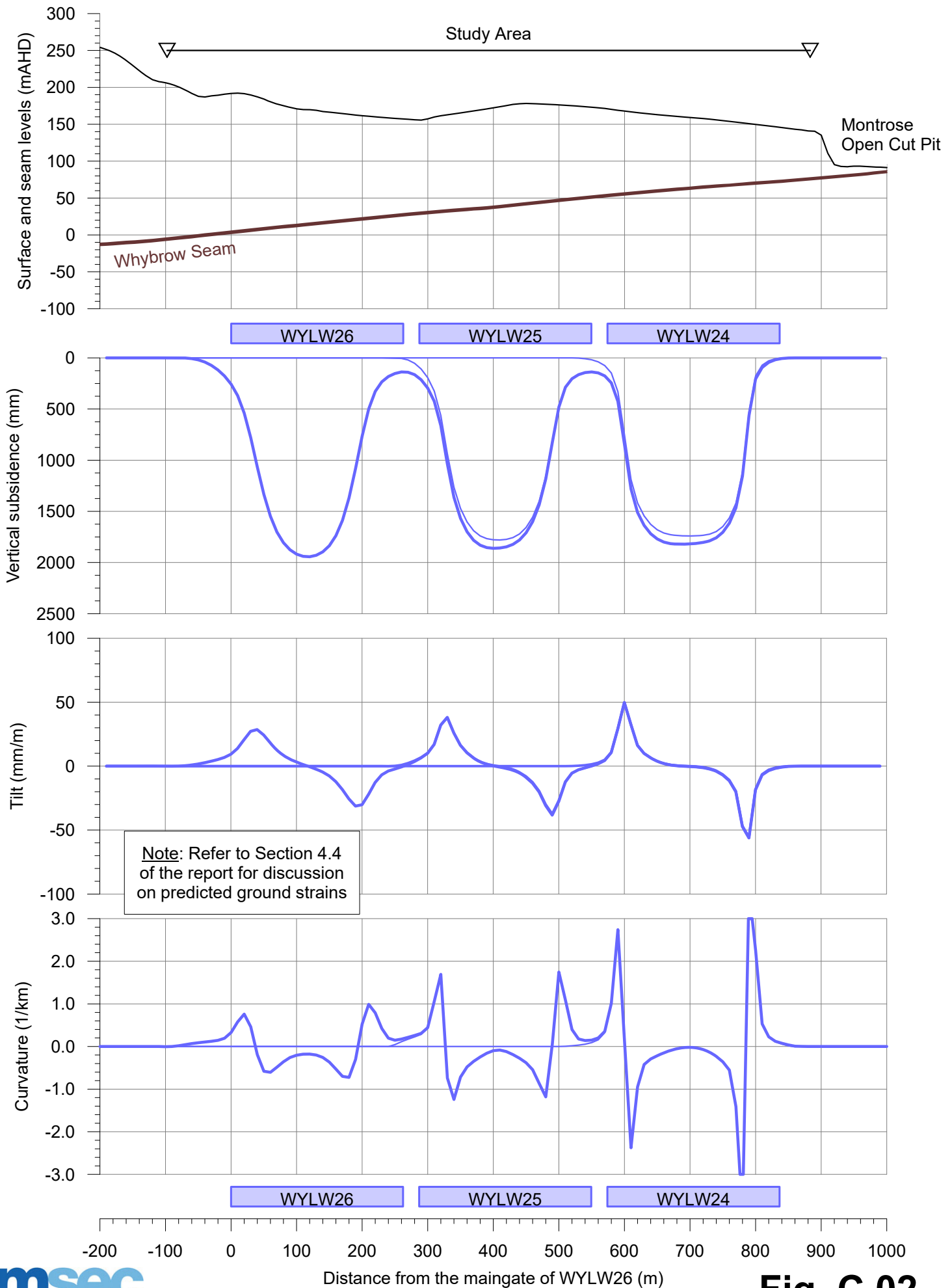
APPENDIX C.   FIGURES

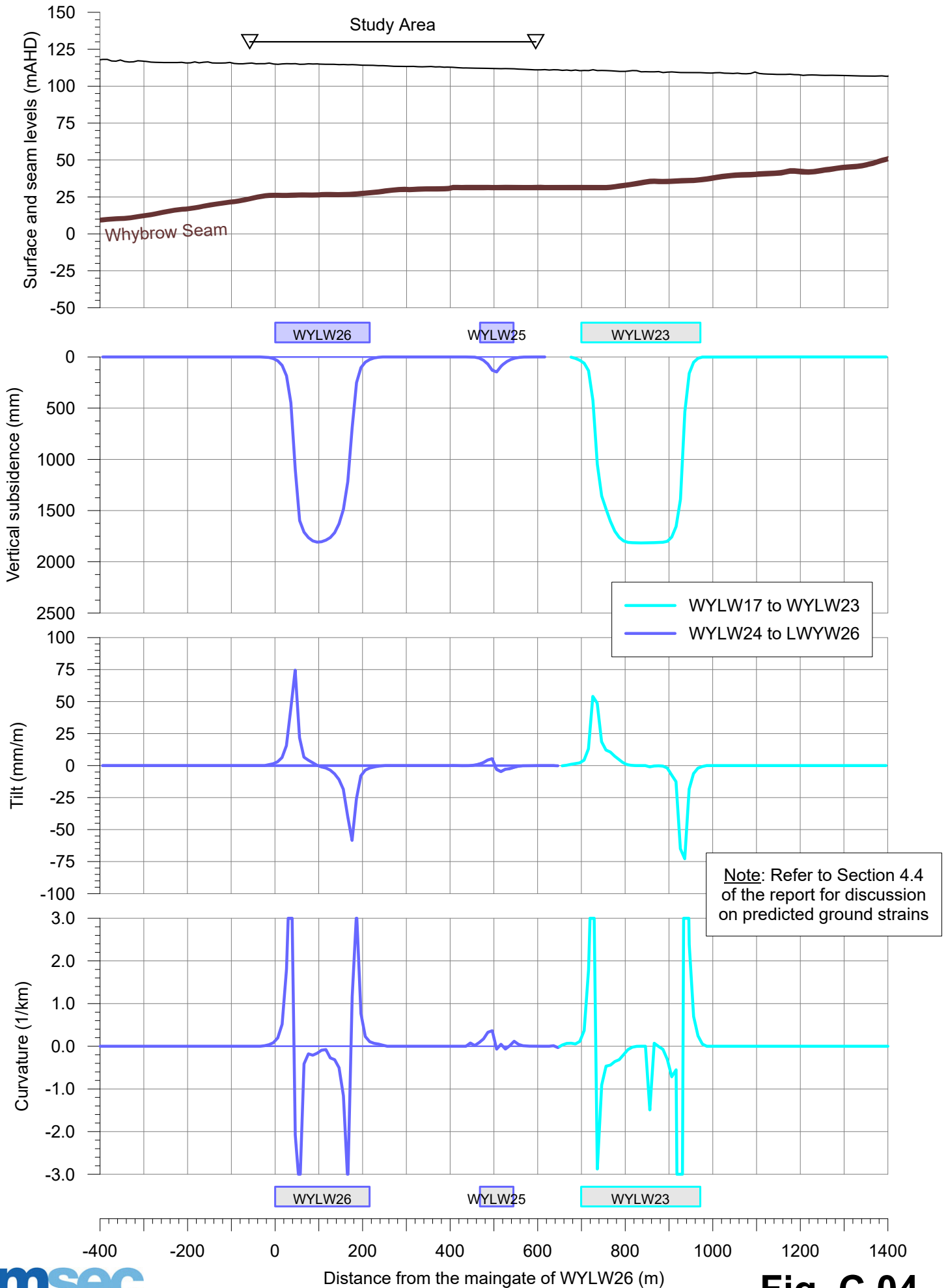# Predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 1 due to WYLW24 to WYLW26

Note: Refer to Section 4.4 of the report for discussion on predicted ground strains

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Fig. C.01
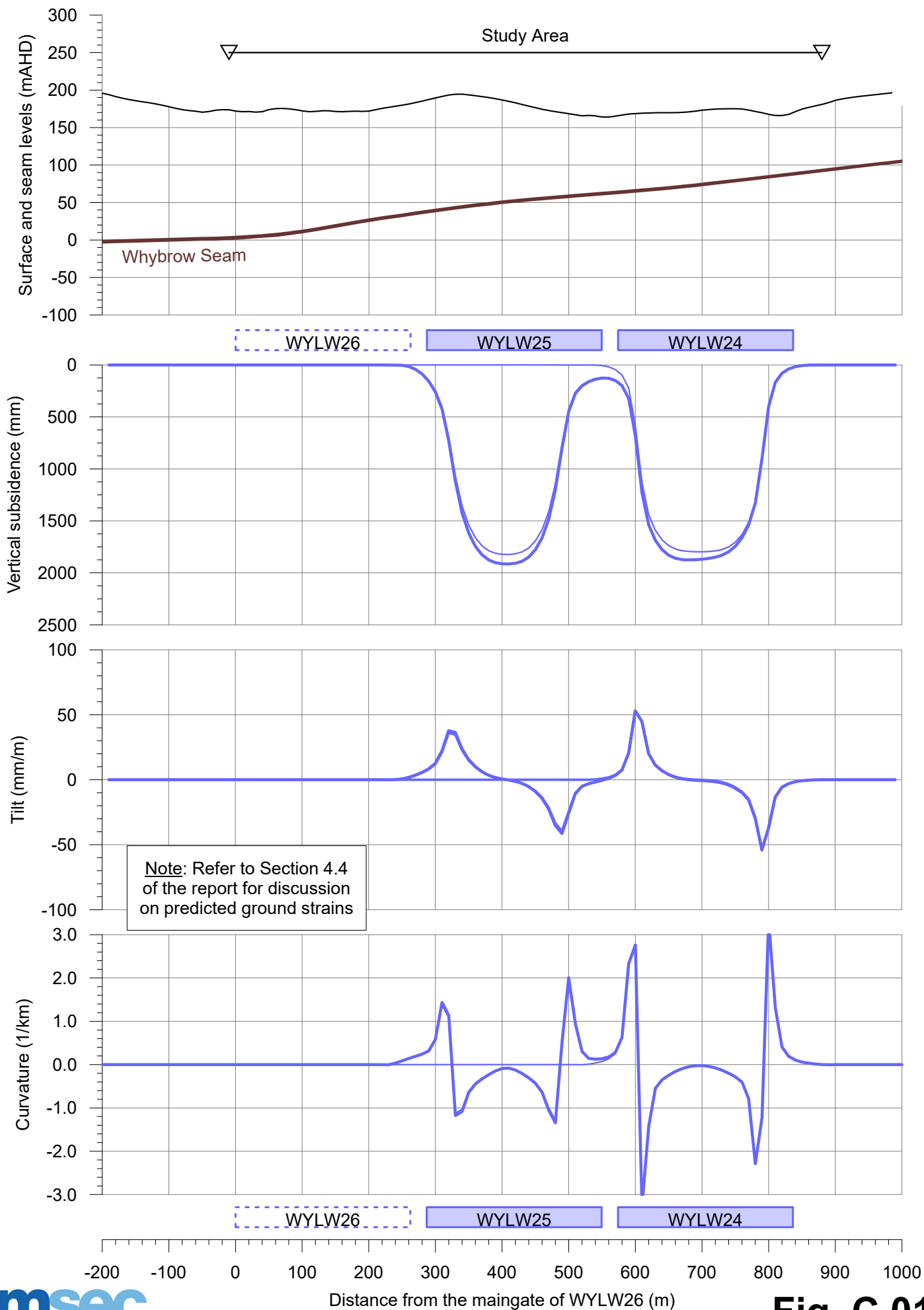
Predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 2 due to WYLW24 to WYLW26

Fig. C.02

Predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 3 due to WYLW24 to WYLW26
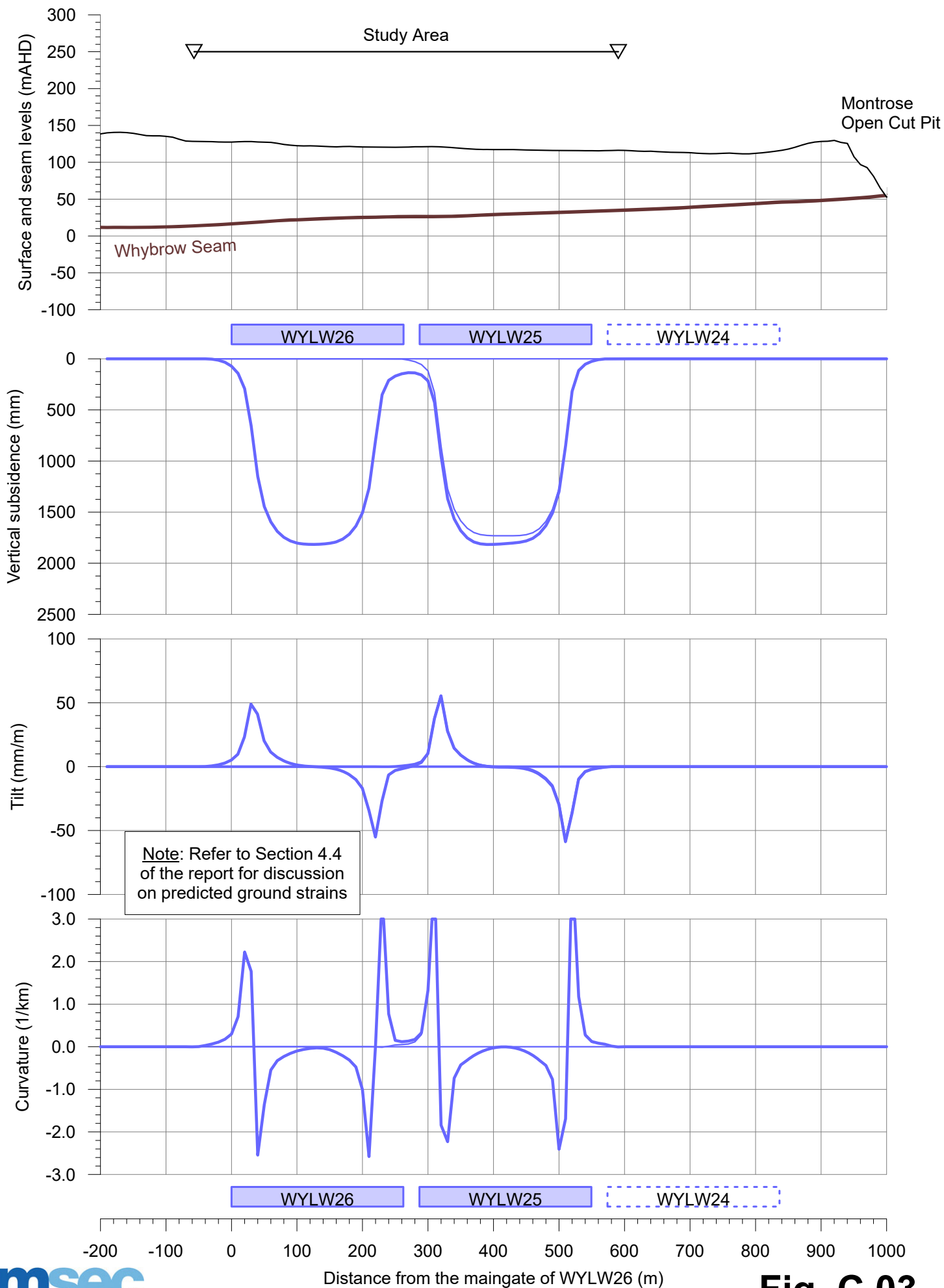
Fig. C.03

Predicted profiles of vertical subsidence, tilt and curvature along North Wambo Creek and Diversion due to WYLW17 to WYLW26

Fig. C.04

Predicted profiles of vertical subsidence, tilt and curvature along Waterfall Creek due to WYLW24 to WYLW26

Fig. C.05
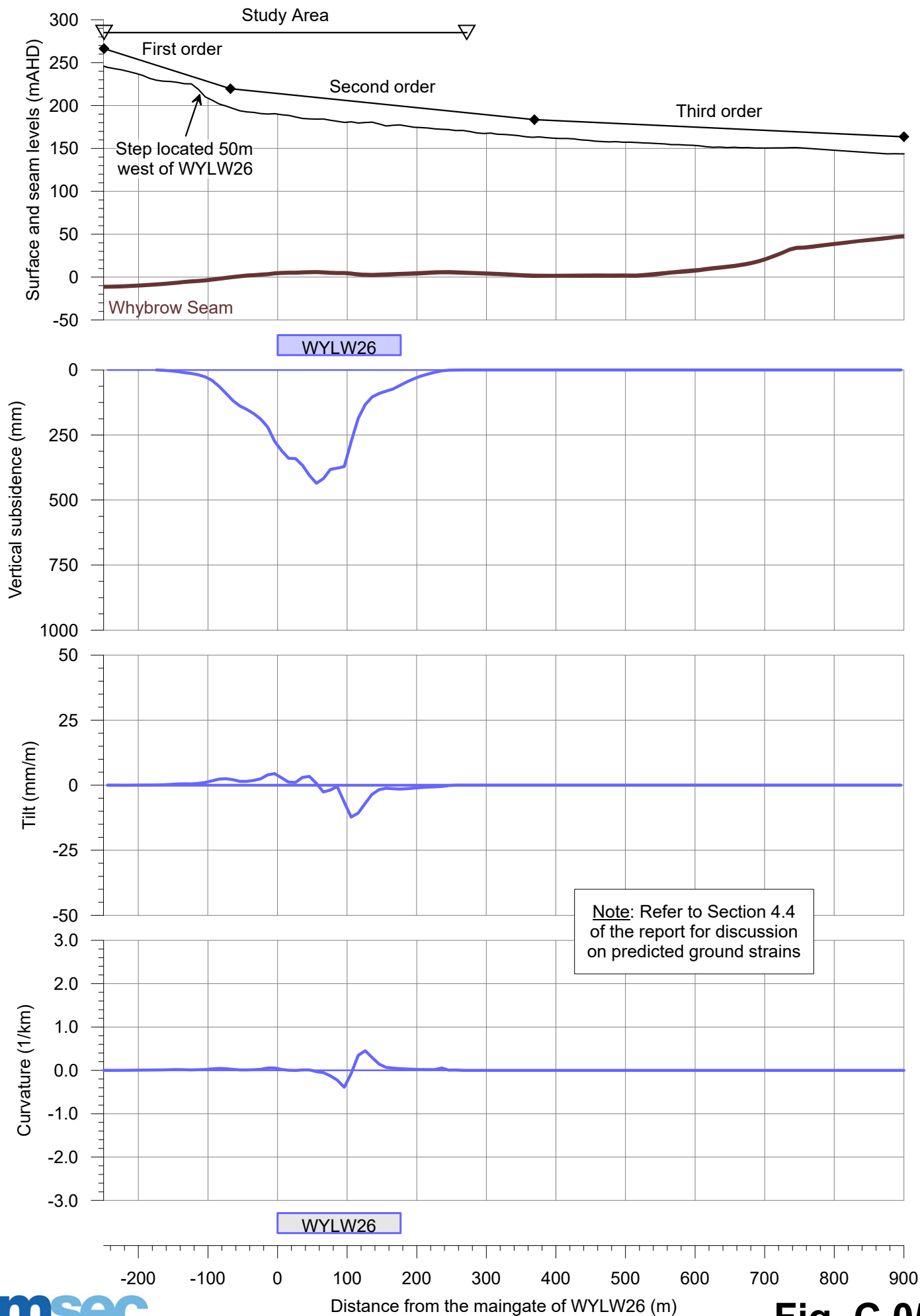
APPENDIX D.   TABLES

Table D.01 - Maximum predicted subsidence effects for the Aboriginal heritage sites

Reference	Type	Maximum Predicted Total Subsidence after WYLW24 (mm)	Maximum Predicted Total Subsidence after WYLW25 (mm)	Maximum Predicted Total Subsidence after WYLW26 (mm)	Maximum Predicted Total Tilt due to WYLW24 to WYLW26 (mm/m)	Maximum Predicted Total Hogging Curvature due to WYLW24 to WYLW26 (1/km)	Maximum Predicted Total Sagging Curvature due to WYLW24 to WYLW26 (1/km)
37-5-0359	Open site	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-5-0360	Open site	1800	1900	1900	75	> 3.0	> 3.0
37-5-0605	Open site	< 20	250	250	25	3	0.9
37-5-0659	Open site	< 20	< 20	1800	2	3	> 3.0
37-5-0661	Open site	< 20	150	250	9	0.7	0.2
37-5-0662	Open site	< 20	< 20	1600	35	1.5	1.5
37-5-0663	Open site	< 20	50	500	35	2.5	0.8
37-5-0664	Open site	< 20	1800	1900	55	> 3.0	> 3.0
37-5-0668	Open site	1750	1850	1850	75	> 3.0	> 3.0
37-5-0692	Open site	25	25	25	2	0.2	0.1
37-5-0767	Open site	< 20	1750	1850	55	> 3.0	> 3.0
37-5-0782	Open site	< 20	< 20	1800	10	2.5	3
37-5-0783 and 37-5-0807	Open site	< 20	1800	1900	25	> 3.0	> 3.0
37-5-0786	Open site	< 20	1850	1950	5	> 3.0	> 3.0
37-5-0787	Open site	< 20	1800	1900	50	> 3.0	> 3.0
37-5-0788	Open site	< 20	1850	1950	45	> 3.0	> 3.0
37-5-0789	Open site	< 20	1700	1800	55	> 3.0	> 3.0
37-5-0790	Open site	< 20	25	25	2	0.6	0.1
37-5-0791	Open site	< 20	1750	1850	60	> 3.0	> 3.0
Wambo Site 483	Open Artefact Site	< 20	1550	1650	55	> 3.0	> 3.0
Wambo Site 513	Open site	< 20	1650	1700	35	1	1.5
Wambo Site 514	Open site	< 20	1550	1650	40	1.5	2
Wambo Site 515	Open site	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
Wambo Site 519	Open site	1500	1550	1550	70	> 3.0	> 3.0
Wambo Site 520	Open site	< 20	< 20	< 20	1	0.1	< 0.01
Wambo Site 521	Open site	< 20	25	25	3	0.2	0.1
Wambo Site 522	Open site	< 20	< 20	50	2	0.1	0.02
Wambo Site 523	Open site	< 20	< 20	1300	30	0.5	1
Wambo Site 524	Open site	1800	1900	1900	3	> 3.0	> 3.0
Wambo Site 525	Open site	< 20	< 20	1650	40	2	2
Wambo Site 526	Open site	< 20	< 20	1600	35	1.5	1
Wambo Site 527	Open site	< 20	1750	1850	10	1.5	2
Wambo Site 528	Open site	1750	1850	1850	55	> 3.0	> 3.0
Maximum		**1800**	**1900**	**1950**	**75**	**> 3.0**	**> 3.0**

APPENDIX E.   DRAWINGS

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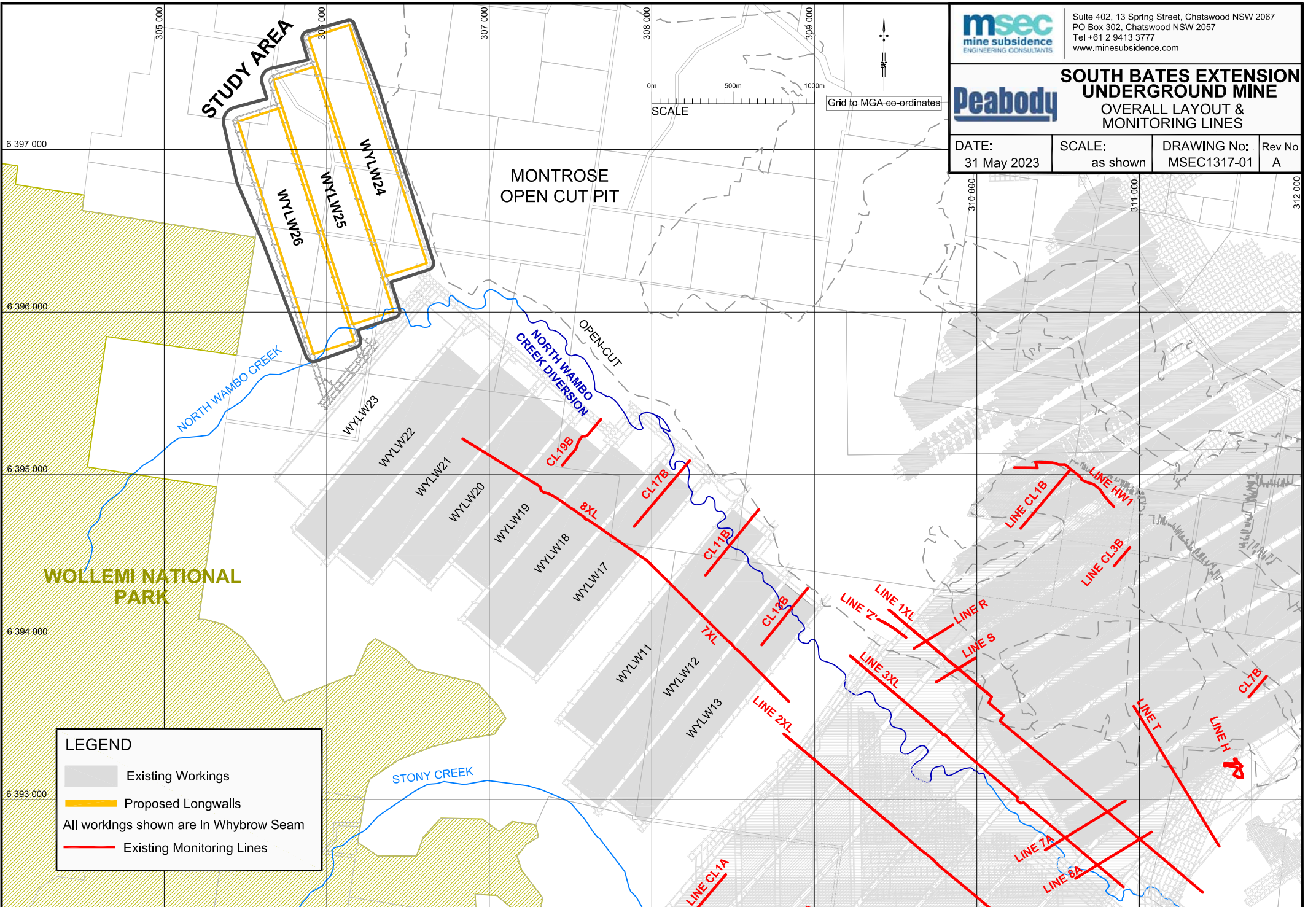mine subsidence
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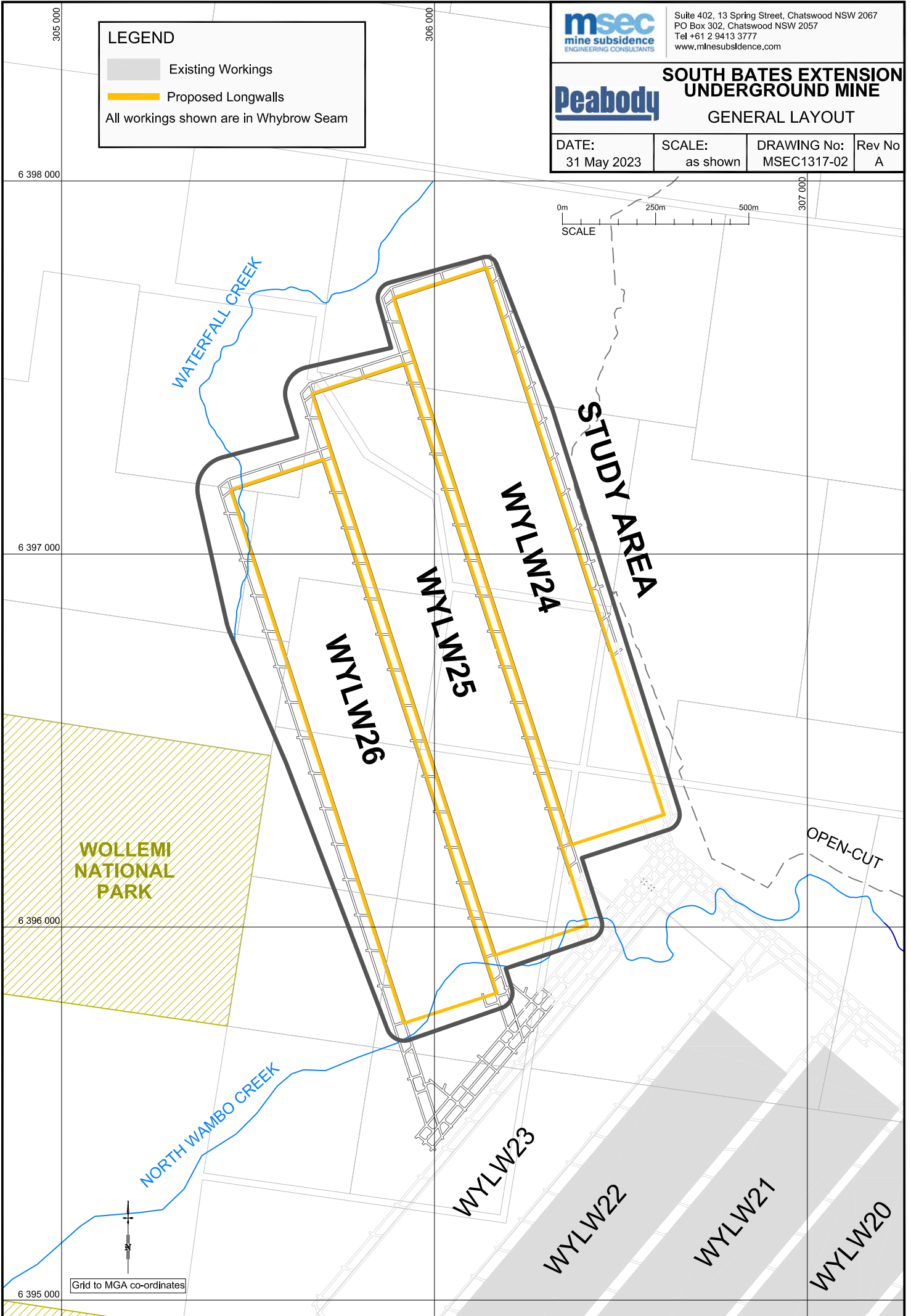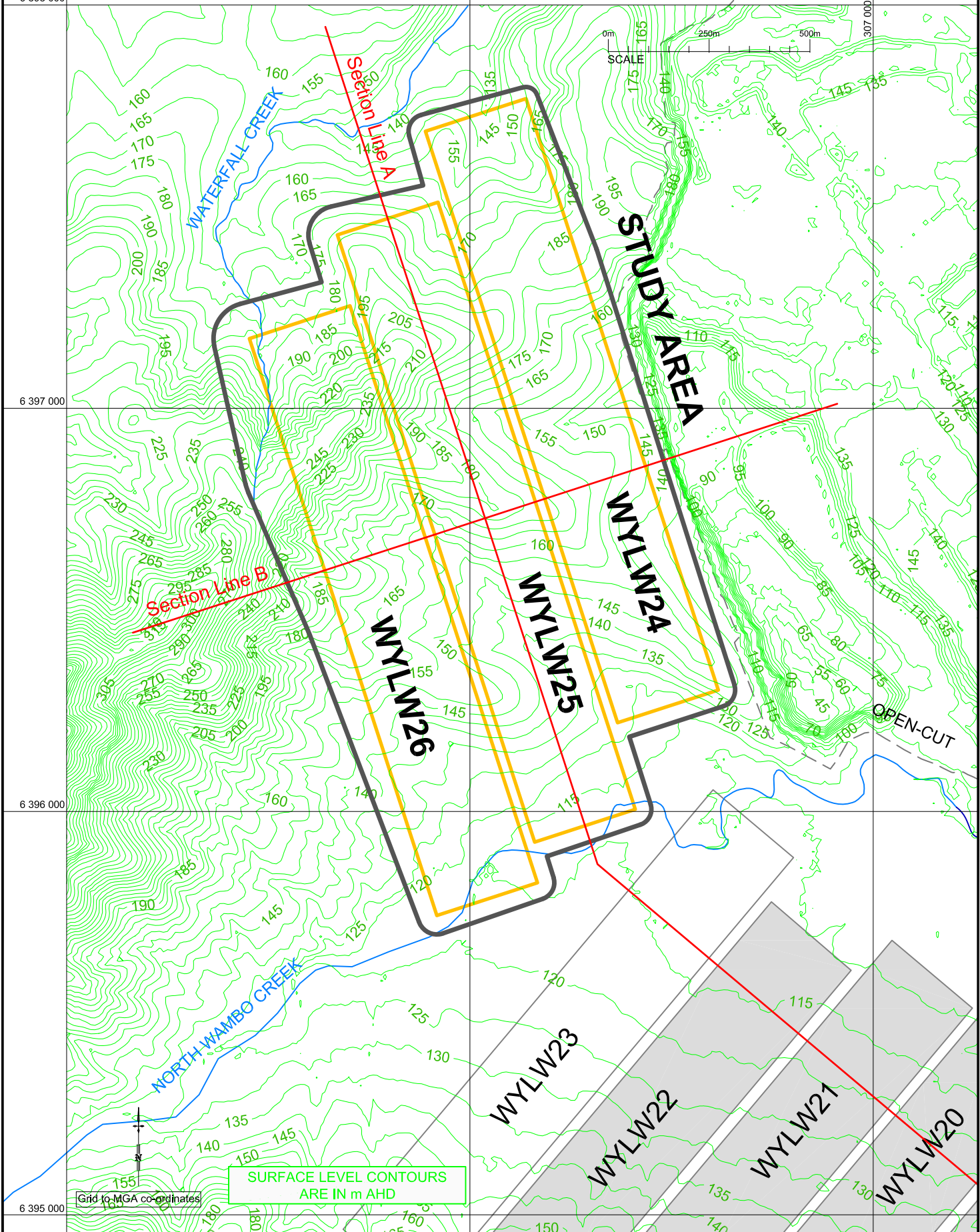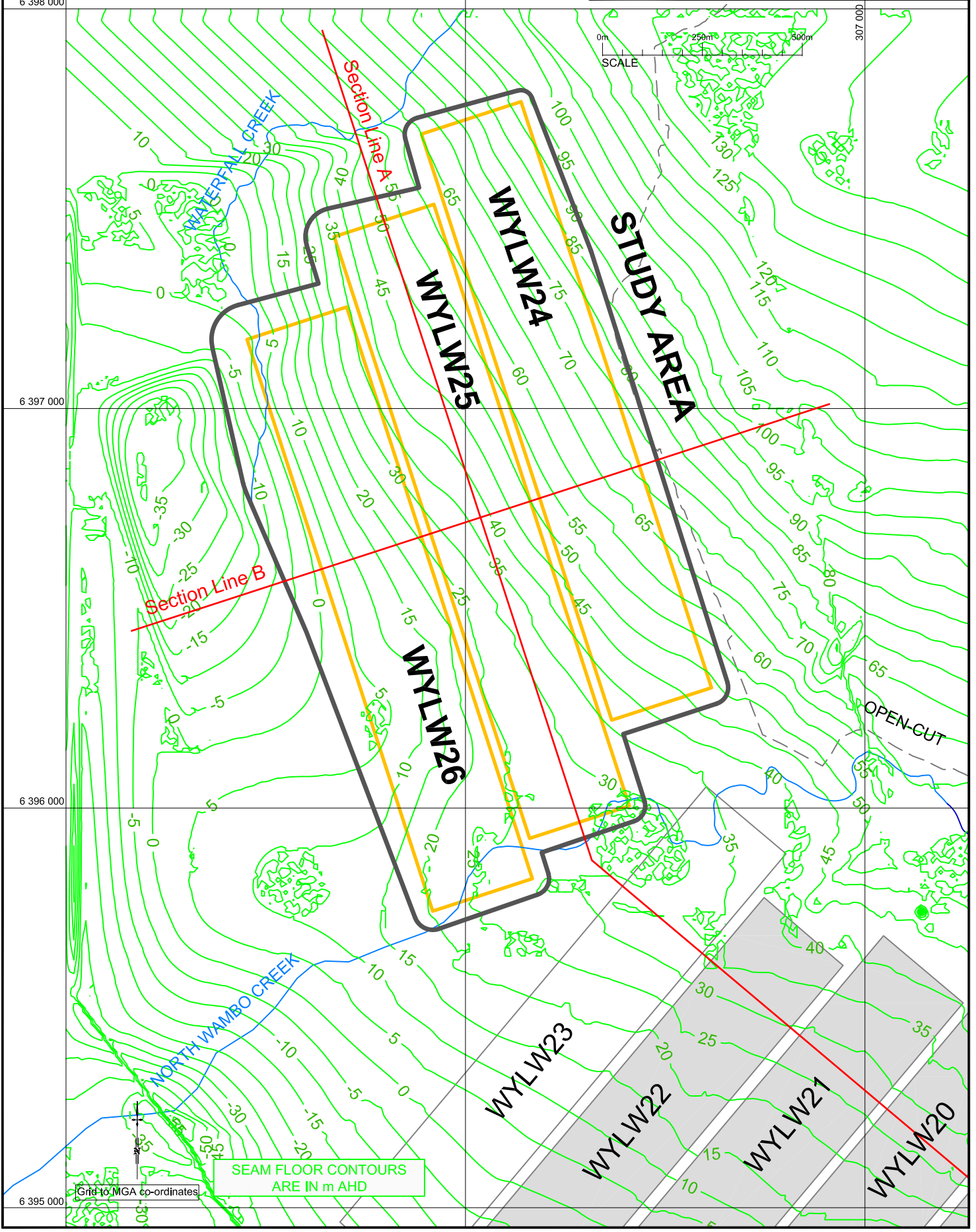www.minesubsidence.com

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SOUTH BATES EXTENSION UNDERGROUND MINE
OVERALL LAYOUT &
MONITORING LINES

DATE: 31 May 2023	SCALE: as shown	DRAWING No: MSEC1317-01	Rev No A

SCALE

0m   500m   1000m

Grid to MGA co-ordinates

STUDY AREA

WYLW24
WYLW25
WYLW26
WYLW23
WYLW22
WYLW21
WYLW20
WYLW19
WYLW18
WYLW17
WYLW11
WYLW12
WYLW13

MONTROSE
OPEN CUT PIT

NORTH WAMBO CREEK

NORTH WAMBO CREEK DIVERSION

OPEN-CUT

WOLLEMI NATIONAL PARK

STONY CREEK

CL19B
CL17B
CL11B
CL13B
8XL
7XL

LINE CL1B
LINE HW1
LINE CL3B
LINE 1XL
LINE 'Z'
LINE R
LINE S
LINE 3XL
LINE 2XL
LINE T
LINE H
LINE CL1A
LINE 7A
LINE 8A
CL7B

305 000
306 000
307 000
308 000
309 000
310 000
311 000
312 000

6 397 000
6 396 000
6 395 000
6 394 000
6 393 000

LEGEND

Existing Workings

Proposed Longwalls

All workings shown are in Whybrow Seam

Existing Monitoring Lines

LEGEND

Existing Workings

Proposed Longwalls

All workings shown are in Whybrow Seam

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**SOUTH BATES EXTENSION
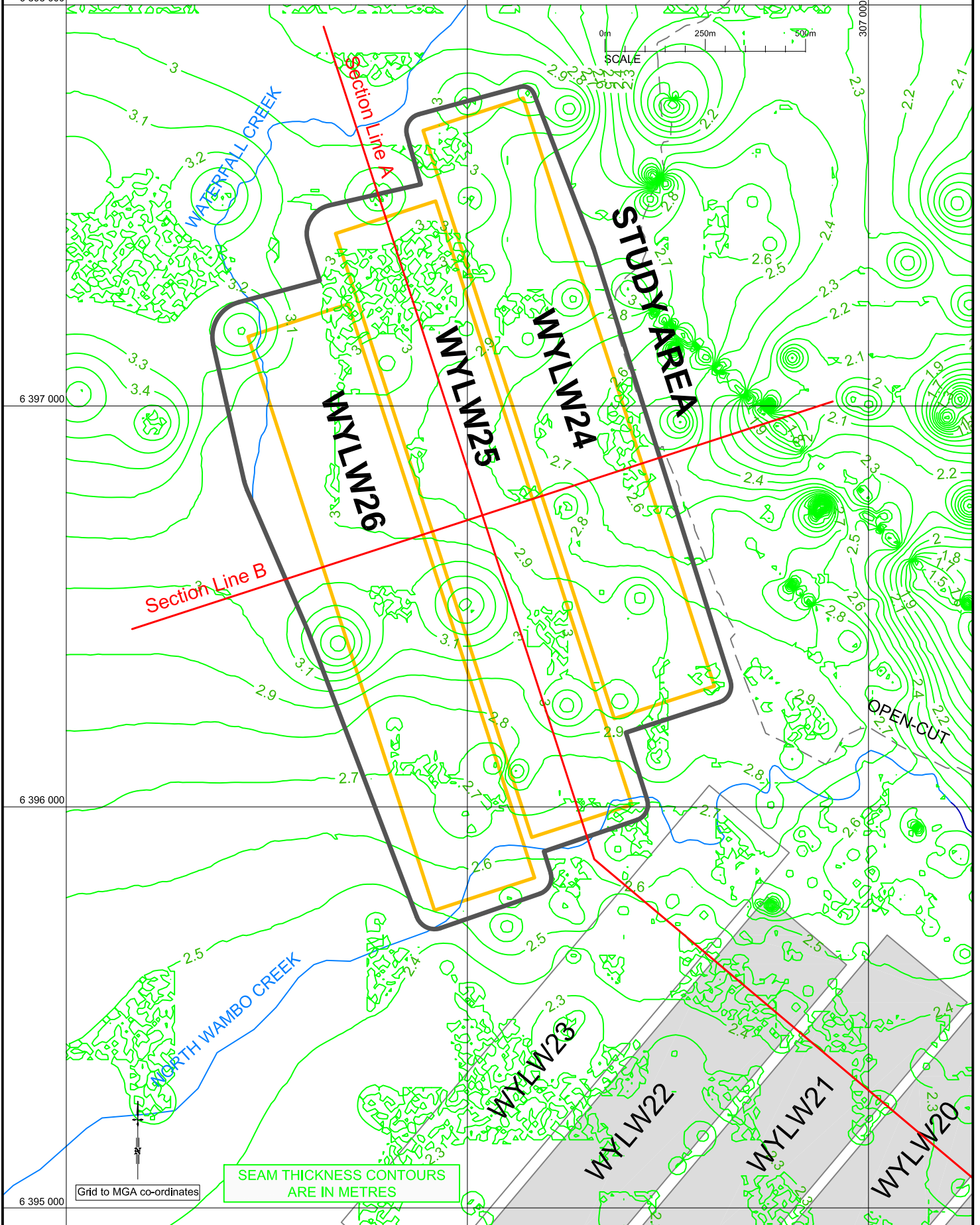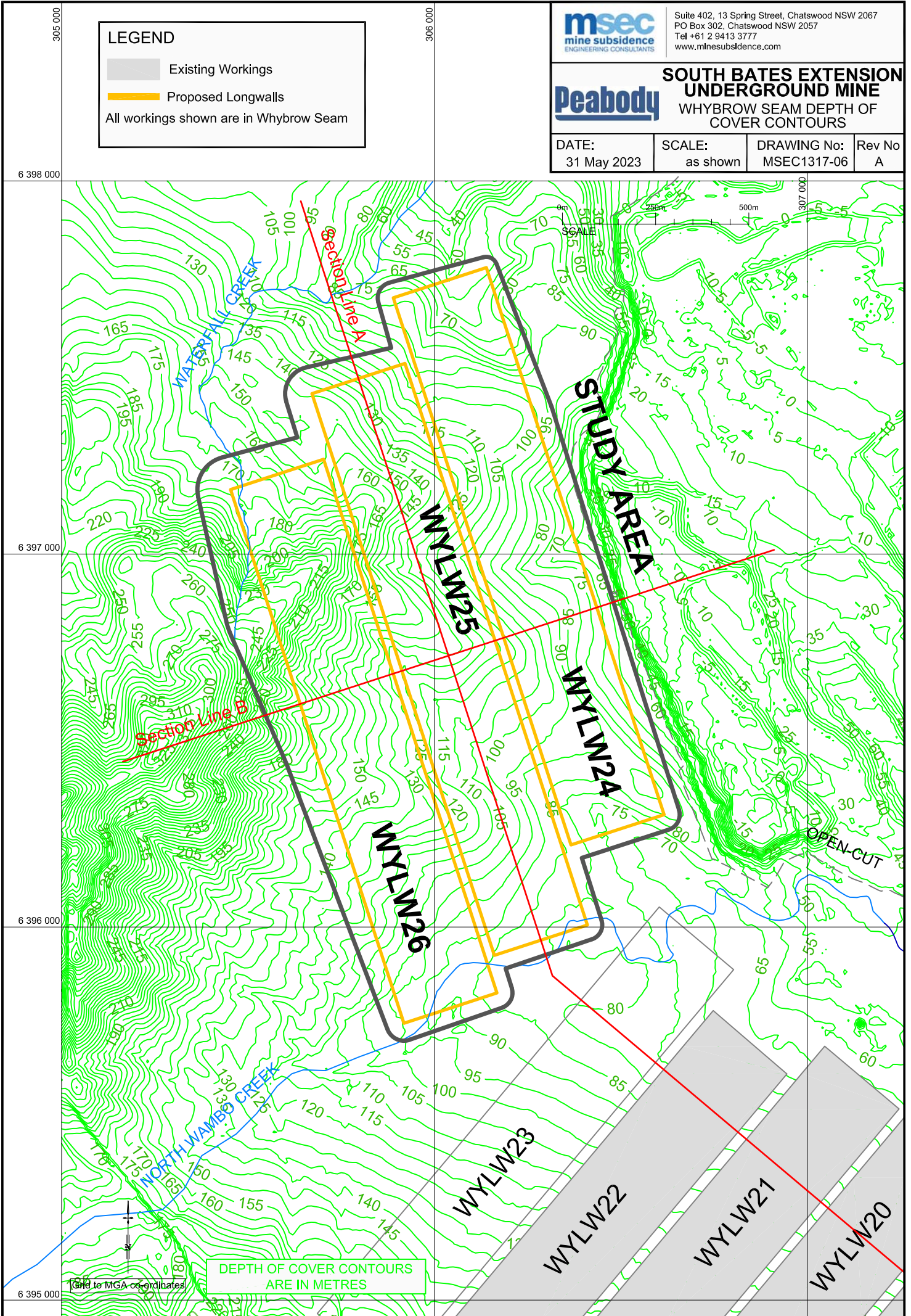UNDERGROUND MINE**

GENERAL LAYOUT

DATE: 31 May 2023	SCALE: as shown	DRAWING No: MSEC1317-02	Rev No A

0m   250m   500m
SCALE

STUDY AREA

WYLW24

WYLW25

WYLW26

WATERFALL CREEK

WOLLEMI
NATIONAL
PARK

NORTH WAMBO CREEK

OPEN-CUT

WYLW23

WYLW22

WYLW21

WYLW20

305 000

306 000

307 000

6 398 000

6 397 000

6 396 000

6 395 000

Grid to MGA co-ordinates

LEGEND

Existing Workings

Proposed Longwalls

All workings shown are in Whybrow Seam

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**SOUTH BATES EXTENSION
UNDERGROUND MINE**

SURFACE LEVEL CONTOURS

DATE: 31 May 2023	SCALE: as shown	DRAWING No: MSEC1317-03	Rev No A

STUDY AREA

WYLW24

WYLW25

WYLW26

WYLW23

WYLW22

WYLW21

WYLW20

Section Line A

Section Line B

WATERFALL CREEK

NORTH WAMBO CREEK

OPEN-CUT

SURFACE LEVEL CONTOURS
ARE IN m AHD

Grid to MGA co-ordinates

0m   250m   500m
SCALE

LEGEND

Existing Workings

Proposed Longwalls

All workings shown are in Whybrow Seam

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SOUTH BATES EXTENSION
UNDERGROUND MINE
WHYBROW SEAM FLOOR
CONTOURS

DATE: 31 May 2023	SCALE: as shown	DRAWING No: MSEC1317-04	Rev No A

SCALE
0m   250m   500m

STUDY AREA

WYLW24

WYLW25

WYLW26

WYLW23

WYLW22

WYLW21

WYLW20

Section Line A

Section Line B

WATERFALL CREEK

NORTH WAMBO CREEK

OPEN-CUT

SEAM FLOOR CONTOURS
ARE IN m AHD

Grid to MGA co-ordinates

mSec
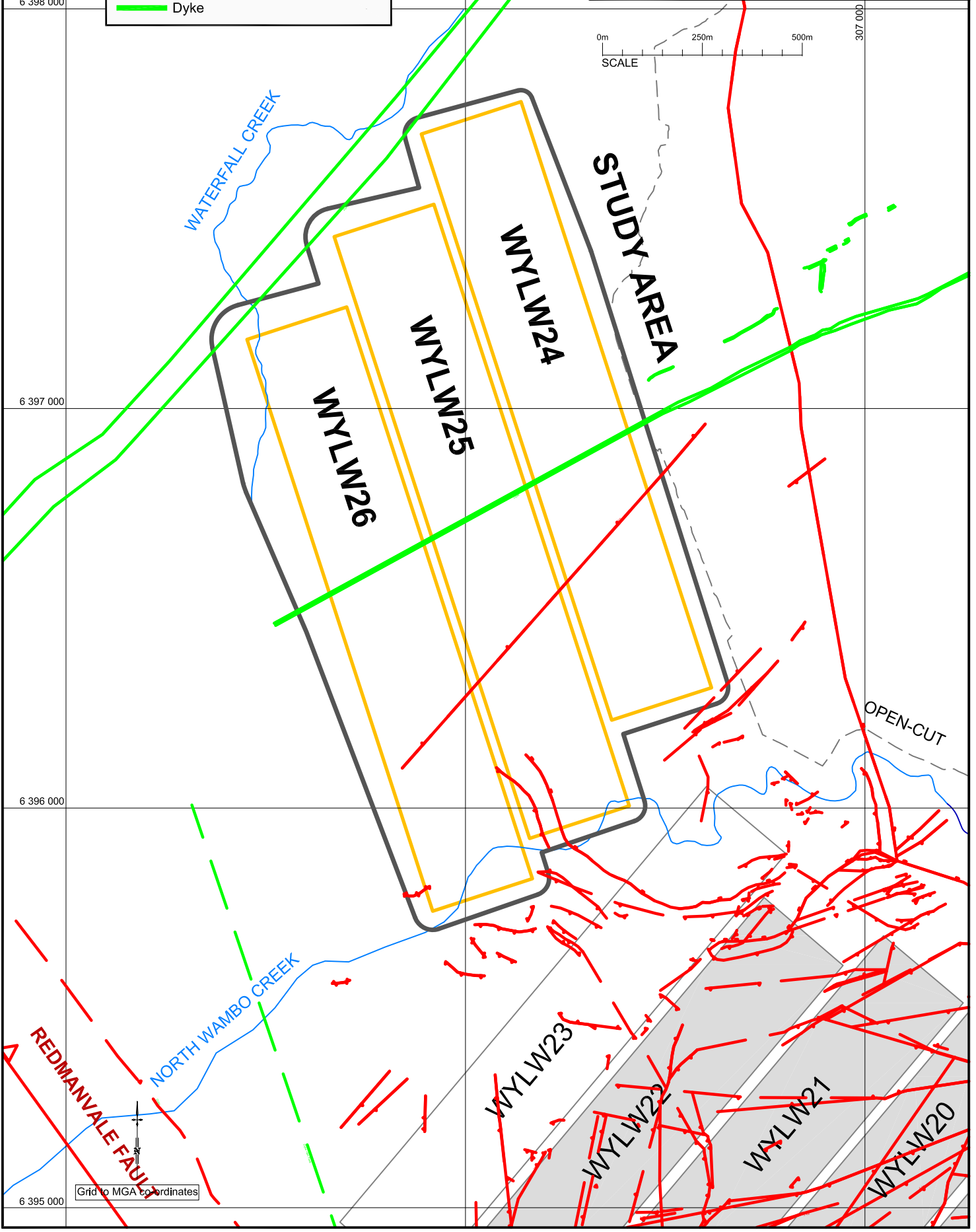mine subsidence
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SOUTH BATES EXTENSION UNDERGROUND MINE
WHYBROW SEAM
THICKNESS CONTOURS

Peabody

DATE: 31 May 2023	SCALE: as shown	DRAWING No: MSEC1317-05	Rev No A

LEGEND

Existing Workings

Proposed Longwalls

All workings shown are in Whybrow Seam

SCALE
0m   250m   500m

STUDY AREA

WYLW24
WYLW25
WYLW26

Section Line A
Section Line B

WATERFALL CREEK
NORTH WAMBO CREEK

OPEN-CUT

WYLW23
WYLW22
WYLW21
WYLW20

Grid to MGA co-ordinates

SEAM THICKNESS CONTOURS
ARE IN METRES

LEGEND

Existing Workings

Proposed Longwalls

All workings shown are in Whybrow Seam

msec
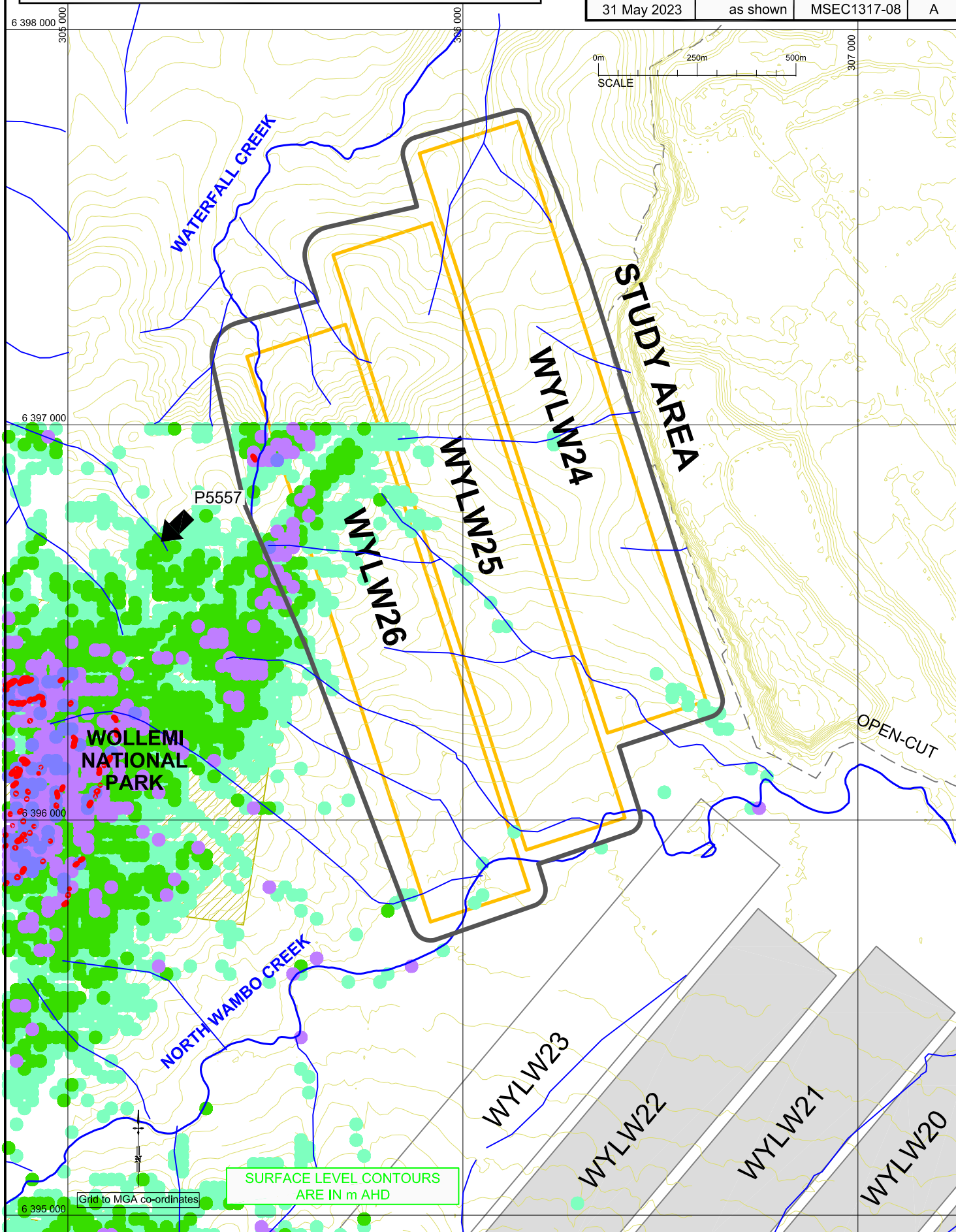mine subsidence
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**SOUTH BATES EXTENSION
UNDERGROUND MINE**
WHYBROW SEAM DEPTH OF
COVER CONTOURS

DATE: 31 May 2023	SCALE: as shown	DRAWING No: MSEC1317-06	Rev No A

STUDY AREA

WYLW25

WYLW24

WYLW26

OPEN-CUT

WYLW23

WYLW22

WYLW21

WYLW20

Section Line A

Section Line B

WATERFALL CREEK

NORTH WAMBO CREEK

DEPTH OF COVER CONTOURS
ARE IN METRES

Grid to MGA co-ordinates

0m   250m   500m
SCALE

LEGEND

Existing Workings

Proposed Longwalls

All workings shown are in Whybrow Seam

Geological Structures -

Faults

Dyke

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**SOUTH BATES EXTENSION
UNDERGROUND MINE**

GEOLOGY AT SEAM LEVEL

| DATE:
31 May 2023 | SCALE:
as shown | DRAWING No:
MSEC1317-07 | Rev No
A |

SCALE 0m 250m 500m

WYLW24

WYLW25

WYLW26

STUDY AREA

OPEN-CUT

WATERFALL CREEK

NORTH WAMBO CREEK

REDMANVALE FAULT

WYLW23

WYLW22

WYLW21

WYLW20

Grid to MGA coordinates

305 000

306 000

307 000

6 398 000

6 397 000

6 396 000

6 395 000

LEGEND

Existing Workings

Proposed Longwalls

All workings shown are in Whybrow Seam

Cliffs
Slopes (1 in 1 to 2 in 1)
Slopes (1 in 1.5 to 1 in 1)
Slopes (1 in 2 to 1 in 1.5)
Slopes (1 in 3 to 1 in 2)
5m Surface Level Contours
Drainage Lines

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
SOUTH BATES EXTENSION UNDERGROUND MINE

NATURAL FEATURES

DATE: 31 May 2023	SCALE: as shown	DRAWING No: MSEC1317-08	Rev No A

SCALE

0m   250m   500m

STUDY AREA

WYLW24

WYLW25

WYLW26

P5557

WATERFALL CREEK

WOLLEMI NATIONAL PARK

NORTH WAMBO CREEK

OPEN-CUT

WYLW23

WYLW22

WYLW21

WYLW20

SURFACE LEVEL CONTOURS ARE IN m AHD

Grid to MGA co-ordinates

6 398 000
6 397 000
6 396 000
6 395 000

305 000
306 000
307 000

LEGEND

- Existing Workings
- Proposed Longwalls

All workings shown are in Whybrow Seam

- ▲ Aboriginal Heritage Sites
- --- Tracks
- ⬛ Buildings
- 🐋 Dams
- 🔵 Groundwater Bores
- ⊠ Exploration Bores

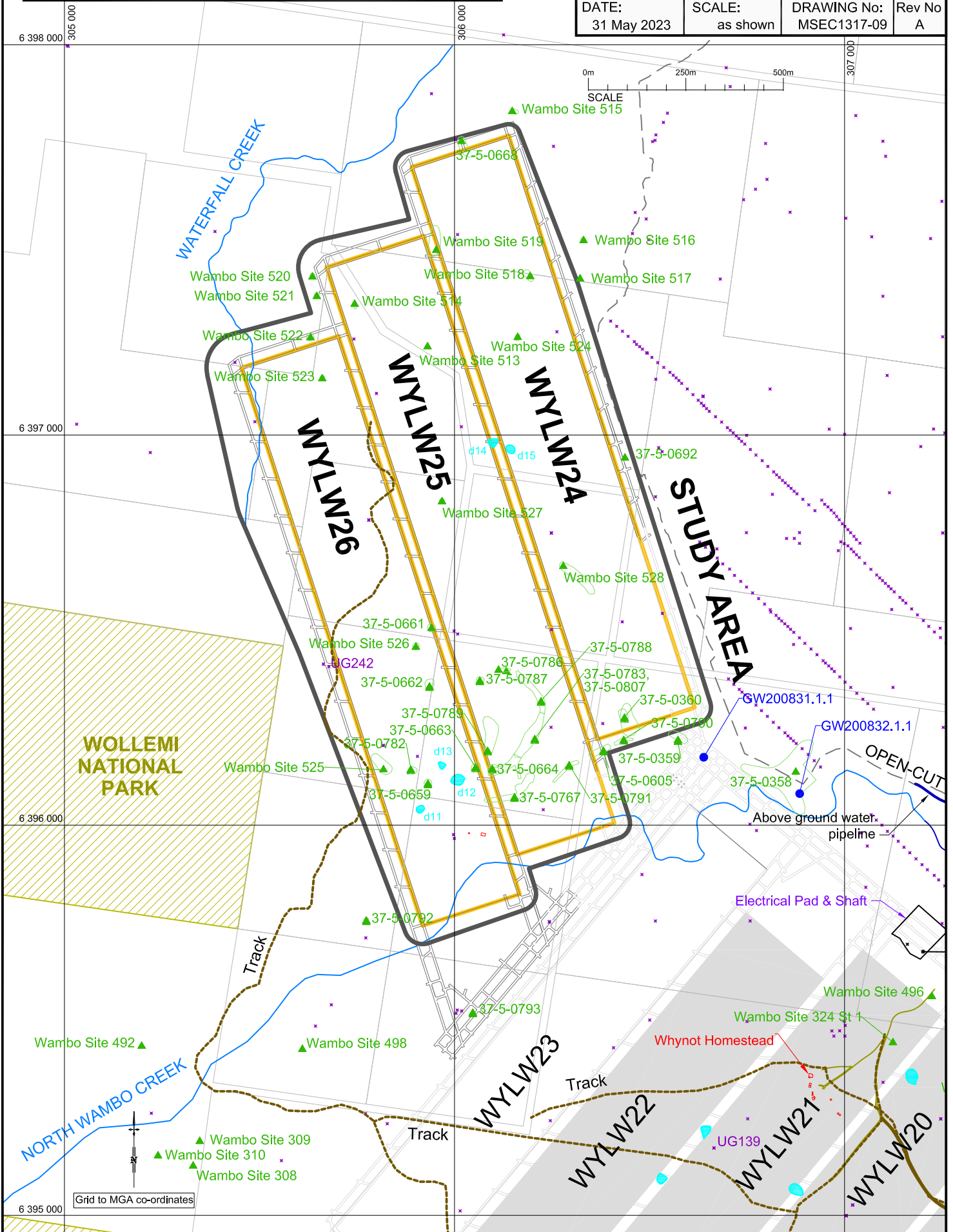msec
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SOUTH BATES EXTENSION
UNDERGROUND MINE
BUILT FEATURES & ABORIGINAL
HERITAGE SITES

| DATE:
31 May 2023 | SCALE:
as shown | DRAWING No:
MSEC1317-09 | Rev No
A |

LEGEND

Existing Workings

Proposed Longwalls

All workings shown are in Whybrow Seam

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SOUTH BATES EXTENSION UNDERGROUND MINE
PREDICTED TOTAL SUBSIDENCE
AFTER WYLW24

DATE: 31 May 2023	SCALE: as shown	DRAWING No: MSEC1317-10	Rev No A

SCALE: 0m — 250m — 500m

LEGEND
SUBSIDENCE
CONTOUR COLOUR
SCALE (mm)

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

WATERFALL CREEK

1850

Prediction Line 1

WYLW26

WYLW25

WYLW24

Prediction Line 2

1800

WOLLEMI
NATIONAL
PARK

Prediction Line 3

OPEN-CUT

NORTH WAMBO CREEK

WYLW23

WYLW22

WYLW21

WYLW20

Grid to MGA co-ordinates

NOTE:
The value of the Subsidence Contours, from the outside to the inside of the panels, are 20mm, 50mm, 100mm, 200mm, and so forth, in 100mm increments. The maximum subsidence is shown in brackets

LEGEND

Existing Workings

Proposed Longwalls

All workings shown are in Whybrow Seam

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mine subsidence
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**SOUTH BATES EXTENSION
UNDERGROUND MINE**
PREDICTED TOTAL SUBSIDENCE
AFTER WYLW25

DATE: 31 May 2023	SCALE: as shown	DRAWING No: MSEC1317-11	Rev No A

0m   250m   500m
SCALE

LEGEND
SUBSIDENCE
CONTOUR COLOUR
SCALE (mm)

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

1950

1850

WATERFALL CREEK

Prediction Line 1

WYLW24

WYLW25

WYLW26

1850

Prediction Line 2

WOLLEMI
NATIONAL
PARK

Prediction Line 3

OPEN-CUT

NORTH WAMBO CREEK

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 100mm increments.
The maximum subsidence is
shown in brackets

Grid to MGA co-ordinates

WYLW23

WYLW22

WYLW21

WYLW20

305 000

306 000

307 000

6 398 000

6 397 000

6 396 000

6 395 000

LEGEND

Existing Workings

Proposed Longwalls

All workings shown are in Whybrow Seam

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mine subsidence
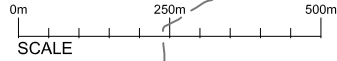ENGINEERING CONSULTANTS

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SOUTH BATES EXTENSION
UNDERGROUND MINE
PREDICTED TOTAL SUBSIDENCE
AFTER WYLW26

DATE: 31 May 2023	SCALE: as shown	DRAWING No: MSEC1317-12	Rev No A

0m   250m   500m
SCALE

LEGEND
SUBSIDENCE
CONTOUR COLOUR
SCALE (mm)

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

305 000

306 000

307 000

6 398 000

6 397 000

6 396 000

6 395 000

WATERFALL CREEK

1950

1950

Prediction Line 1

1900

Prediction Line 2

1950

Prediction Line 3

WYLW24

WYLW25

WYLW26

WOLLEMI
NATIONAL
PARK

OPEN-CUT

NORTH WAMBO CREEK

WYLW23

WYLW22

WYLW21

WYLW20

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 100mm increments.
The maximum subsidence is
shown in brackets

Grid to MGA co-ordinates