MAXWELL UNDERGROUND MINE PROJECT

APPENDIX A

Subsidence Assessment

mine subsidence
ENGINEERING CONSULTANTS

MALABAR

MAXWELL UNDERGROUND MINE PROJECT:

Modification Application – Subsidence Assessment

Subsidence Predictions and Impact Assessments for Natural and Built Features due to Multi-seam Mining in the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams, in Support of the Modification Application

DOCUMENT REGISTER

Revision	Description	Author	Checker	Date
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Report produced to: support the Modification Application for the Maxwell Underground Mine Project.

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

Introduction to Longwall Mining and Subsidence (Revision A)

General Discussion of Mine Subsidence Ground Movements (Revision A)

Mine Subsidence Damage to Building Structures (Revision A)

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

The Maxwell Underground Mine Project (the Project) is an approved underground coal mining operation owned by Maxwell Ventures (Management) Pty Ltd, a wholly owned subsidiary of Malabar Resources Limited (Malabar). Malabar will utilise bord and pillar panels (with partial pillar extraction) in the Whynot Seam and longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams within Mining Lease 1822.

Malabar submitted an Environmental Impact Statement (EIS) for the Project in July 2019 (SSD-9526). Mine Subsidence Engineering Consultants (MSEC) prepared Report No. MSEC986 (Rev. A) which provided the subsidence predictions and assessed impacts in support of the EIS Application. The layout of the panels and longwalls adopted in the EIS Application and Report No. MSEC986 is referred to as the *EIS Layout* in this report.

Malabar seeks to modify the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams to enhance safety and longwall productivity. The modifications include rotating the longwalls by approximately 35° clockwise from the orientations adopted in the EIS Layout. The widths of some longwalls have been reduced and the lengths modified to optimise resource extraction, resulting in mining areas within each seam being similar to those based on the EIS Layout.

The revised layout of the panels and longwalls in the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams is referred to as the *Modified Layout* in this report. The layouts of the mining operations based on the Modified Layout are shown in Drawings Nos. MSEC1186-01 to MSEC1186-05, in Appendix E. This subsidence report has been prepared to support the Modification Application which will be submitted to the Department of Planning and Environment.

The subsidence predictions for the underground mining operations have been obtained using the Incremental Profile Method. This method has been calibrated using the available single-seam and multi-seam monitoring data from the New South Wales coalfields. The maximum predicted subsidence effects due to mining in the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams based on the Modified Layout are:

- vertical subsidence of 6500 mm (65 % of the total mining height in all seams);
- tilt of 50 mm/m (i.e. 5 % or 1 in 20);
- hogging and sagging curvatures of 2.0 per kilometre (km^{-1}, i.e. minimum radius of curvature of 0.5 km); and
- strains typically between 10 mm/m and 20 mm/m, with localised strains greater than 20 mm/m.

The maximum predicted total vertical subsidence, based on the Modified Layout, is approximately 16 % greater than the maximum predicted value based on the EIS Layout. However, the potential for impacts does not result from absolute vertical subsidence but rather from the differential movements (i.e. tilt, curvature and strain).

The maximum predicted total tilt, curvatures and strains, based on the Modified Layout, are the same as the maximum predicted values based on the EIS Layout. While the maximum predicted values do not change, the predicted subsidence effects increase in some locations and decrease in other locations, depending on their positions relative to the panels and longwalls.

The *Study Area* is defined as the surface area that is likely to be affected by the secondary extraction of the panels and longwalls in the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams based on the Modified Layout. The extent of the Study Area has been calculated, as a minimum, as the surface area enclosed by the greater of the 26.5° angles of draw from the limits of secondary extraction in each seam and by the predicted total 20 mm subsidence contour. Natural and built features that could be subjected to far-field or valley-related movements and could be sensitive to such effects have also been assessed in this report.

The surface area located within the Study Area is 1989 ha based on the Modified Layout and 1891 ha based on the EIS Layout. The surface area within the Study Area therefore increases by 98 ha; however, this represents a change of only approximately 5 %. While the Study Area slightly increases, due to the modification, the types of natural and built features located within this area remain the same. The Study Area also remains within Malabar-owned land.

The assessments provided in this report should be read in conjunction with the assessments provided in the reports by other specialist consultants for the Modification Application. The main findings from this report are as follows:

- The Hunter River is located to the south of the mining area. The thalweg (i.e. centreline) of the river channel is at minimum distances from the mining area of 470 m based on the Modified Layout and 525 m based on the EIS Layout. The river will be located approximately 290 m outside the 26.5° angle of draw, at its closest point, based on the Modified Layout.

At this distance, the river channel itself is expected to experience negligible vertical subsidence due to mining based on the Modified Layout. The river channel could experience low levels of far-field or valley-related effects. However, it is highly unlikely that these low-level movements would result in adverse impacts on the river channel itself.

The mapped limit of alluvium for the Hunter River within the relevant Water Sharing Plan is located more than 50 m outside the 26.5° angle of draw lines from the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams. Consistent with the EIS Layout, the alluvium is predicted to experience less than 20 mm vertical subsidence and is not expected to experience measurable tilts, curvatures or strains. The potential impacts on the alluvium and associated aquifer are discussed by the specialist surface groundwater consultant for the Modification Application.

- Saddlers Creek is located to the north of the mining area. The thalweg of the creek channel is at minimum distances from the mining area of 125 m based on the Modified Layout and 230 m based on the EIS Layout. The creek will be located approximately 60 m from the 26.5° angle of draw, at its closest point, based on the Modified Layout.

  Consistent with the EIS Layout, the creek is predicted to experience less than 20 mm vertical subsidence and only low level valley-related effects due to mining based on the Modified Layout. The creek channel is not expected to experience adverse surface impacts due to mining. Further discussions are provided by the specialist surface water and groundwater consultants for the Modification Application.

- The ephemeral[2] drainage lines above the southern part of the mining area are tributaries to Saltwater Creek and the Hunter River and the ephemeral drainage lines above the northern part of the mining area are tributaries to Saddlers Creek. The upper reaches are first and second order streams and some parts of the lower reaches are third order streams.

  The maximum predicted total subsidence effects for the drainage lines, based on the Modified Layout, are the same as the maximum predicted values based on the EIS Layout. The predicted subsidence effects will vary along each of the drainage lines, with locally higher values in some locations and locally lower values in other locations, depending on their positions relative to the panels and longwalls for each layout.

  The assessed impacts for the drainage lines, based on the Modified Layout, are similar to those based on the EIS Layout. The potential for surface cracking increases in some locations and decreases in other locations, depending on the locations relative to the panels and longwalls. It is considered that the overall level of potential impact does not significantly change.

- Steep slopes have been identified along the ridgelines predominately in the south-eastern part of the Study Area. The natural grades of the steep slopes are typically between 1 in 3 (i.e. 33 % or 18.3°) and 1 in 2 (i.e. 50 % or 26.6°), with isolated areas with natural grades up to approximately 1 in 1 (i.e. 100 % or 45°).

  The assessed impacts for the steep slopes, based on the Modified Layout, are similar to those based on the EIS Layout. The potential for surface cracking increases in some locations and decreases in other locations, depending on the locations relative to the panels and longwalls. It is considered that the overall level of potential impact does not significantly change.

  It is considered unlikely that mining would result in adverse impacts on the stability of the steep slopes based on the experience from the NSW coalfields. The Land Management Plan component of the Extraction Plan should include more detailed consideration of slope stability, including input from a specialist geotechnical expert.

- The Golden Highway is located on the south-western boundary of the Study Area at distances of 170 m based on the Modified Layout and 150 m based on the EIS Layout. Consistent with the EIS Layout, the highway is predicted to experience less than 20 mm vertical subsidence due to mining based on the Modified Layout. It is unlikely that these low-level movements would result in adverse impacts on the highway.

- The Golden Highway crosses the Hunter River to the south of the mining area. A bridge crosses the river and the adjacent floodplain comprising a suspended concrete deck supported on concrete abutment wingwalls and nine intermediate concrete headstocks on dual concrete columns. The bridge is located at distances from the mining area of 750 m based on the Modified Layout and 800 m based on the EIS Layout.

  The bridge is predicted to experience negligible vertical subsidence, tilt, curvature and strain due to mining based on the Modified Layout. It could experience small far-field horizontal movements due to mining. The predicted differential horizontal movements between the intermediate supports are between ±6 mm and ±9 mm based on the 95 % confidence levels.

[2] Drainage lines where surface water only flows during and for short periods after rainfall events.

The predicted movements should be provided to the bridge engineers so that its design can be reviewed based on the predicted mining-induced movements. The bridge should also be monitored during active subsidence.

- Edderton Road crosses directly above the longwalls in the Woodlands Hill Seam and it will be realigned before the commencement of secondary extraction in the Arrowfield and Bowfield Seams. The maximum predicted total subsidence effects for the road after mining in the Woodlands Hill Seam, based on the Modified Layout, are similar to the maximum predicted values based on the EIS Layout.
- There are unsealed tracks across the Study Area that are located on Malabar-owned land. The assessed impacts for these tracks, based on the Modified Layout, are similar to those based on the EIS Layout. It is expected that cracking, rippling and stepping of the unsealed tracks would occur as each of the panels and longwalls mine beneath them. The unsealed tracks can be maintained in safe and serviceable conditions using normal road maintenance techniques.
- An 11 kilovolt powerline follows the alignment of Edderton Road and it is located directly above the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams. The powerline comprises aerial copper conductors supported by timber poles. The maximum predicted total subsidence effects for the powerline, based on the Modified Layout, are similar to the maximum predicted values based on the EIS Layout. The assessed impacts for the powerline, based on the Modified Layout, are the same as those based on the EIS Layout.

  The powerline could experience impacts due to the extraction of the longwalls directly beneath it. These impacts can be managed with the implementation of preventive measures, such as realignment of the powerline or the provision of cable rollers, guy wires or additional poles.
- Plashett Reservoir and dam wall are located more than 2 km east of the mining area based on the Modified Layout. At this distance, the vertical subsidence at the reservoir and dam wall are expected to be negligible.

  The reservoir and dam wall could experience very small far-field horizontal movements due to the mining, typically less than 25 mm, which is in the order of survey tolerance for absolute position. It is unlikely that the differential horizontal movements (i.e. strains) at the dam wall would be measurable.

  The assessed impacts for the dam wall, based on the Modified Layout, are the same as those based on the EIS Layout. Longwall mining has been previously carried out near other prescribed dams in the NSW coalfields at distances of less than 1 km. This previous underground mining has not resulted in adverse impacts on these structures.
- The land above the mining area is owned by Malabar and it is used for cattle grazing. The agricultural improvements include fences, farm dams, land contours and cattle yards. The assessed impacts for the improvements, based on the Modified Layout, are the same as those based on the EIS Layout.

  Management strategies can be developed for the mining-induced surface cracking, to manage the potential impacts on these cattle grazing operations. It may be necessary to install temporary fencing or to temporarily relocate stock to areas outside the active subsidence zone.
- There are 21 farm dams within the Study Area, all on Malabar-owned land. The dams are of earthen construction and have been established by localised cut and fill operations within the natural drainage lines. The assessed impacts for the farm dams, based on the Modified Layout, are the same as those based on the EIS Layout.

  The mining-induced tilts could reduce the storage capacities of the larger dams that are located above the mining area. It is also likely, that the farm dams would be affected by cracking, heaving or stepping in the bases or dam walls. Surface cracking or leakages in the dams could be identified by visual inspections and repaired as required.
- There are 18 groundwater bores within the Study Area, all on Malabar-owned land. The assessed impacts for the groundwater bores, based on the Modified Layout, are the same as those based on the EIS Layout.

  The groundwater bores could experience impacts including 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 are other privately-owned groundwater bores located outside and near to the Study Area. The potential impacts on these bores and the groundwater resources are provided by the specialist groundwater consultant for the Modification Application.

- There are no business or commercial establishments within the Study Area. There are business and commercial establishments located along the Golden Highway to the south of the Study Area, including horse studs and a vineyard.

  The building structures, surface infrastructure and improvements on the properties located outside the Study Area are predicted to experience negligible vertical subsidence, tilts, curvatures and strains due to mining based on the Modified Layout. It is unlikely that these features would experience adverse impacts due to mining. All structures, infrastructure and improvements on the private properties are expected to remain in safe and serviceable conditions throughout the mining period.

- Aboriginal heritage sites located within the Study Area comprise isolated artefacts, artefact scatters and an artefact scatter with an associated potential archaeological deposit. There are also two Stone quarry sites that are located inside the Study Area.

  The assessed impacts for the Aboriginal heritage sites, based on the Modified Layout, are the same as those based on the EIS Layout. The Aboriginal heritage sites can potentially be affected by cracking and heaving of the surface soils due to mining. It is unlikely that the finds, artefacts and deposits themselves would be impacted by surface cracking.

  Malabar has specifically designed the Modified Layout to avoid mining beneath the Aboriginal stone quarry Site 37-2-1954 in order to reduce potential subsidence-related impacts, i.e. the site is not predicted to experience measurable tilts, curvatures or strains.

  The maximum predicted vertical subsidence for the stone quarries are less than 20 mm for Site 37-2-1954 and 50 mm for Site 37-2-1955 (which was not located during contemporary surveys). It is recommended that Aboriginal heritage sites are managed in accordance with the recommendations in AECOM (2022).

- The survey control marks near the longwalls could experience vertical subsidence and far-field horizontal movements. The assessed impacts for the survey control marks, based on the Modified Layout, are the same as those based on the EIS Layout. It may be necessary on the completion of the longwalls within each seam, when the ground has stabilised, to re-establish any state survey control marks that are required for future use.

The Modification results in only minor changes in the predicted subsidence effects and assessed impacts for the natural and built features from those presented in the EIS Subsidence Assessment (Report No. MSEC986). The assessments provided in this report indicate that the levels of impact on these 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.

CONTENTS

Tables

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

Figures

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

Drawings

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

1.1. Background

The Maxwell Underground Mine Project (the Project) is an approved underground coal mining operation owned by Maxwell Ventures (Management) Pty Ltd, a wholly owned subsidiary of Malabar Resources Limited (Malabar). Malabar will extract bord and pillar panels (with partial pillar extraction) in the Whynot Seam and longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams within Mining Lease (ML) 1822.

Development Consent SSD 9526 for the Project was granted by the Independent Planning Commission (IPC) on 22 December 2020. The Project was subsequently approved under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) on 10 March 2021 (EPBC 2018/8287).

Malabar previously sought to modify Development Consent SSD 9526 under section 4.55(1A) of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for a minor extension to the mine entry area (MEA) (Modification 1). Modification 1 was subsequently approved on 19 November 2021 and EPBC 2018/8287 was varied on 14 December 2021.

A proposed Modification is being sought under section 4.55(2) of the EP&A Act (the Modification). The Modification is located wholly within the approved Development Application Area and would comprise the following components:

- re-orientation of the longwall panels in the Woodlands Hill, Arrowfield and Bowfield Seams resulting in a minor increase in the approved underground mining extent;
- reduction in the width of some of the longwall panels in the Woodlands Hill Seam, which facilitates earlier commencement of longwall mining;
- repositioning of the upcast ventilation shaft site and associated infrastructure; and
- other minor works and ancillary infrastructure components (e.g. access road and ancillary water management infrastructure for the repositioned ventilation shaft site).

The Project is located in the Hunter Coalfield of New South Wales (NSW) east-southeast of Denman and south-southwest of Muswellbrook. The locations of ML 1822 and the modified underground mining area are shown in Fig. 1.1.

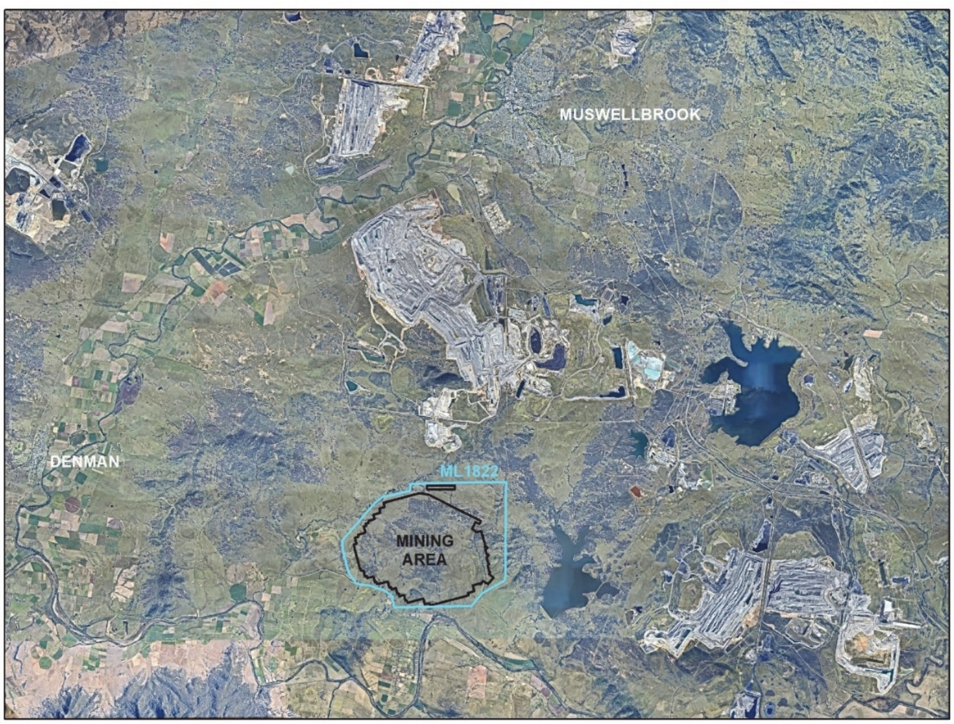


Fig. 1.1 Locations of ML 1822 and the underground mining area

Malabar submitted an Environmental Impact Statement (EIS) for the Project in July 2019 (SSD-9526). Mine Subsidence Engineering Consultants (MSEC) prepared Report No. MSEC986 (Rev. A) which provided the subsidence predictions and impact assessment in support of the EIS Application.

The previous layout of the panels and longwalls adopted in the EIS Application and the EIS Subsidence Assessment (Report No. MSEC986) is referred to as the *EIS Layout* in this report. The EIS Layout is shown in Drawing No. MSEC986-01 in the EIS Subsidence Assessment which has been reproduced in Fig. 1.2.

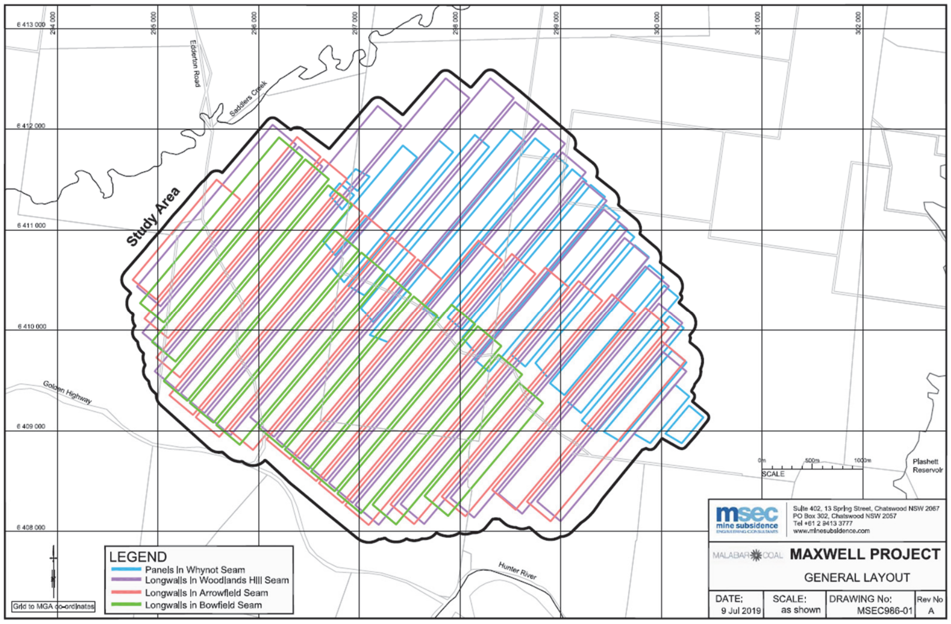


Fig. 1.2 Previous panels and longwalls based on the EIS Layout

Malabar seeks to modify the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams to enhance safety and longwall productivity. The modifications include rotating the longwalls by approximately 35° clockwise from the orientations adopted in the EIS Layout. The widths of some longwalls have been reduced and the lengths modified to optimise resource extraction, resulting in mining areas within each seam being similar to those based on the EIS Layout.

The longwall void widths and solid chain pillar widths generally do not change; however, the first four longwalls in the Woodlands Hill Seam have been narrowed. The layout of the panels in the Whynot Seam do not change.

The layout of the approved panels in the Whynot Seam and the revised longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams is referred to as the *Modified Layout* in this report. The Modified Layout is shown in Drawing No. MSEC1186-01, in Appendix E, which has been reproduced in Fig. 1.3.

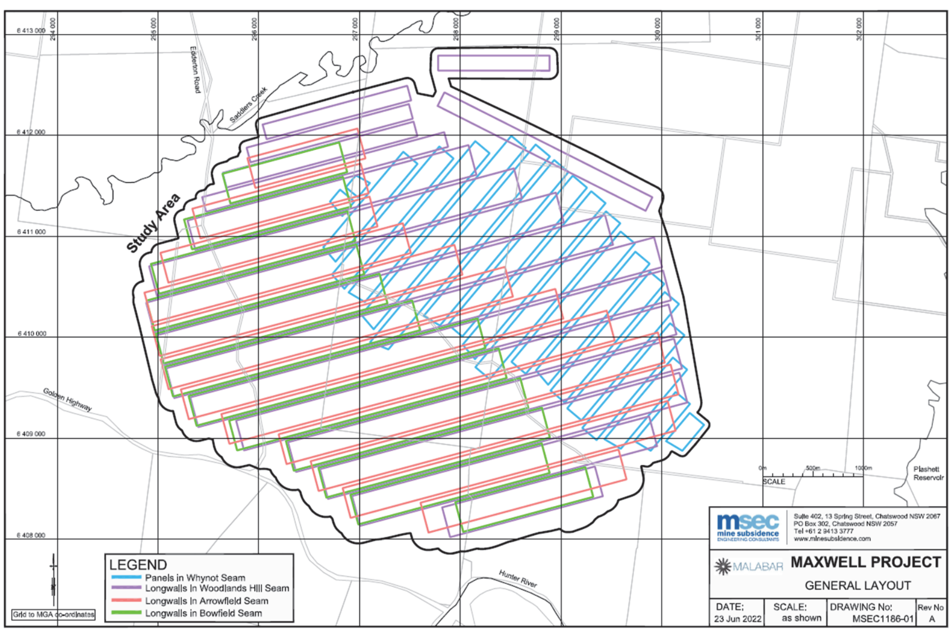


Fig. 1.3 Approved panels and revised longwalls based on the Modified Layout

Comparisons of the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams, based on the EIS Layout and Modified Layout, are provided in Fig. 1.4 to Fig. 1.6.

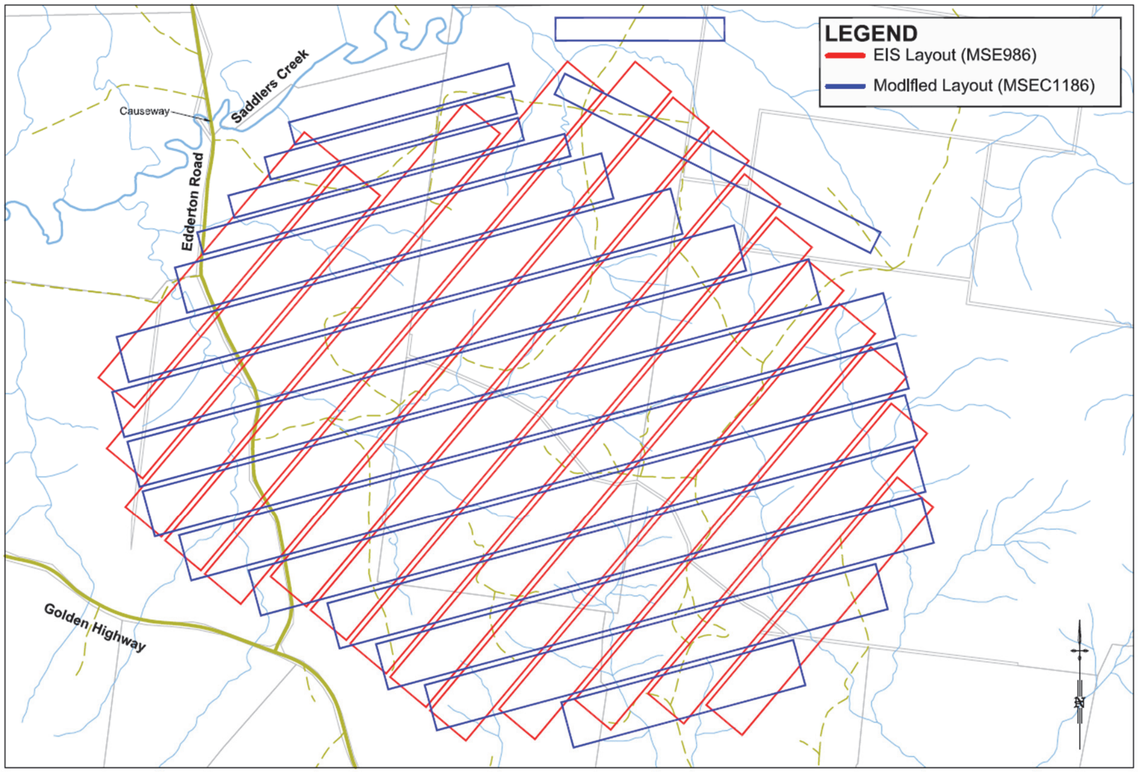
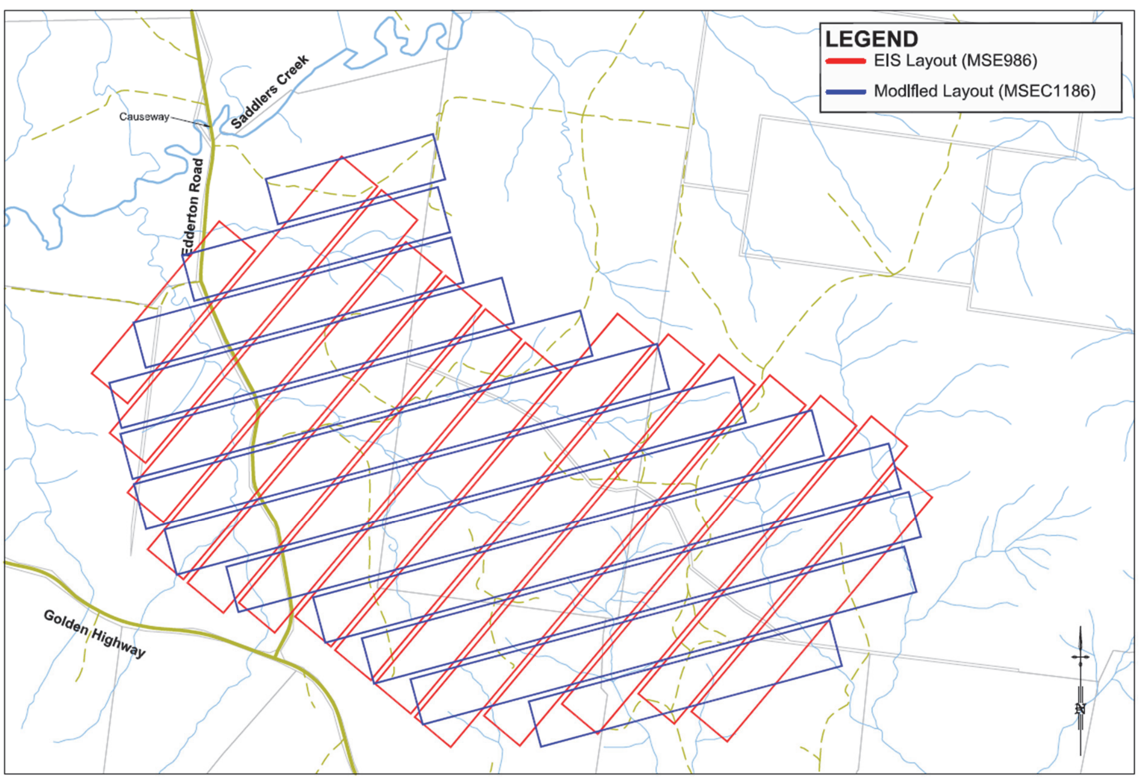
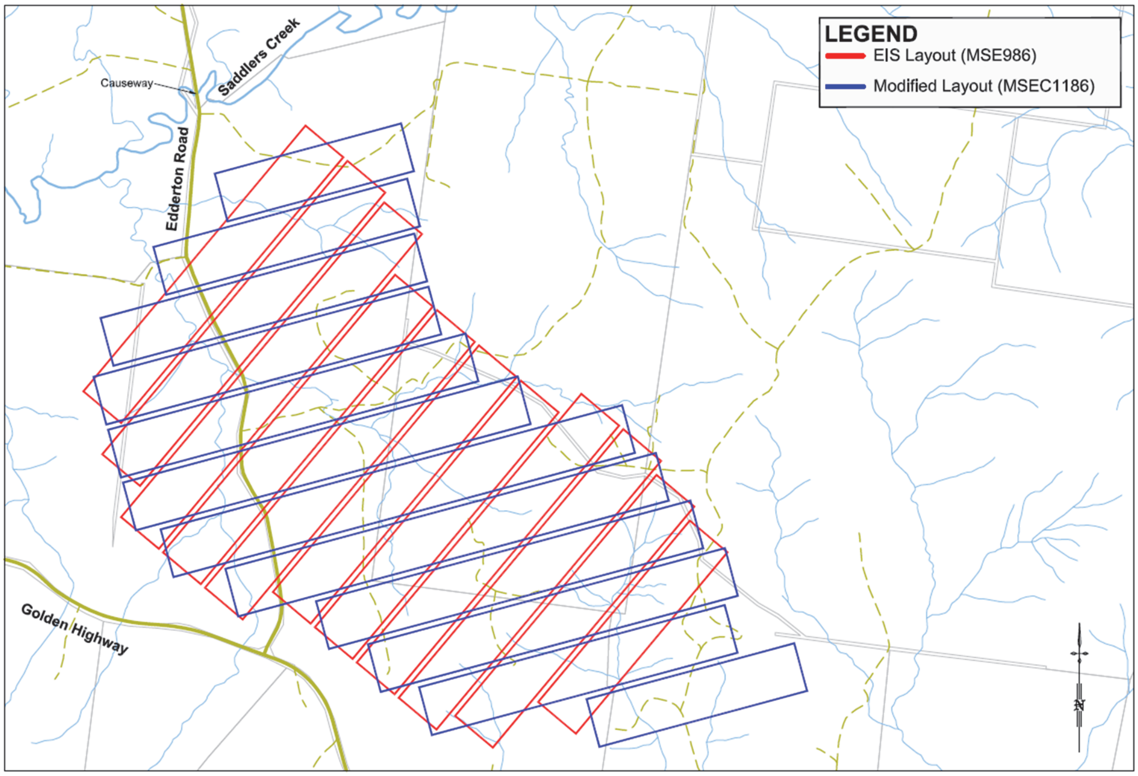


Fig. 1.4 Comparison of the longwalls in the Woodlands Hill Seam based on the EIS Layout and Modified Layout



<u>Note</u>: Edderton Road would be re-aligned prior to secondary extraction in the Arrowfield and Bowfield Seams.

Fig. 1.5 Comparison of the longwalls in the Arrowfield Seam based on the EIS Layout and Modified Layout



Note: Edderton Road would be re-aligned prior to secondary extraction in the Arrowfield and Bowfield Seams.

Fig. 1.6 Comparison of the longwalls in the Bowfield Seam based on the EIS Layout and Modified Layout

MSEC has been commissioned by Malabar to:

- update the predicted subsidence effects for the panels and longwalls in the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams based on the Modified Layout;
- compare the maximum predicted subsidence effects with the maximum predicted values provided in the EIS Subsidence Assessment (Report No. MSEC986);
- update the predicted subsidence effects for each of the natural and built features within the mining area based on the Modified Layout;
- review and, if required, update the impact assessments for each of these natural and built features based on the Modified Layout; and
- provide recommendations for strategies to manage the potential impacts resulting from mining.

This report has been prepared to support the Modification Application for the Project that will be submitted to the Department of Planning and Environment (DPE).

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

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

Chapter 3 includes an overview of conventional and non-conventional subsidence movements and the methods which have been used to predict the multi-seam mine subsidence movements for the Project and the Modification.

Chapter 4 provides the maximum predicted subsidence effects due to the mining of the approved panels in the Whynot Seam and the modified longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams.

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

1.2. Mining geometry

Malabar proposes to extract bord and pillar panels (with partial extraction) in the Whynot Seam and longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams. The layouts of the panels and longwalls are shown in Drawings Nos. MSEC1186-01 to MSEC1186-05.

The layout of the panels in the Whynot Seam, based on the Modified Layout, is the same as that for the EIS Layout. The longwall void widths and the solid chain pillar widths for the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams, based on the Modified Layout, are generally the same as the widths based on the EIS Layout; however, six longwalls in the Woodlands Hill Seam have been narrowed.

There are 19 approved panels in the Whynot Seam referred to as WNP1 to WNP19. A summary of the panel dimensions is provided in Table 1.1. The dimensions represent the maximum extents of first workings for each of the panels.

Table 1.1 Geometry of the bord and pillar panels in the Whynot Seam

Panel	Overall void lengths including roadways (m)	Overall panel widths including first workings (m)	Solid barrier pillar widths (m)
WNP1	2555	185	-
WNP2	2330	185	55
WNP3	1955	185	55
WNP4	1685	185	55
WNP5	1265	185	55
WNP6	185	185	55
WNP7	185	155	55
WNP8	2015	185	55
WNP9	1925	185	55
WNP10	2015	185	55
WNP11	2015	185	55
WNP12	1685	185	55
WNP13	1565	185	55
WNP14	1535	185	55
WNP15	1505	185	55
WNP16	1355	185	55
WNP17	1055	185	55
WNP18	635	185	55
WNP19	365	185	55

The panels each comprise six rows of pillars along their lengths, as shown in Drawing No. MSEC1186-02. The pillars have dimensions of 25 m by 25 m and are separated by 5 m wide development roadways.

Malabar intends to carry out partial extraction of the pillars within each of the panels to achieve approximately 55 % to 70 % coal recovery based on both first and second workings. There are various partial extraction methods that could achieve this level of coal recovery. The final layout in the Whynot Seam would be presented by Malabar in future Extraction Plans, with the subsidence predictions based on the selected pillar extraction method.

The subsidence predictions provided in this report have been based on the extraction of the two rows of pillars adjacent to each of the barrier pillars (i.e. four rows of pillars within each panel) and leaving the two central rows of pillars unmined (i.e. central spine pillar). Small sections of the coal seam will be left as a result of the mining process, known as stooks, representing approximately 15 % of the coal for the rows of mined pillars. The recovery method used for the predictions in this report would result in higher levels of vertical subsidence compared to other recovery methods that would achieve similar coal recovery, i.e. the predictions are conservative if Malabar elects to use an alternative recovery method.

This partial extraction method achieves approximately 71% coal recovery, within each of the panels, based on both first and second workings. The overall coal recovery is approximately 55 % when considering both the panels and the barrier pillars.

The partial extraction within each of the panels results in two voids between each of the barrier pillars and the central spine pillar. These two voids each have a width of 65 m. The overall width of the central spine pillar is 55 m, which is split by a 5 m wide roadway.

Malabar plans to extract 17 longwalls in the Woodlands Hill Seam (WHLW1 to WHLW17), 12 longwalls in the Arrowfield Seam (AFLW1 to AFLW12) and 12 longwalls in the Bowfield Seam (BFLW1 to BWLW12). Summaries of the longwall dimensions are provided in Table 1.2 for the Woodlands Hill Seam, Table 1.3 for the Arrowfield Seam and Table 1.4 for the Bowfield Seam.

Table 1.2 Geometry of the modified longwalls in the Woodlands Hill Seam

Longwall	Overall void lengths including installation headings (m)	Overall void widths including first workings (m)	Overall tailgate chain pillar widths (m)
WHLW1	1485	150	-
WHLW2	1665	150	30
WHLW3	1960	150	30
WHLW4	2485	150	30
WHLW5	2885	305	35
WHLW6	3750	305	35
WHLW7	4210	305	35
WHLW8	4610	305	35
WHLW9	5010	305	35
WHLW10	4855	306	35
WHLW11	4440	305	35
WHLW12	3965	305	35
WHLW13	3690	305	35
WHLW14	3050	305	35
WHLW15	1570	305	35
WHLW16	2310	150	-
WHLW17	1105	150	-

Table 1.3 Geometry of the modified longwalls in the Arrowfield Seam

Longwall	Overall void lengths including installation headings (m)	Overall void widths including first workings (m)	Overall tailgate chain pillar widths (m)
AFLW1	1130	305	-
AFLW2	1730	305	37
AFLW3	2150	305	35
AFLW4	2655	305	35
AFLW5	3110	305	35
AFLW6	3535	305	35
AFLW7	3845	305	35
AFLW8	3960	305	35
AFLW9	3890	305	35
AFLW10	3695	305	35
AFLW11	3340	305	35
AFLW12	2035	305	35

Table 1.4 Geometry of the modified longwalls in the Bowfield Seam

Longwall	Overall void lengths including installation headings (m)	Overall void widths including first workings (m)	Overall tailgate chain pillar widths (m)
BFLW1	1200	305	-
BFLW2	1630	305	35
BFLW3	2015	305	35
BFLW4	2155	305	35
BFLW5	2300	305	35
BFLW6	2540	305	35
BFLW7	2965	305	35
BFLW8	2770	305	35
BFLW9	2405	305	35
BFLW10	2295	305	35
BFLW11	1965	305	35
BFLW12	1335	305	35

The lengths of longwall extraction excluding the installation headings are approximately 10 m less than the overall void lengths provided in Table 1.2 to Table 1.4. The longwall face widths excluding the first workings are typically 295 m except for WHLW1 to WHLW4, WHLW16 and WHLW17 which have longwall face widths of 140 m.

The longwalls within each of the seams have been staggered so that the chain pillars are not aligned. The longwalls in the Arrowfield Seam have been offset by approximately 100 m from the longwalls in the overlying Woodlands Hill Seam. The longwalls in the Bowfield Seam have been offset by approximately 80 m from the longwalls in the overlying Arrowfield Seam.

1.3. Surface and seam information

The surface level contours within the mining area are shown in Drawing No. MSEC1186-06. The land generally falls towards the Hunter River to the south of the mining area and towards Saddlers Creek to the north of the mining area.

The surface elevations directly above the mining area vary from a low point of 110 metres above Australian Height Datum (mAHD) within tributaries to the Hunter River to a high point of 240 mAHD at the top of a hill in the eastern side of the mining area.

The seam floor contours for the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams are shown in Drawings Nos. MSEC1186-07, MSEC1186-08, MSEC1186-09 and MSEC1186-10, respectively. The target seams generally dip from the north-north-west towards the south-south-east, with average gradients varying between 3 % and 5 % within the mining area.

The seam thickness contours for the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams are shown in Drawings Nos. MSEC1186-11, MSEC1186-12, MSEC1186-13 and MSEC1186-14, respectively. The full seam thicknesses will be extracted, within the ranges of 1.5 m to 2.3 m in the Whynot Seam and 2.4 m to 3.4 m in the Woodlands Hill, Arrowfield and Bowfield Seams. The subsidence predictions provided in this report have been based on the variable seam thicknesses shown in Drawings Nos. MSEC1186-11, MSEC1186-12, MSEC1186-13 and MSEC1186-14, within the prescribed ranges of mining heights.

The depth of cover contours for the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams are shown in Drawings Nos. MSEC1186-15, MSEC1186-16, MSEC1186-17 and MSEC1186-18, respectively. The depths of cover are shallowest in the north-western part of the mining area and generally increase towards the south-eastern part of the mining area. The Whynot Seam outcrops in the northern part of ML 1822.

The interburden thickness contours between the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams are shown in Drawings Nos. MSEC1186-19, MSEC1186-20 and MSEC1186-21, respectively. The depth of cover to the Whynot Seam is less than 50 m in the northern part of the mining area. Secondary extraction will only occur within this seam where the depths of cover are greater than 50 m.

A summary of the ranges of depths of cover, interburden thicknesses, working section thicknesses and mining heights is provided in Table 1.5. The values represent the ranges within the mining areas for each of the seams.

Table 1.5 Depths of cover, interburden thicknesses, working sections and mining heights for each of the seams

Seam	Depth of cover (m)	Interburden thickness to the overlying seam (m)	Working section thickness (m)	Mining height (m)
Whynot Seam (WN)	40* ~ 180 (100 average)	N/A (Single-seam)	1.3 ~ 2.3 (2.0 average)	1.5 ~ 2.3
Woodlands Hill (WH)	125 ~ 365 (250 average)	155 ~ 185 (165 average)	1.7 ~ 3.5 (2.7 average)	2.4 ~ 3.4
Arrowfield (AF)	170 ~ 415 (310 average)	40 ~ 75 (50 average)	2.1 ~ 3.7 (2.9 average)	2.4 ~ 3.4
Bowfield (BF)	200 ~ 430 (330 average)	20 ~ 45 (30 average)	2.2 ~ 3.3 (2.8 average)	2.4 ~ 3.3

*Note: * denotes that secondary extraction will only occur at depths of cover greater than 50 m.*

The surface and seam levels are illustrated along Sections 1 to 3 in Fig. 1.7 to Fig. 1.9, respectively. The locations of these sections are shown in Drawings Nos. MSEC1186-06 to MSEC1186-10. The Study Area is defined in Section 2.2.

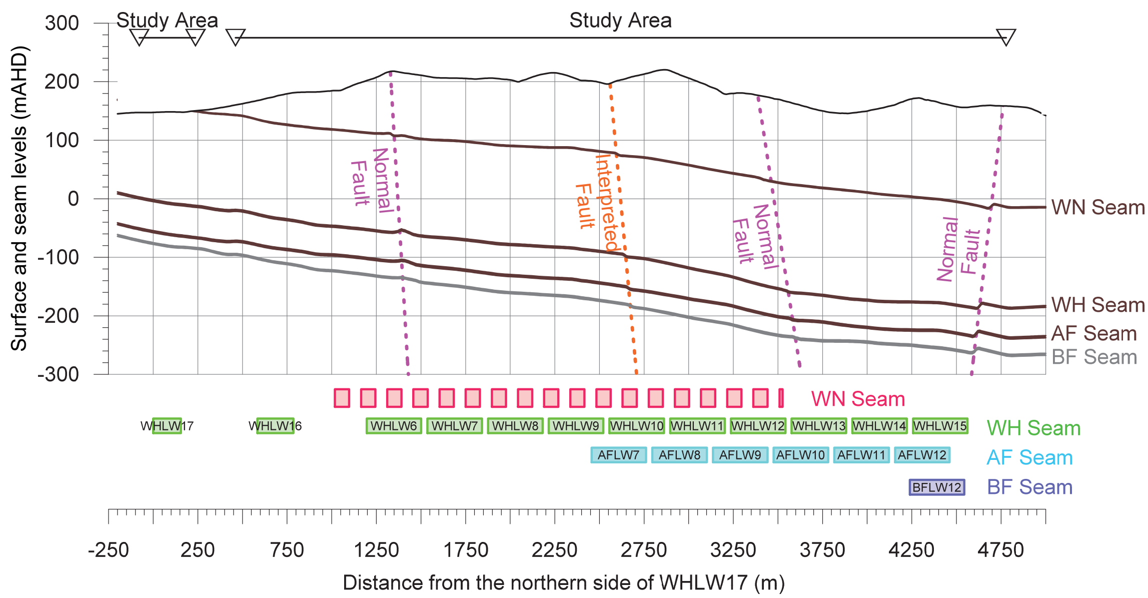


Fig. 1.7 Surface and seam levels along Section 1

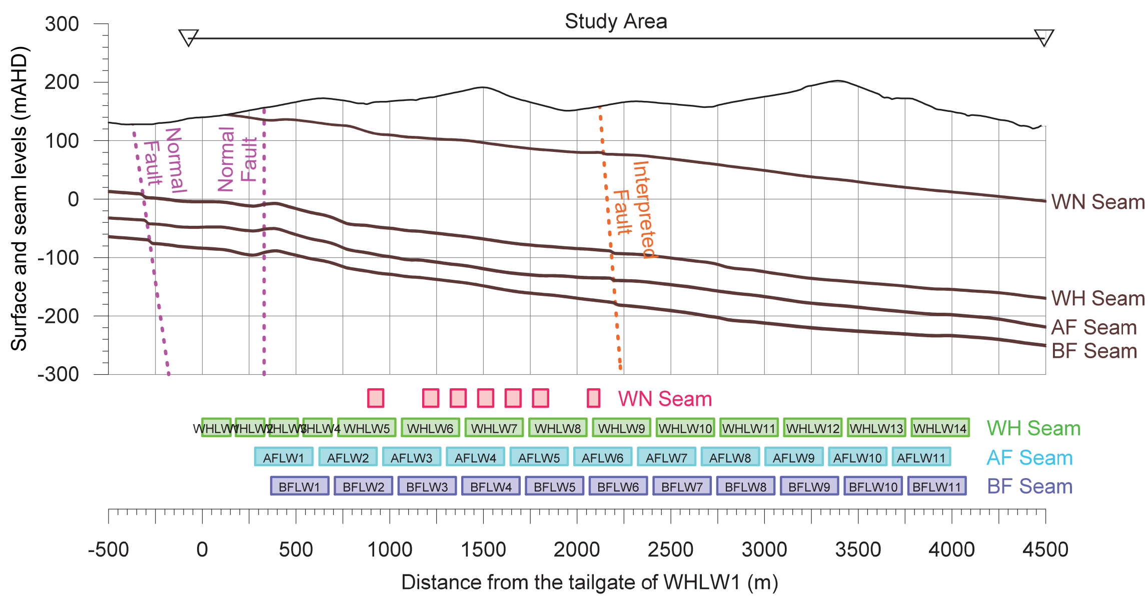


Fig. 1.8 Surface and seam levels along Section 2

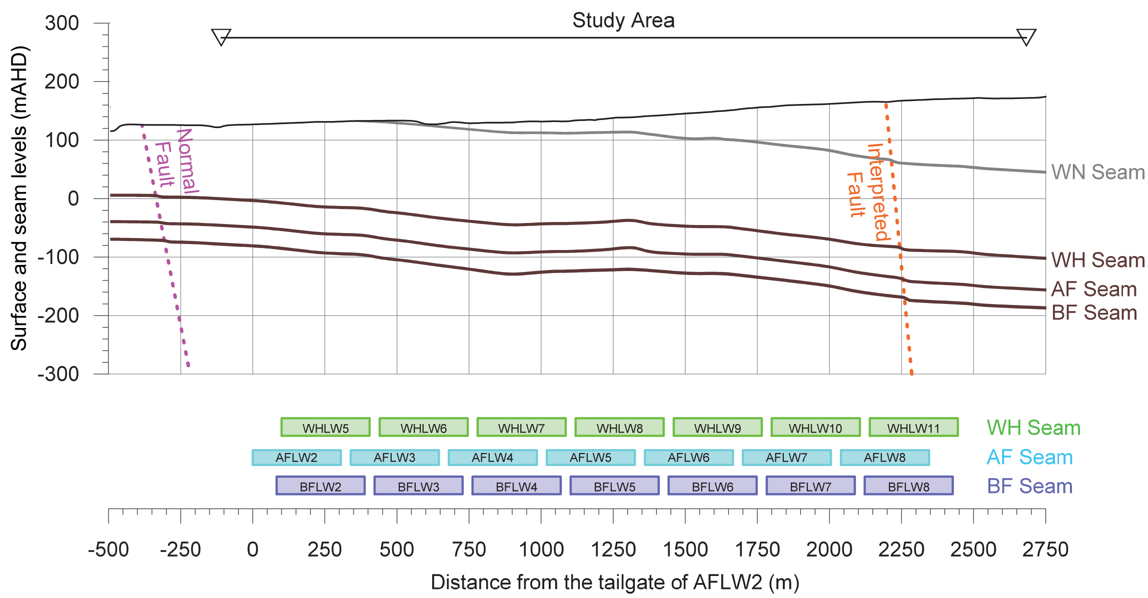


Fig. 1.9 Surface and seam levels along Section 3

1.4. Geological details

ML 1822 lies in the Hunter Coalfield within the Northern Sydney Basin. The general stratigraphy of the Hunter Coalfield is shown in Table 1.6 (after Stevenson, et al., 1998). The target seams lie within the Jerrys Plains Subgroup of the Wittingham Coal Measures, which is shown in more detail in Table 1.7. The Newcastle Coal Measures and overlying groups are generally not present in the mining area.

Table 1.6 Middle Permian to Quaternary stratigraphy of the Hunter Coalfield (after Stevenson, et al., 1998)

Period	Stratigraphy			Lithology
Quaternary				silt, sand, gravel
Tertiary				basalt
Jurassic				basalt
Triassic	Hawkesbury Sandstone			massive quartz sandstone with minor siltstone
	Narrabeen Group	Terrigal Formation		sandstone, interbedded sandstone and siltstone, mudstone, claystone
		Clifton Subgroup	Patonga Claystone Tuggerah Formation Widden Brook Conglomerate	sandstone, interbedded sandstone and siltstone, claystone
Permian	Singleton Supergroup	Newcastle Coal Measures	Glen Gallic Subgroup Doyles Creek Subgroup Horseshoe Creek Subgroup Apple Tree Flat Subgroup	coal, claystone, siltstone, shale, sandstone, conglomerate, tuffaceous sediments
			Watts Sandstone	medium to coarse sandstone
		Wittingham Coal Measures	Denman Formation Jerrys Plains Subgroup Archerfield Sandstone Vane Subgroup Saltwater Creek Formation	sandstone, siltstone, laminate coal, claystone, tuff, siltstone, sandstone, conglomerate well-sorted quartz-lithic sandstone coal, siltstone, lithic sandstone, shale, conglomerate sandstone, siltstone, minor coal

Table 1.7 Stratigraphy of the Wittingham Coal Measures

Stratigraphy			Lithology	
Wittingham Coal Measures	Denman Formation			
	Jerrys Plains Subgroup	Mount Leonard Formation Althorpe Formation	Whybrow seam	
		Malabar Formation	Redbank Creek seam Wambo seam **Whynot seam**	
		Mount Ogilvie Formation	Blakefield seam Saxonvale Member Glen Munro seam **Woodlands Hill seam**	
		Millbrodale 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		
		Foy Brook Formation	Lemington seam Pikes Gully seam Arties seam Liddell seam Barrett seam Hebden seam	Wynn C. M. Edderton C. M. Clanricard C. M. Bengalla C. M. Edinglassie C. M. Ramrod Ck. C.M.
	Saltwater Creek Subgroup			

Note: C. M. = Coal Measure

There have been a number of drilling campaigns in the vicinity of the Project from the late 1940's through to the present. Other geological exploration includes: 3D seismic surveys in 2003, 2004, 2005 and 2006; a high-resolution ground magnetic survey in 1998; a low-level aero-magnetic survey in 2002; and a radiometric survey for the purposes of detecting and mapping intrusive bodies (Malabar, pers. comm., April 2018, and MBGS, 2018).

Geophysical logging has been generally carried out on the drillholes since 1998. The testing identified the coal seam floors, coal seam roofs, partings, igneous intrusions and tuff marker bands, lithological boundaries and structural features (Malabar, pers. comm., April 2018). Geotechnical logging to identify natural fractures has been carried out since 2008.

The south-southeast trending Muswellbrook Anticline is located east of ML 1822 and well outside the mining area. The strata dip steeply along this structure with gradients varying between 35 % and 85 %. On the western side of the anticline, the strata dip gently with gradients varying between 3 % and 5 % within the mining area. The Calool Syncline crosses the mining area. The syncline is sub-parallel to the East Graben Fault and it has a dip between 2° and 5° towards the south (MBGS, 2018).

The mapped geological structures in the vicinity of ML 1822 are shown in Drawing No. MSEC1186-22.

The faults have been interpreted from the seismic surveys and from the structure contour plans. The positions and throws of some faults have been confirmed using a series of closely spaced non-core drillholes (MBGS, 2018). These drillholes indicate that the throws of the normal faults are generally consistent through the target coal seams.

A complex north-northwest orientated graben structure is located west of ML 1822, comprising the East Graben Fault (Ref. F4) and the Randwick Park Fault, which is part of a regional graben system. The East Graben Fault has a dip of 70° and a throw of up to 20 m near the modified mining area. The Randwick Park Fault is sub-vertical and it has a throw of up to 30 m.

The western ends of the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams have been set back from the graben structure. The locations of the East Graben Fault and the Randwick Park Fault relative to the longwalls are shown along Section 4 in Fig. 1.10. This section has been taken where the graben structure is located closest to the longwalls, as shown in Drawing No. MSEC1186-22.

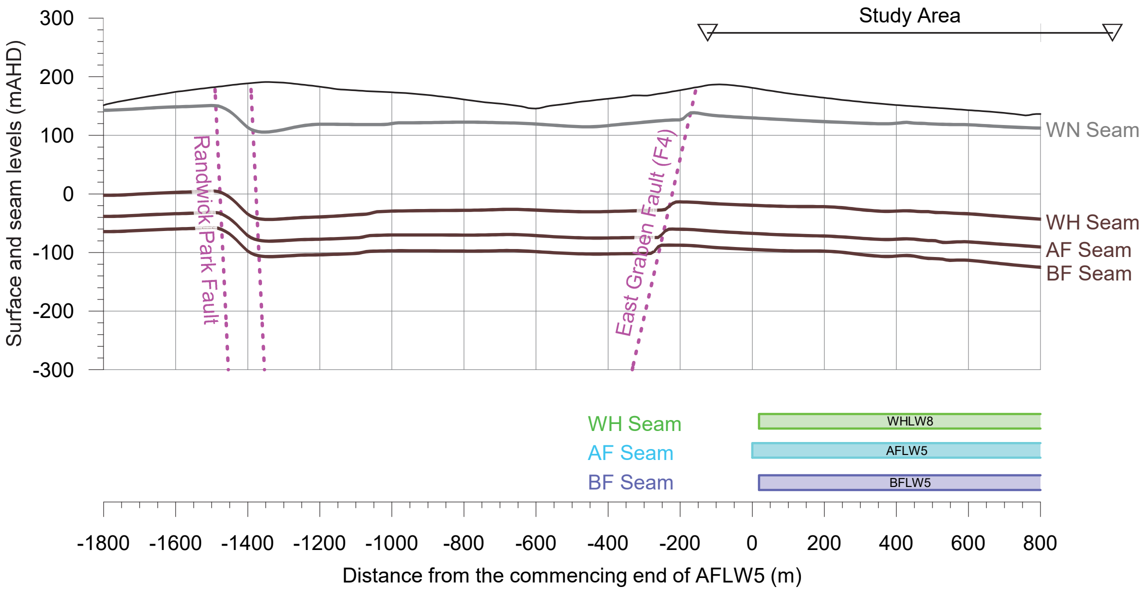


Fig. 1.10 Surface and seam levels along Section 4

The projected surface expression of the East Graben Fault is located at a minimum distance of 180 m from the western ends of the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams. It is possible that localised surface deformations could develop at the surface expression of this fault where it is located closest to the longwalls. Further discussion is provided in Section 1.4.

A north-east trending fault (Ref. F3) is located on the south-eastern side of the modified mining area. This normal fault has a dip of approximately 70° and a throw of 10 m. There are also north-west trending faults and interpreted north-east trending faults within the modified mining area. These normal faults have dips of approximately 70° to 75° and throws of 2 m to 6 m. The north-east trending faults and interpreted faults are shown in Fig. 1.7 to Fig. 1.9.

There are two parallel north trending dykes in the northern part of the mining area with widths of approximately 1.8 m. There are also two north-east trending interpreted dykes within the modified mining area. The dykes have been delineated by the magnetic surveys and some have been confirmed by trenching (MBGS, 2018).

Dolerite sills have intruded into the Whynot, Arrowfield and Bowfield Seams within ML 1822. The layouts of the approved panels and modified longwalls within these seams have been designed to avoid these igneous intrusions. The mapped extents of the sills within the Whynot, Arrowfield and Bowfield Seams are illustrated in Fig. 1.11 to Fig. 1.13, respectively.

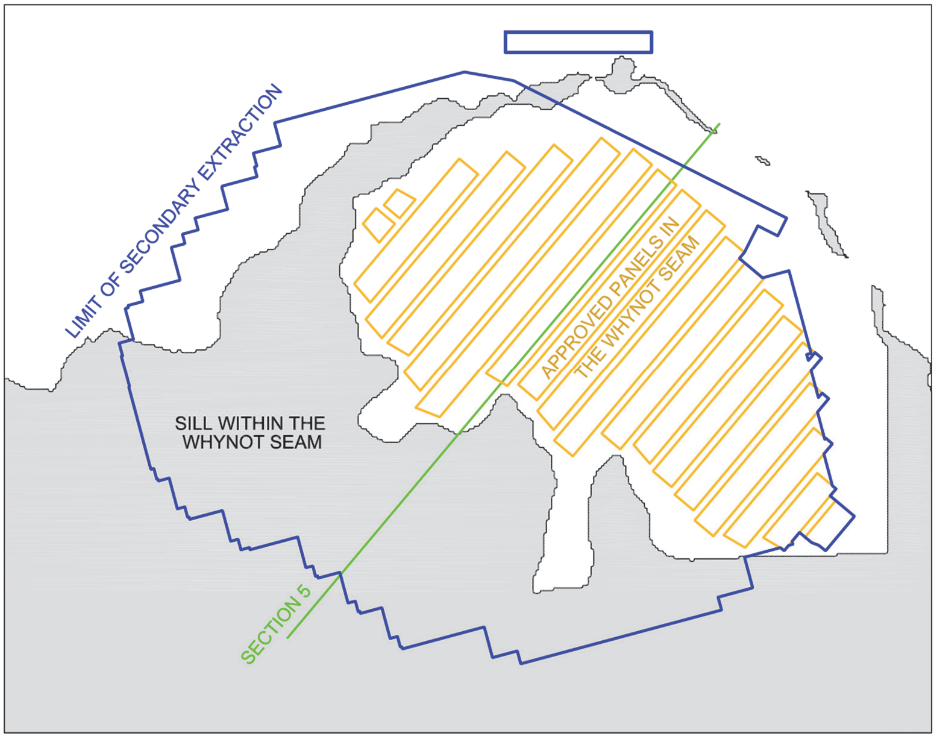


Fig. 1.11 Mapped extent of the sill within the Whynot Seam

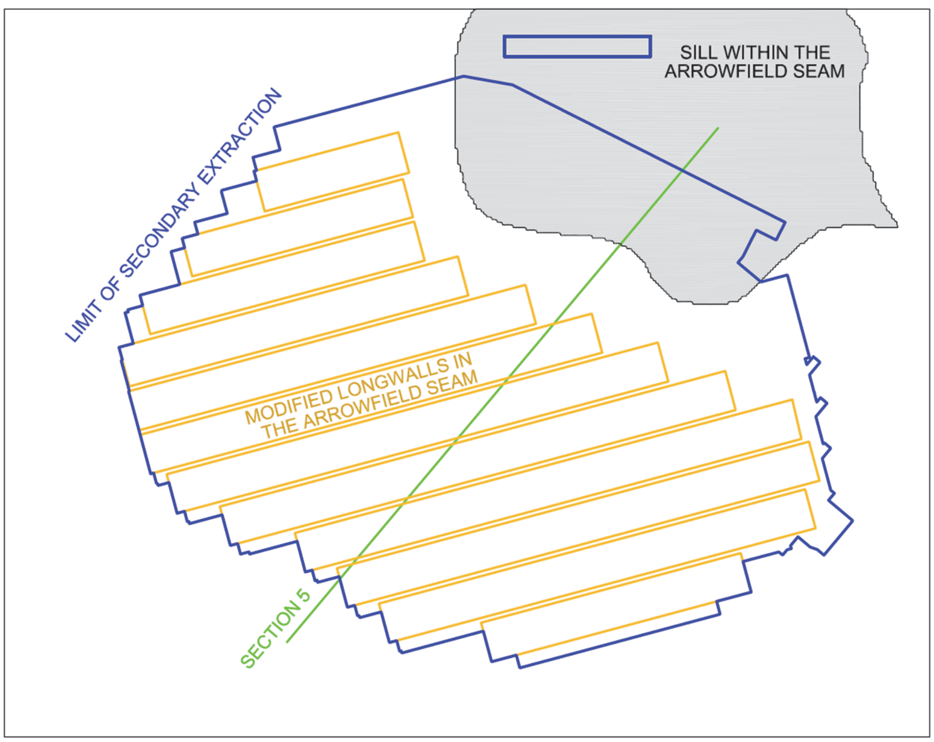


Fig. 1.12 Mapped extent of the sill within the Arrowfield Seam

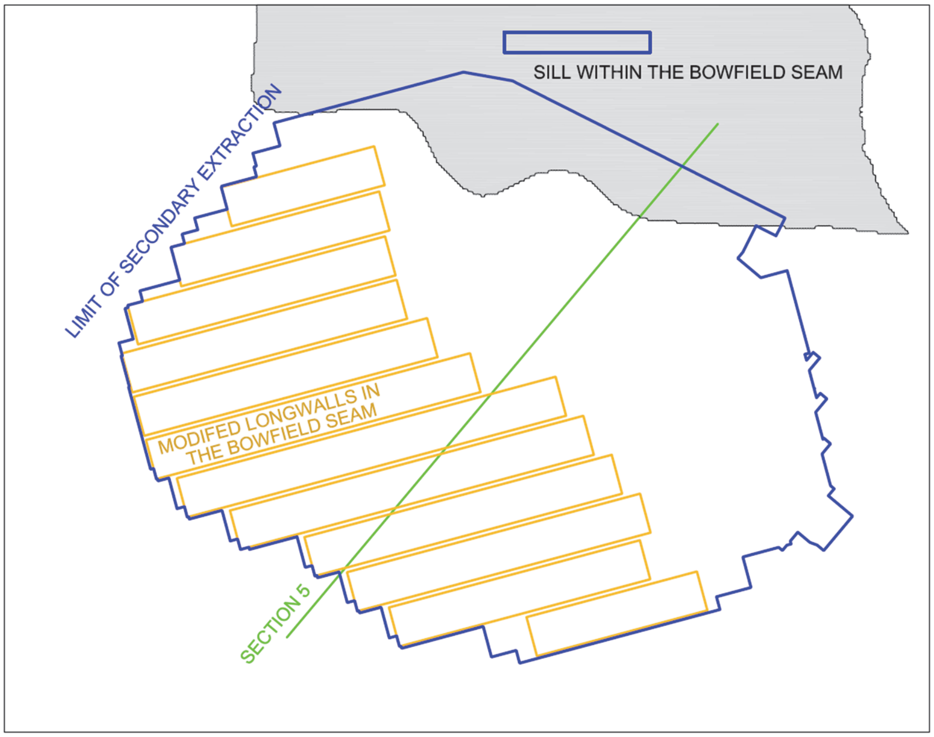


Fig. 1.13 Mapped extent of the sill within the Bowfield Seam

The Edderton Sill has also intruded into the interburden between the Whynot and Woodlands Hill Seams. This sill extends across the modified mining area and has a thickness of approximately 20 m for much of its extent (MBGS, 2018). Two samples of the Edderton Sill have been tested and the measured Unconfined Compressive Strength (UCS) was up to 186 megapascals (MPa).

The levels of the Whynot, Arrowfield and Bowfield Seams and the extents of the sills in each of these seams are illustrated along Section 5 in Fig. 1.14. The position of the Edderton Sill is also shown in this figure. The location of Section 5 is shown in Fig. 1.11 to Fig. 1.13.

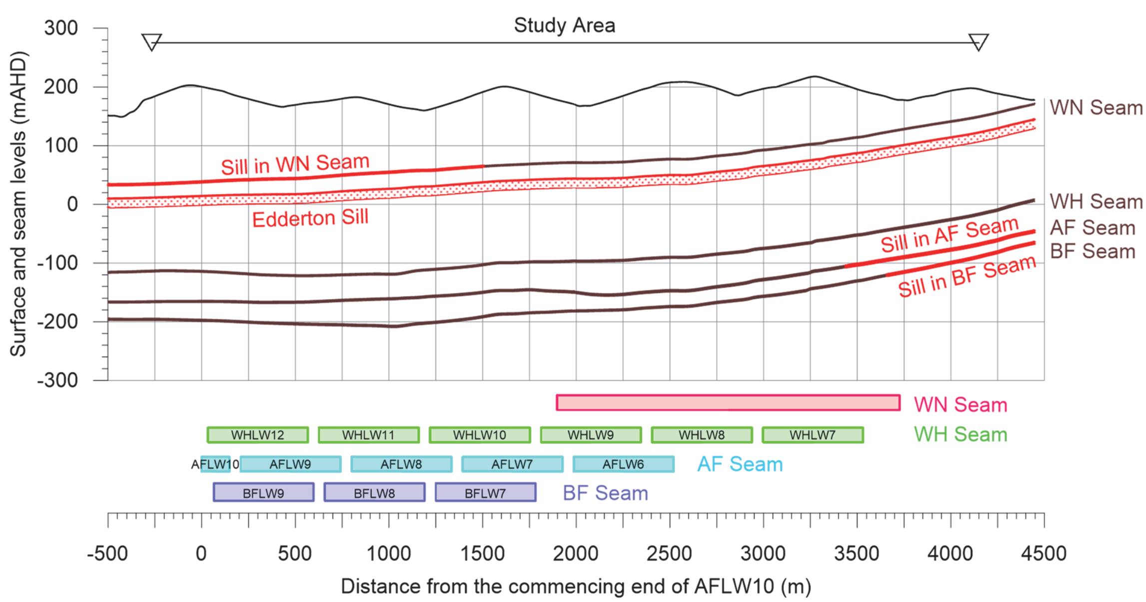


Fig. 1.14 Surface, seam and sill levels along Section 5

The longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams will be extracted beneath the Edderton Sill. This sill is located approximately 110 m to 130 m above the Woodlands Hill Seam.

The western ends of the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams will also be extracted beneath the sill in the Whynot Seam. This sill has a thickness ranging between 1 m and 10 m within the modified mining area.

The Whynot and Edderton Sills are located in the upper part of the overburden and their strengths and stiffnesses are greater than those of the sedimentary strata. These sills could therefore result in reduced vertical subsidence (i.e. less than predicted) due to mining in the Woodlands Hill, Arrowfield and Bowfield Seams.

The potential for subsidence reduction due to the presence of these sills is dependent on the strengths and spanning capabilities of the materials and whether they are massive (i.e. devoid of faults, inclusions and defects), which is not certain at this stage.

The critical span of an igneous sill (i.e. the maximum distance that a sill can span without failure) can be estimated using *Equation 1* (after Galvin, 1981). This equation was developed using empirical results from mining beneath dolerite sills in South Africa. The empirical data comprised of dolerite sills with strengths typically ranging between 250 MPa and 390 MPa. The application of this equation, therefore, could over-estimate the spanning capacities of the sills within the mining area. It is also noted that the method has yet to be verified for "*sills exceeding a depth (to the base) of 140 m*" (Galvin, 1981).

Equation 1

$$S = \sqrt{1165 t_D - \frac{935 t_D^2}{D_D}} + 2 t_p \tan(\beta - 90)$$

where
t_D = Thickness of sill (m);
D_D = Depth to sill base from surface (m);
t_p = Thickness of parting between sill base and seam (m); and
β = Caving angle of strata between the seam and sill base (degrees).

A summary of the estimated critical spans of the Whynot and Edderton Sills is provided in Table 1.8. The caving angle of the strata (β) has been taken to be 110°, i.e. an angle of break of 20°.

Table 1.8 Estimated critical spans of the Whynot and Edderton Sills

Location	Thickness of sill (t_D, m)	Depth to sill base (D_D, m)	Thickness of the parting between sill base and seam (t_p, m)	Critical span (S, m)
Whynot Sill	1 ~ 10	100 ~ 170	150 ~ 170	140 ~ 230
Edderton Sill	≈ 20	90 ~ 200	110 ~ 130	≈ 230

The critical spans for the Whynot and Edderton Sills range between 140 m and 230 m. The longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams have void widths of typically 305 m. It is unlikely, therefore, that the Whynot and Edderton Sills could span the void widths of the longwalls in these seams.

It is therefore considered that there is low potential for subsidence reduction due to the Whynot and Edderton Sills. The predicted vertical subsidence for the longwalls, therefore, has not been reduced due to the presence of these sills.

It is possible that the sills could partially span across the corners of the longwalls. However, the potential for this spanning is reduced due to the multi-seam mining, with the longwalls staggered so that the longwall corners are not aligned.

The Whynot and Edderton Sills could potentially result in irregular subsidence profiles if they were to partially span the corners of the longwalls, i.e. reduced subsidence in the corners transitioning to full subsidence towards the middle of the goaf. The sills are generally at depths of cover of 100 m or greater and, therefore, the irregular subsidence is expected to be expressed as rolling or heaving at the surface, rather than as stepping, due to the depths of the overburden. However, it is possible that localised surface cracking and/or stepping could develop near the corners of the longwalls where the depths of cover are the shallowest. Further discussion is provided in Section 1.4.

The longwalls in the Bowfield Seam do not extend beneath the sill within the overlying Arrowfield Seam. The sill within the Arrowfield Seam, therefore, will not affect the subsidence that develops due to the mining in the Bowfield Seam.

The surface lithology above the modified mining area is shown in Fig. 1.15. The surface soils are predominately derived from the Jerrys Plains Subgroup (Pswj) of the Wittingham Coal Measures. There are small areas that are derived from the Newcastle Coal Measures (formerly known as the Wollombi Coal Measures, Psl) and basalt (Jv). Quaternary material is mapped along the alignments of the Hunter River and Saddlers Creek.

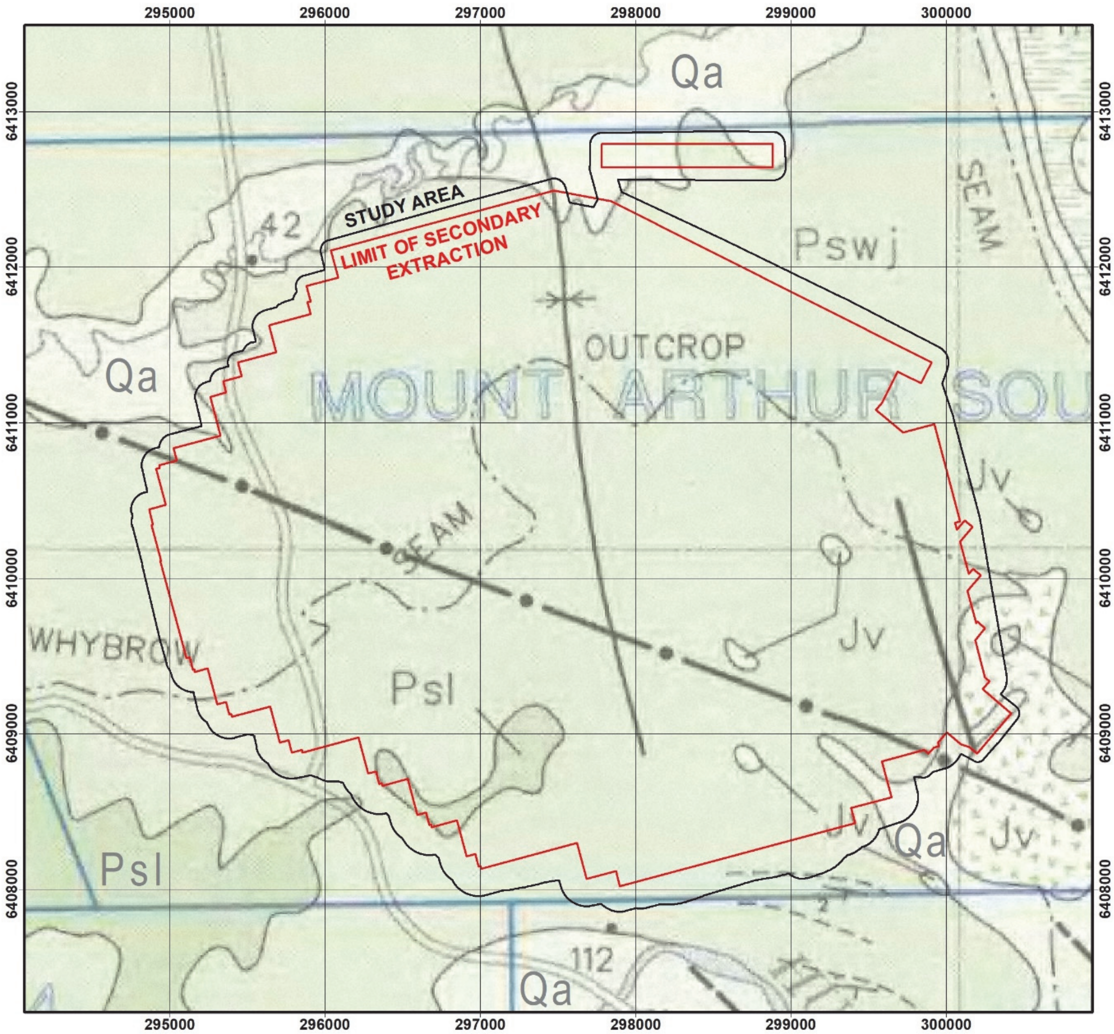


Fig. 1.15 Surface lithology above the modified mining area

2.1. Definition of the Limit of Secondary Extraction

The *Limit of Secondary Extraction* is defined as the surface area above the secondary workings associated with the panels and longwalls and the pillars between each of the panels and longwalls within the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams. This area is shown in Drawings Nos. MSEC1186-02 to MSEC1186-29.

2.2. Definition of the Study Area

The *Study Area* is defined as the surface area that could be affected by the mining of the panels and longwalls in the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams. The extent of the Study Area has been calculated by combining the areas bounded by the following limits:

- 26.5° angle of draw from the extents of the panels and longwalls in each seam; and
- predicted limit of vertical subsidence, taken as the 20 mm subsidence contour, resulting from the extraction of the panels and longwalls in all seams.

The depths of cover contours are shown in Drawings Nos. MSEC1186-15 to MSEC1186-18. The depths of cover above the panels in the Whynot Seam vary between 40 m and 180 m. The depths of cover above the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams vary between 125 m and 430 m. The 26.5° angles of draw, therefore, have been determined by drawing a line that is a horizontal distance varying between 20 m and 215 m around the limits of the mining areas.

The 26.5° angles of draw for the panels and longwalls in each of the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams are shown in Drawings Nos. MSEC1186-02 to MSEC1186-05, respectively.

The predicted limit of vertical subsidence, taken as the predicted total 20 mm subsidence contour, has been determined using the Incremental Profile Method (IPM), which is described in Chapter 3. The predicted total subsidence contours after the completion of mining in each of the seams, including the predicted 20 mm subsidence contours, are shown in Drawings Nos. MSEC1186-26 to MSEC1186-29.

The predicted 20 mm subsidence contour is generally located inside of the 26.5° angle of draw. However, the contour extends slightly outside of the angle of draw near the re-entrant corners of the longwalls, in the south-eastern and north-western parts of the mining area. The Study Area based on the greater of the combined 26.5° angle of draw and the predicted 20 mm total subsidence contour is shown in Drawings Nos. MSEC1186-01 to MSEC1186-25.

There are surface features that are located outside the Study Area that could experience either far-field horizontal movements or valley-related movements. The surface features that could be sensitive to such effects have been identified and have also been included in the assessments provided in this report. These features include the Golden Highway road bridge at Bowmans Crossing, Plashett Reservoir (including the dam wall) and survey control marks.

A comparison of the Study Areas based on the EIS Layout (red line) and Modified Layout (blue line) is provided Fig. 2.1. The areas where the Study Area increases (cyan hatch) and decreases (green hatch) due to the modification are also show on this figure.

The Study Area generally increases on the northern, eastern and southern sides of the mining area and it generally decreases on the western side of the mining area.

The surface area located within the Study Area is 1989 hectares (ha) based on the Modified Layout and 1891 ha based on the EIS Layout. The surface area within the Study Area therefore increases by 98 ha; however, this represents a change of only approximately 5 %.

While the Study Area slightly increases, due to the modification, the types of natural and built features located within this area remain the same. The Study Area also remains within Malabar-owned land.

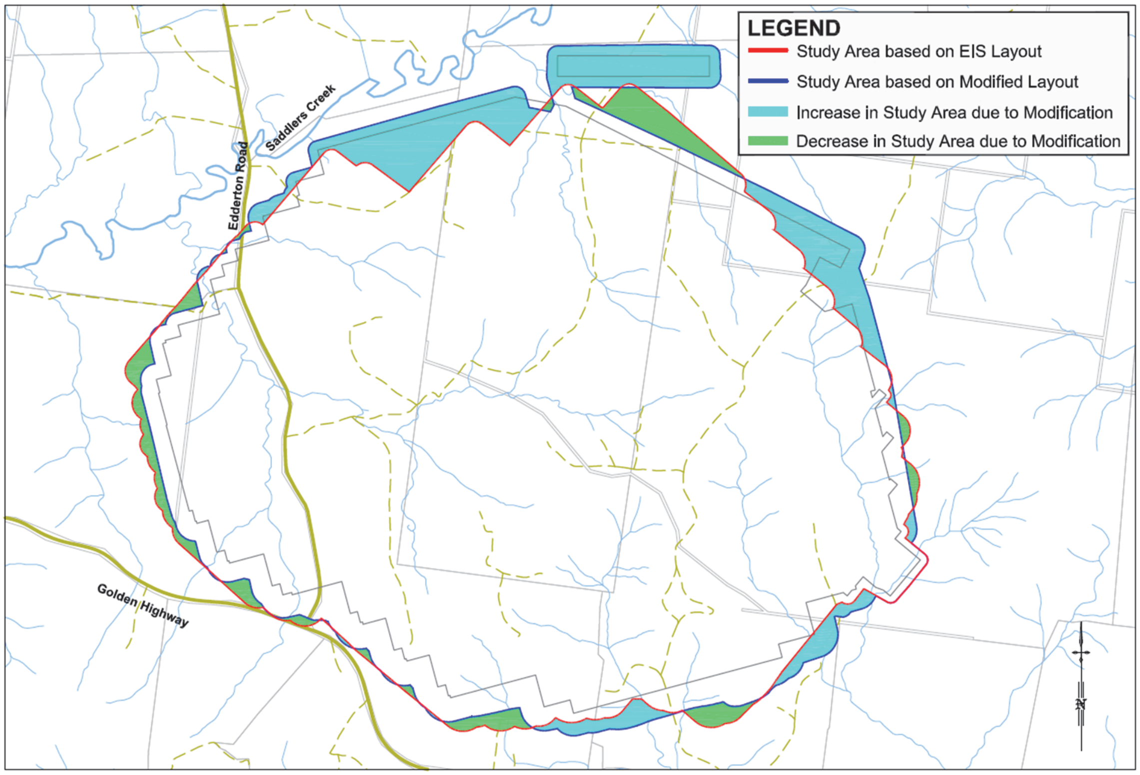


Fig. 2.1 Comparison of the Study Areas based on the EIS Layout and Modified Layout

2.3. Natural and built features within the Study Area

The major natural and built features within the Study Area can be seen in the 1:25,000 topographic map of the area from the Central Mapping Authority (CMA) shown in Fig. 2.2. The surface topography and the larger natural and built features can also be seen in an aerial photograph of the area shown in Fig. 2.3.

A summary of the natural and built features located within the Study Area is provided in Table 2.1. The locations of these features are shown in Drawing Nos. MSEC1186-23 to MSEC1186-25. The descriptions, predictions and impact assessments for the natural and built features are provided in Chapters 5 and 6. The section number references are provided in Table 2.1.

The natural and build features located within and adjacent to the Study Area, based on the Modified Layout, are the same as those located within and adjacent to the Study Area based on the EIS Layout. While the locations of some features relative to the longwalls slightly change, the overall levels of the predicted movements and assessed impacts are similar.

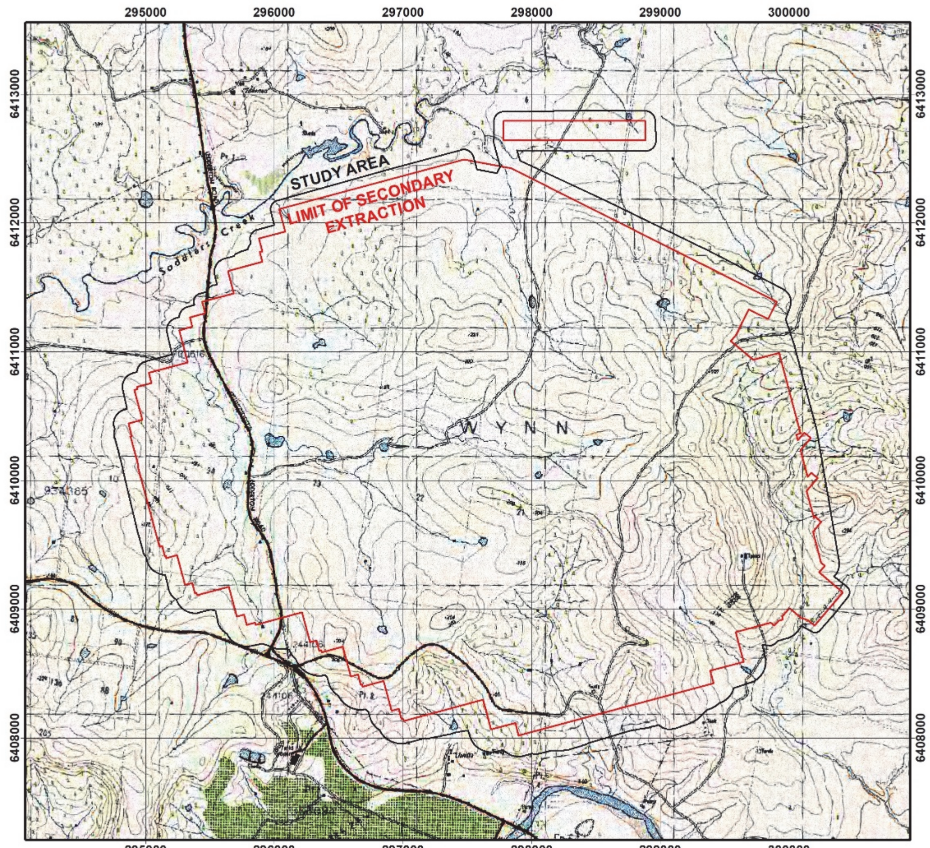


Fig. 2.2 The Study Area overlaid on CMA Map No. 9033-2

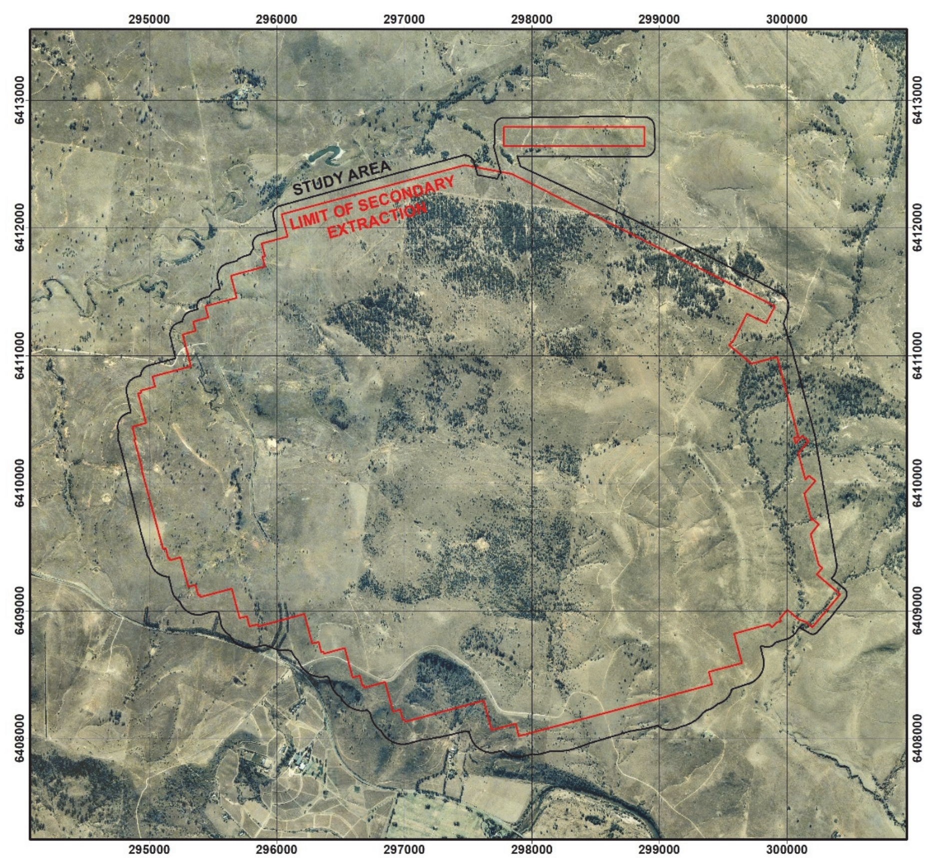


Fig. 2.3 The Study Area overlaid on an aerial photograph

Table 2.1 Natural and built features within the Study Area

Item	Within Study Area	Section number reference
NATURAL FEATURES		
Catchment Areas or Declared Special Areas	×	
Rivers or Creeks	✓	5.1 to 5.3
Aquifers or Known Groundwater Resources	✓	5.4
Springs	×	
Sea or Lake	×	
Shorelines	×	
Natural Dams	×	
Cliffs or Pagodas	×	
Steep Slopes	✓	5.5
Escarpments	×	
Land Prone to Flooding or Inundation	✓	5.6
Swamps, Wetlands or Water Related Ecosystems	✓	5.7
Threatened or Protected Species	✓	5.8
National Parks	×	
State Forests	×	
State Conservation Areas	×	
Natural Vegetation	✓	5.9
Areas of Significant Geological Interest	×	
Any Other Natural Features Considered Significant	×	
PUBLIC UTILITIES		
Railways	×	
Roads (All Types)	✓	6.1 & 6.3
Bridges	×	6.2
Tunnels	×	
Culverts	✓	6.3 & 6.5
Water, Gas or Sewerage Infrastructure	×	
Liquid Fuel Pipelines	×	
Electricity Transmission Lines or Associated Plants	✓	6.6
Telecommunication Lines or Associated Plants	×	6.7
Water Tanks, Water or Sewage Treatment Works	×	
Dams, Reservoirs or Associated Works	×	6.8
Air Strips	×	
Any Other Public Utilities	×	
PUBLIC AMENITIES		
Hospitals	×	
Places of Worship	×	
Schools	×	
Shopping Centres	×	
Community Centres	×	
Office Buildings	×	
Swimming Pools	×	
Bowling Greens	×	
Ovals or Cricket Grounds	×	
Race Courses	×	
Golf Courses	×	
Tennis Courts	×	
Any Other Public Amenities	×	

Item	Within Study Area	Section number reference
FARM LAND AND FACILITIES		
Agricultural Utilisation or Agricultural Suitability of Farm Land	✓	6.9
Farm Buildings or Sheds	✓	6.10
Tanks	✓	6.10
Gas or Fuel Storages	×	
Poultry Sheds	×	
Glass Houses	×	
Hydroponic Systems	×	
Irrigation Systems	×	
Fences	✓	6.11
Farm Dams	✓	6.12
Wells or Bores	✓	6.13
Any Other Farm Features	×	
INDUSTRIAL, COMMERCIAL AND BUSINESS ESTABLISHMENTS		
Factories	×	
Workshops	×	
Business or Commercial Establishments or Improvements	×	6.14
Gas or Fuel Storages or Associated Plants	×	
Waste Storages or Associated Plants	×	
Buildings, Equipment or Operations that are Sensitive to Surface Movements	×	
Surface Mining (Open Cut) Voids or Rehabilitated Areas	×	
Mine Infrastructure Including Tailings Dams or Emplacement Areas	×	
Any Other Industrial, Commercial or Business Features	×	
AREAS OF ARCHAEOLOGICAL OR HERITAGE SIGNIFICANCE	✓	6.15 & 6.16
ITEMS OF ARCHITECTURAL SIGNIFICANCE	×	
PERMANENT SURVEY CONTROL MARKS	✓	6.17
RESIDENTIAL ESTABLISHMENTS		
Houses	×	
Flats or Units	×	
Caravan Parks	×	
Retirement or Aged Care Villages	×	
Associated Structures such as Workshops, Garages, On-Site Waste Water Systems, Water or Gas Tanks, Swimming Pools or Tennis Courts	×	
Any Other Residential Features	×	
ANY OTHER ITEM OF SIGNIFICANCE	×	
ANY KNOWN FUTURE DEVELOPMENTS	×	

3.0 OVERVIEW OF MINE SUBSIDENCE AND THE METHODS THAT HAVE BEEN USED TO PREDICT THE MINE SUBSIDENCE EFFECTS FOR THE APPROVED PANELS AND MODIFIED LONGWALLS

3.1. Introduction

Overviews of longwall mining, the development of mine subsidence and the methods of predicting mine subsidence movements are provided in the background reports entitled *Introduction to Longwall Mining and Subsidence* and *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*.

The following sections provide overviews of conventional and non-conventional mine subsidence effects and the methods that have been used to predict these movements.

3.2. Overview of conventional subsidence effects

The normal ground movements resulting from the extraction of pillars or longwalls are referred to as conventional or systematic subsidence movements. These subsidence effects 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 such as 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 distance between two points increases and **Compressive Strains** occur when the distance between two points decreases. So that ground strains can be compared between different locations, they are typically measured over bay lengths that are equal to the depth of cover between the surface and seam divided by 20.

  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 panel or longwall. The **additional** subsidence, tilts, curvatures and strains are the maximum changes in the parameters due to the extraction of a series of panels or longwalls within a single seam. The **total** subsidence, tilts, curvatures and strains are the accumulated parameters which result from the extraction of panels and longwalls from a number of seams.

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 surface infrastructure, 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.

3.4. Overview of non-conventional subsidence effects

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 there is a high depth of cover, the observed subsidence profiles along monitoring survey 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 and strains at very shallow depths of cover where the collapsed zone above the extracted longwalls extends up to or near to the surface.

Non-conventional ground movements are likely to occur, in this case, due to the multi-seam mining conditions where longwalls are to be extracted below the previously extracted panels and longwalls. Additional subsidence, accompanied by locally elevated tilts, curvatures and strains are expected to occur, particularly in the immediate vicinity of the chain pillars in the overlying seams, where extra voids may have been formed as the overlying strata cantilevered into the overlying goafs.

Non-conventional ground movements also occur at the higher depths of cover and in single-seam mining conditions, although much less frequently than observed at very shallow depths of cover or in multi-seam mining conditions. The irregular movements appear as a localised bump in an otherwise smooth subsidence profile, accompanied by locally elevated tilts, curvatures and strains. 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 the above mechanisms are discussed in the following sections.

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

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

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

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

In this report, non-conventional ground movements have been considered in the statistical analyses of strain, provided in Section 4.4, which have been based on measurements for both conventional and non-conventional anomalous movements. The management strategies developed for the natural and built features should be designed to accommodate movements greater than the predicted conventional movements, so that the potential impacts resulting from non-conventional movements can be adequately managed.

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 along 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 in the downslope direction include tension cracks at the tops and on the sides of the steep slopes and compression ridges at the bottoms of the steep slopes.

3.4.3. Valley-related effects

Valley bulging movements are a natural phenomenon, resulting from the formation and ongoing development of the valley, as illustrated in Fig. 3.1. The potential for these natural movements are influenced by the geomorphology of the valley.

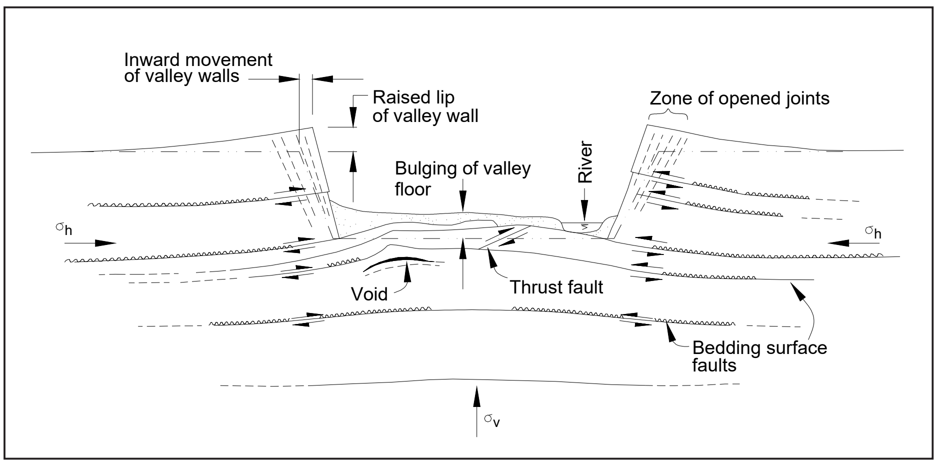


Fig. 3.1 Valley formation in flat-lying sedimentary rocks (after Patton and Hendren 1972)

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

- **Upsidence** is the reduced subsidence, or the relative uplift within a valley which results from the dilation or buckling of near-surface strata at or near the base of the valley. The magnitude of upsidence, which is typically expressed in the units of *millimetres (mm)*, is the difference between the observed subsidence profile within the valley and the conventional subsidence profile which would have otherwise been expected in flat terrain;
- **Closure** is the reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of *millimetres (mm)*, is the greatest reduction in distance between any two points on the opposing valley sides; and
- **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 resulting from the extraction of the panels and longwalls were made using the empirical method outlined in Australian Coal Association Research Program (ACARP) Project No. C9067 (Waddington and Kay, 2002). Further details can be obtained from the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

3.5. The Incremental Profile Method

Subsidence predictions for the bord and pillar and longwall panels were determined using the Incremental Profile Method (IPM) in the EIS Subsidence Assessment (Report No. MSEC986). The IPM involves the use of subsidence prediction curves derived from empirical data obtained in the Hunter, Newcastle, Southern and Western Coalfields. The IPM was calibrated for local single-seam and multi-seam mining (including bord and pillar mining), along with the geological conditions for the Project, as discussed in the EIS Subsidence Assessment (Report No. MSEC986).

In relation to the subsidence prediction methodology, the peer reviewer, Professor Bruce Hebblewhite, noted:

> *"It is noted that much of the Study Area is agricultural land with relatively few sensitive features that could be adversely impacted by the subsidence effects discussed. To this extent, the application of the MSEC IPM prediction methodology is considered to provide reasonable levels of confidence for subsidence prediction and impact assessment, given that "worst-case" scenarios have been adopted in the cases where greatest uncertainty exists."*

The IPM has also been used to determine the subsidence predictions for the bord and pillar and longwall panels based on the Modified Layout. Incremental impacts of the Modification have been determined by comparing the updated subsidence predictions for the Modification to the predictions for the approved layout in the EIS Subsidence Assessment (Report No. MSEC986).

3.6. Reliability of the predicted conventional subsidence effects

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

In this case, the IPM was calibrated using monitoring data from elsewhere in the Hunter Coalfield. The subsidence model was also calibrated using the available multi-seam monitoring data from the NSW coalfields.

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

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

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

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

4.1. Introduction

The following sections provide the maximum predicted conventional subsidence effects resulting from the extraction of the approved panels in the Whynot Seam and the modified longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams. The predicted subsidence effects and the impact assessments for the natural and built features within the Study Area are provided in Chapters 5 and 6.

The predicted subsidence, tilts and curvatures have been obtained using the IPM, which has been calibrated for single-seam and multi-seam conditions. The predicted strains have been determined by analysing the strains measured in the NSW coalfields, where the mining geometries and overburden geologies are similar to those for the Project (as modified).

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 and are provided in Chapters 5 and 6.

4.2. Maximum predicted subsidence, tilt and curvature

The predicted total subsidence contours after the extraction of the panels and longwalls in the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams are shown in Drawings Nos. MSEC1186-26, MSEC1186-27, MSEC1186-28 and MSEC1186-29, respectively.

A summary of the maximum predicted additional conventional subsidence effects, due to the extraction of the series of panels or longwalls in each of the seams, is provided in Table 4.1. The values in this table represent the maximum additional movements due to mining in each seam.

Table 4.1 Maximum predicted additional conventional subsidence effects for each seam

Due to each seam	Maximum predicted additional vertical subsidence (mm)	Maximum predicted additional tilt (mm/m)	Maximum predicted additional hogging curvature (km^{-1})	Maximum predicted additional sagging curvature (km^{-1})
Whynot Seam (single-seam conditions)	350	15	0.5	1.0
Woodlands Hill Seam (including reactivation)	3200	35	1.5	1.5
Arrowfield Seam (including reactivation)	2600	20	0.5	0.5
Bowfield Seam (including reactivation)	2500	20	0.5	0.5

A summary of the maximum predicted cumulative (i.e. total) conventional subsidence effects, after the completion of the series of panels or longwalls in each of the seams, is provided in Table 4.2. The predicted tilts are the maxima after the completion of all panels or longwalls within each of the seams. The predicted curvatures are the maxima at any time during or after the extraction of the panels or longwalls within each of the seams.

Table 4.2 Maximum predicted cumulative conventional subsidence effects after each seam

After each seam	Maximum predicted cumulative vertical subsidence (mm)	Maximum predicted cumulative tilt (mm/m)	Maximum predicted cumulative hogging curvature (km^{-1})	Maximum predicted cumulative sagging curvature (km^{-1})
Whynot Seam	350	15	0.5	1.0
Woodlands Hill Seam	3300	35	1.5	1.5
Arrowfield Seam	4700	40	2.0	2.0
Bowfield Seam	6500	50	2.0	2.0

The maximum predicted additional vertical subsidence, as percentages of the mining heights, are 17 % for the Whynot Seam, 100 % for the Woodlands Hill Seam, 95 % for the Arrowfield Seam and 95 % for the Bowfield Seam.

The maximum predicted total vertical subsidence, after the extraction of the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams, is 6500 mm and it represents approximately 65 % of the combined mining heights of these seams. It is noted that the percentage of the total mining height is less than the percentages of the mining heights for individual seams for multi-seam conditions, as the positions of maximum subsidence do not coincide due to the stagger of the longwalls.

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

It can be seen from Drawings Nos. MSEC1186-26 to MSEC1186-29, that the magnitude of the predicted subsidence varies over the mining area, due to the single-seam and multi-seam mining conditions, as well as the variations in the depths of cover and mining heights. It can also be inferred from the spacing of the contours shown in these drawings, that the magnitudes of the predicted tilts and curvatures also vary over the mining area.

To illustrate this variation, the predicted profiles of vertical subsidence, tilt and curvature have been determined along three prediction lines, the locations of which are shown in Drawings Nos. MSEC1186-26 to MSEC1186-29. The predicted profiles of vertical subsidence, tilt and curvature along Prediction Lines 1 to 3 are shown in Figs. C.01 to C.03, respectively, in Appendix C. The predicted profiles are shown after the completion of the Whynot Seam (red lines), Woodlands Hill Seam (green lines), Arrowfield Seam (cyan lines) and Bowfield Seam (blue lines). The maximum predicted tilts and curvatures after any panel or longwall in any seam are shown by the grey shading.

4.3. Comparison of the maximum predicted subsidence effects

A comparison of the maximum predicted total conventional subsidence effects, based on the EIS Layout and Modified Layout, is provided in Table 4.3. The values in this table represent the maximum cumulative movements after the mining of each seam. A summary of the changes in the maximum predicted subsidence effects due to the Modification is provided in Table 4.4.

Table 4.3 Comparison of the maximum predicted total subsidence effects

Layout	After each seam	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})
EIS Layout (MSEC986)	Whynot Seam	350	15	0.5	1.0
	Woodlands Hill	3200	45	2.0	1.5
	Arrowfield Seam	5400	50	2.0	2.0
	Bowfield Seam	5600	50	2.0	2.0
Modified Layout (MSEC1186)	Whynot Seam	350	15	0.5	1.0
	Woodlands Hill	3300	35	1.5	1.5
	Arrowfield Seam	4700	40	2.0	2.0
	Bowfield Seam	6500	50	2.0	2.0

Table 4.4 Changes in the maximum predicted total subsidence effects

Layout	After each seam	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})
Change due to the Modification*	Whynot Seam	*No change*	*No change*	*No change*	*No change*
	Woodlands Hill	+3 %	-22 %	-25 %	*No change*
	Arrowfield Seam	-13 %	-20 %	*No change*	*No change*
	Bowfield Seam	+16 %	*No change*	*No change*	*No change*

Note: * denotes negative percentages indicate reductions and positive percentages indicate increases in the associated values due to the Modification.

A comparison of the predicted total subsidence contours is provided in Fig. 4.1 based on the EIS Layout (top of figure) and the Modified Layout (bottom of figure).

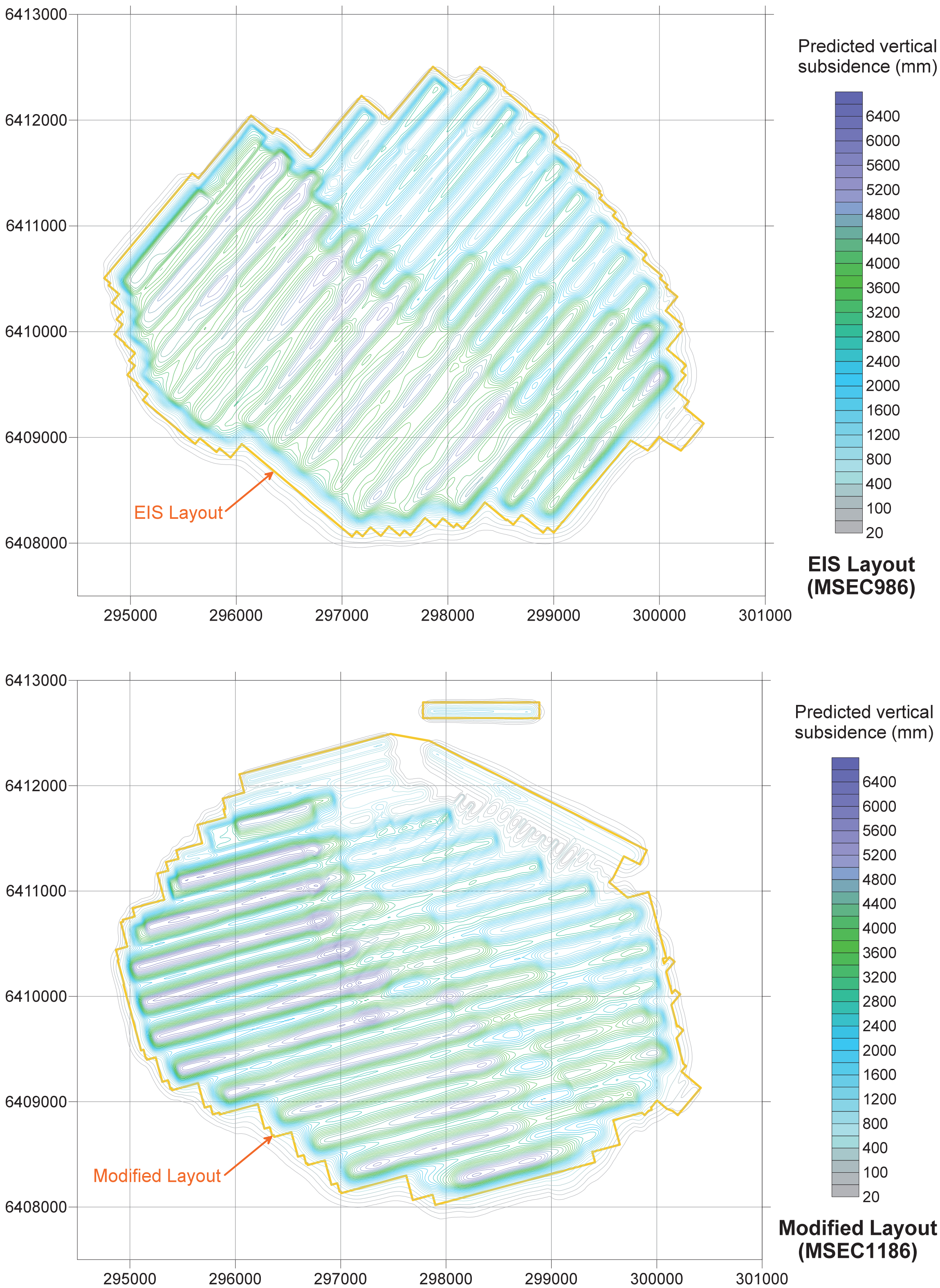


Fig. 4.1 Predicted total subsidence contours based on the EIS Layout (top) and the Modified Layout (bottom)

The maximum predicted total vertical subsidence after the completion of mining in all seams of 6500 mm, based on the Modified Layout, is greater than the maximum predicted value based on the EIS Layout of 5600 mm. The reason is the overlap between longwalls within each of the seams is slightly greater for the Modified Layout and, therefore, the predicted accumulated subsidence also increases.

The potential for impacts does not result from absolute vertical subsidence but rather from the differential movements (i.e. tilt, curvature and strain). Also, the surface areas where the predicted vertical subsidence is greater than 5600 mm occurs only locally where the western extents of the panels in the Whynot Seam are located above the longwalls in all of the Woodlands Hill, Arrowfield and Bowfield Seams. The surface areas where the predicted total subsidence is greater than 5600 mm is shown in Fig. 4.2.

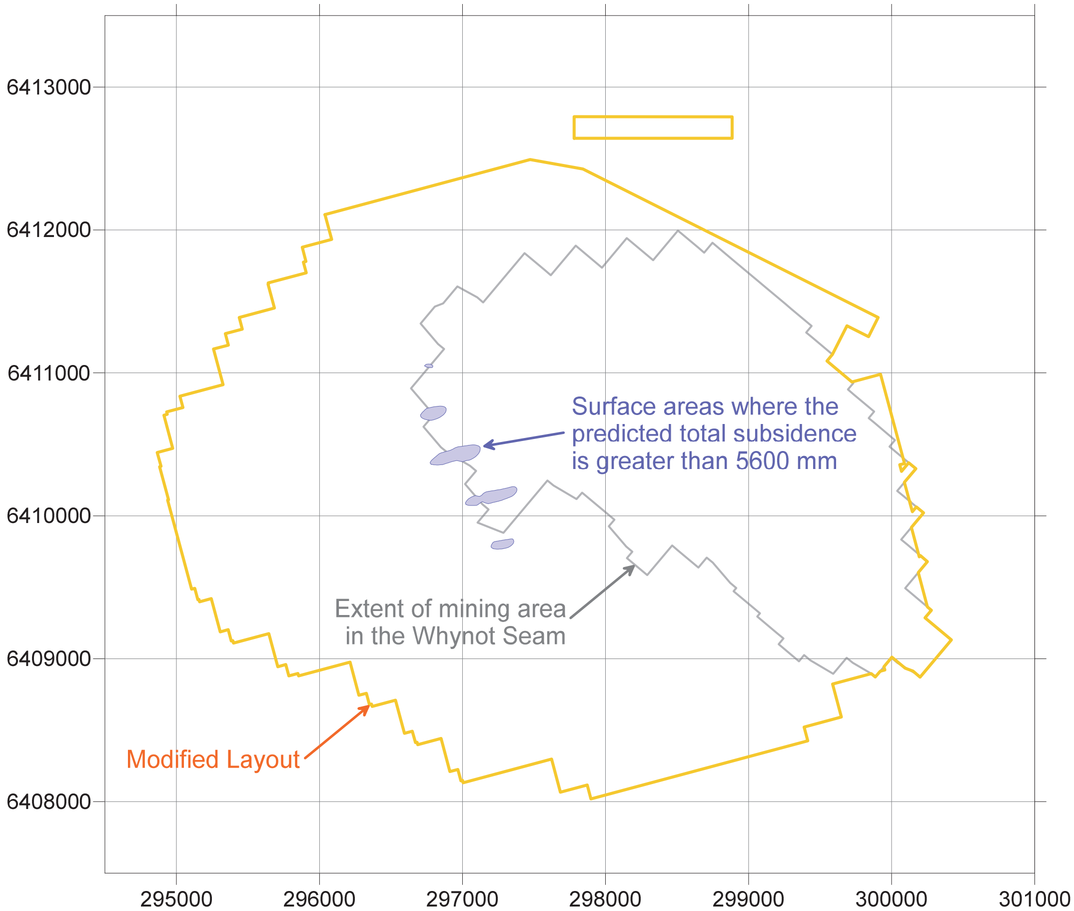


Fig. 4.2 Surface areas where the predicted total subsidence based on the Modified Layout is greater than 5600 mm

The surface area located within the limit of predicted vertical subsidence (i.e. 20 mm subsidence contour) is 1892 hectares (ha) based on the Modified Layout and 1805 ha based on the EIS Layout. The surface area within the limit of vertical subsidence therefore increases by 87 ha; however, this represents a change of only approximately 5 %. The predicted 20 mm subsidence contours are the outmost contours shown in Fig. 4.1 based on the EIS Layout (top of figure) and Modified Layout (bottom of figure).

The maximum predicted total tilt and curvatures after the completion of mining in all seams, based on the Modified Layout, are the same as the predicted values based on the EIS Layout. While the maximum predicted values do not change, the predicted total tilts and curvatures increase in some locations and decrease in other locations, depending on the position relative to the longwalls. The predicted subsidence effects for the natural and built features located within and near to the Study Area are discussed in Chapters 5 and 6.

4.4. Predicted strains

The prediction of strain is more difficult than the prediction of vertical subsidence, tilt and curvature. The reason 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.

Consistent with the EIS Subsidence Assessment (Report No. MSEC986), the predicted strains for the Modified Layout have been determined by analysing the strains measured in the NSW coalfields, where the mining geometries and overburden geologies are similar to those for the Project (as modified). A full description of the methodology, including relevant probability distribution functions, are provided in the EIS Subsidence Assessment (Report No. MSEC986).

4.4.1. Single-seam mining conditions

It has been found, for single-seam mining conditions, that applying a constant factor to the predicted maximum curvatures provides a reasonable prediction for the maximum conventional or typical 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 maximum predicted curvatures and the maximum predicted conventional strains, for single-seam mining conditions.

The layout of the panels in the Whynot Seam, based on the Modified Layout, is the same as that based on the EIS Layout. Accordingly, the maximum predicted conventional curvatures due to the mining of the panels in the Whynot Seam remain the same at 0.5 km^{-1} hogging and 1.0 km^{-1} sagging and therefore the maximum predicted conventional strains also remain the same at 5 mm/m tensile and 10 mm/m compressive. These maximum strains occur where the depths of cover are shallowest, in the northern part of the mining area.

Consistent with the EIS Layout, the modified longwalls in the Woodlands Hill Seam are located outside the extents of the overlying panels in the Whynot Seam in the southern, western and northern parts of the mining area. These parts of the longwalls will be extracted under single-seam mining conditions.

The maximum predicted conventional curvatures for the modified longwalls in the Woodlands Hill Seam, outside the extents of the overlying panels in the Whynot Seam (i.e. single-seam conditions), are 1.5 km^{-1} hogging and sagging. The maximum predicted hogging curvature, based on the Modified Layout, is less than that based on the EIS Layout. The maximum predicted curvature remains unchanged. Adopting a factor of 10, the maximum predicted conventional strains for single-seam mining conditions are 15 mm/m tensile and compressive.

At a point, however, there can be considerable variation from the linear relationship, resulting from non-conventional movements or from the normal scatters which are observed in strain profiles. When expressed as a percentage, observed strains can be many times greater than the predicted conventional strain for low magnitudes of curvature.

Consistent with the EIS Subsidence Assessment (Report No. MSEC986), the range of strains above the modified longwalls in the Woodlands Hill Seam has been determined using monitoring data from previously extracted panels in the Hunter and Newcastle Coalfields, for single-seam mining conditions, where the width-to-depth ratios and mining heights were similar to those of the longwalls.

The maximum predicted strains due to single-seam mining in the Woodlands Hill Seam, based on the Modified Layout, are the same as the maximum predicted values based on the EIS Layout. The strains are greatest in the north-west part of the mining area where the depths of cover are shallowed.

Consistent with the EIS Layout, the maximum predicted strains due to single-seam mining in the Woodlands Hill Seam in the north-western part of the mining area are:

- 8 mm/m tensile and compressive based on the 95 % confidence levels; and
- 21 mm/m tensile and 19 mm/m compressive based on the 99 % confidence levels.

Consistent with the EIS Layout, the maximum predicted strains due to single-seam mining in the Woodlands Hill Seam in the southern part of the mining area are:

- 5 mm/m tensile and 4 mm/m compressive based on the 95 % confidence levels; and
- 9 mm/m tensile and 6 mm/m compressive based on the 99 % confidence levels.

4.4.2. Multi-seam mining conditions

Consistent with the EIS Subsidence Assessment (Report No. MSEC986), the range of potential strains due to the mining of the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams, for multi-seam mining conditions, has been based on the measured strains for multi-seam mining in the Hunter and Newcastle Coalfields.

The maximum predicted strains due to multi-seam mining in the Woodlands Hill, Arrowfield and Bowfield Seams, based on the Modified Layout, are the same as the maximum predicted values based on the EIS Layout. The strains are expected to be greatest for mining in the Woodlands Hill Seam and then reduce for mining in the Arrowfield and Bowfield Seams due to the higher depths of cover.

Consistent with the EIS Layout, the maximum predicted strains due to multi-seam mining in the Woodlands Hill, Arrowfield and Bowfield Seams are:

- 8 mm/m tensile and 9 mm/m compressive based on the 95 % confidence levels; and
- 16 mm/m tensile and compressive based on the 99 % confidence levels.

The predicted range of strains based on multi-seam conditions is similar to but slightly less than that for single-seam conditions in the north-western part of the mining area. The reason is the longwalls in the Woodlands Hill Seam, in the north-western part of the mining area (i.e. single-seam conditions), are supercritical in width and have depths of cover less than 200 m. Whereas the longwalls in the eastern part of the mining area (i.e. multi-seam conditions) are subcritical in width and have depths of cover greater than 200 m.

The experience from Blakefield South Mine found that the highest strains for multi-seam conditions occurred where the chain pillars in the Blakefield Seam were located directly beneath the existing chain pillars in the overlying Whybrow Seam (i.e. stacked case). The longwalls within each of the Woodlands Hill, Arrowfield and Bowfield Seams have been staggered so that the chain pillars are not aligned. The predicted strains for these longwalls, due to the multi-seam conditions, therefore, are expected to be less than those for single-seam conditions due to the overburden being already fractured by the extraction of the earlier seams, and due to the increasing depths of cover.

4.5. Predicted far-field horizontal movements

In addition to the conventional subsidence effects that have been predicted above and adjacent to the mining area, it is also likely that far-field horizontal movements will be experienced outside the mining area. The predicted far-field horizontal movements, based on the Modified Layout, are the same as the predicted movements based on the EIS Layout.

The predicted far-field horizontal movements are very small and could only be detected by precise surveys. Such movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low-levels of strain, which are generally less than the order of survey tolerance (i.e. less than 0.3 mm/m). The impacts of far-field horizontal movements on the natural and built features within the vicinity of the panels and longwalls are not expected to be significant.

4.6. Surface cracking and deformations

Panel and longwall mining can result in surface cracking, heaving, buckling, humping and stepping at the surface. The extent and severity of these mining-induced ground deformations are dependent on a number of factors, including the mine geometry, depth of cover, overburden geology, locations of natural joints in the bedrock, the presence of near-surface geological structures and, in this case, multi-seam mining conditions.

The methodology for predicting surface cracking has been developed based on the longwall mining experience in the NSW coalfields and is described in the EIS Subsidence Assessment (Report No. MSEC986). The predicted range of crack widths, based on the Modified Layout, is the same as the predicted range based on the EIS Layout.

Consistent with the EIS Layout, the surface cracking in the flatter areas and at higher depths of cover above the mining area is expected to be typically between 25 mm and 50 mm in approximately 50 % of cases, between 50 mm and 100 mm in approximately 30 % of cases, between 100 mm and 150 mm in approximately 15 % of cases and greater than 150 mm in approximately 5 % of cases. Consistent with the EIS Layout, multiple cracks resulting in deformations over widths of several metres could also occur in some locations (i.e. less than 1 % of cases).

Consistent with the EIS Layout, the surface cracking along the steep slopes and at shallower depths of cover above the mining area is expected to be typically between 50 mm and 100 mm in approximately 60 % of cases, between 100 mm and 200 mm in approximately 25 % of cases, between 200 mm and 300 mm in approximately 10 % of cases and greater than 300 mm in approximately 5 % of cases. Consistent with the EIS Layout, multiple cracks resulting in deformations over several metres could also occur in some locations (i.e. less than 1 % of cases).

Compression heaving and stepping of the surface could also occur above the mining area. The heights of these deformations are expected to be typically less than 100 mm. However, vertical shear could also occur in some locations with height greater than 300 mm.

The projected surface expression of the East Graben Fault is located approximately 180 m from the mining area. Localised surface deformations could develop at the surface expression of this fault where it is located closest to the mining area.

The predicted vertical subsidence at the surface expression of the East Graben Fault is less than 20 mm. It is possible that the ground movements could concentrate at the surface expression of the fault resulting in minor localised cracking with widths of less than approximately 10 mm.

Sills are located above the mining area, as described in Section 1.4. It is possible that the sills could partially span across the corners of the longwalls resulting in localised and irregular movements where the depth of cover is shallowest. However, the potential for this spanning is reduced due to the multi-seam mining, with the longwalls staggered so that the longwall corners are not aligned. It is expected that localised cracking and stepping at the surface, due to the presence of these sills, would be typically less than 50 mm where the depth of cover is shallowest.

The land above the mining area is owned by Malabar and it is used for cattle grazing. The surface cracking and deformations could result in safety issues (i.e. trip hazards to people and stock), affect vehicle access (i.e. large deformations in access tracks), or result in increased erosion (especially along the drainage lines and the steeper slopes).

Management strategies and remediation measures can be developed for surface cracking and deformations, which could include the following:

- visual monitoring of the surface in the active subsidence zone, to identify the larger surface cracking and deformations that could affect safety, access, or increase erosion;
- establish methods for surface remediation, which could include 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 vegetation in order to stabilise the steeper slopes in the longer term; and
- develop management plans incorporating the agreed methods to remediate the larger surface cracking, as required.

With the implementation of the above measures, the predicted surface cracking and deformations can be suitably managed to avoid safety and material erosion issues. Further discussions are provided in the impact assessments in the following sections of this report.

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. The Hunter River

5.1.1. Description of the Hunter River

The locations of the Hunter River and the extent of associated alluvial material as mapped by Fluvial Systems (2019) are shown in Drawing No. MSEC1186-23.

The Hunter River is located south of the modified mining area. A summary of the minimum distances of the thalweg (i.e. centreline) of the river channel from the panels and longwalls within each seam is provided in Table 5.1. The minimum distances of the river from the 26.5° angle of draw for each seam are also provided in this table.

Table 5.1 Minimum distances of the Hunter River from the panels and longwalls

Seam	Nearest panel or longwall	Minimum distance from the nearest panel or longwall (m)	Minimum distance from the 26.5° angle of draw (m)
Whynot Seam	WNP16	1650	1580
Woodlands Hill Seam	WHLW15	470	305
Arrowfield Seam	AFLW12	570	380
Bowfield Seam	BFLW12	485	290

The thalweg of the channel of the Hunter River is 470 m south of WHLW15, at its closest point to the mining area, based on the Modified Layout. The river channel is located at a minimum distance of 525 m from the mining area based on the EIS Layout.

A section through the Hunter River and the longwalls, where the river channel is located closest to the mining area, is shown in Fig. 5.1. The thalweg of the river is located well outside the 26.5° angles of draw from the panels and longwalls in each of the seams. The 50 m buffer to the mapped limit of alluvium is also located outside the angles of draw.

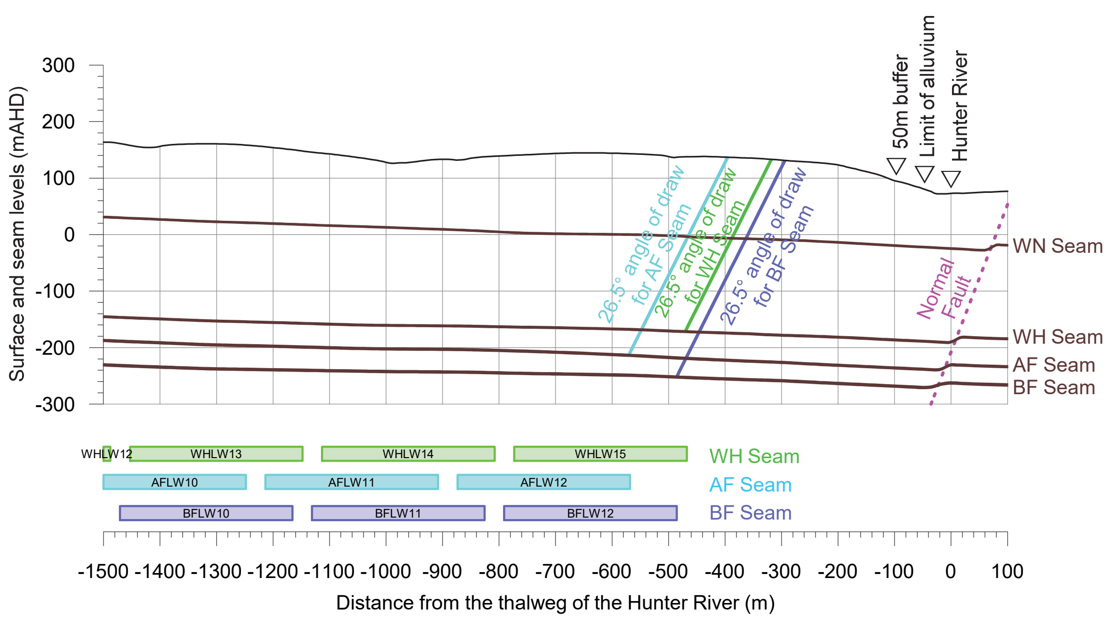


Fig. 5.1 Section through the Hunter River and the longwalls where the river is located closest to the mining area

The river channel is incised into the alluvium. The banks of the river are approximately 5 m to 10 m high. The natural ground rises up towards the mining area, on the northern side of the river channel, with the elevation increasing by 40 m over a distance of approximately 100 m from the river bank. The natural ground is flatter on the southern side of the river, rising by less than 10 m over a distance of approximately 100 m from the river bank.

Photographs of the Hunter River are provided in Fig. 5.2 near the crossing beneath the Golden Highway (left side) and where the river is located closest to the mining area (right side).

Fig. 5.2 Photographs of the Hunter River

Further descriptions of the Hunter River are provided by the specialist surface water and groundwater consultants for the Project.

5.1.2. Predictions for the Hunter River

The thalweg of the Hunter River is located at minimum distances of 470 m from the mining area and 290 m from the 26.5° angle of draw, at its closest point. At these distances, the river channel itself is expected to experience negligible vertical subsidence, i.e. less than 5 mm. The river channel is therefore not expected to experience measurable conventional tilts, curvatures or strains due to mining.

The equivalent valley height for the Hunter River is equal to the average height of the two valley sides within a distance equal to half the depth of cover from the river thalweg. The depth of cover to the Woodlands Hill Seam above the western end of WHLW15 (i.e. closest longwall to the river) is 300 m. The equivalent valley height of the Hunter River is 25 m where it is located closest to the modified mining area.

The predicted total valley-related effects are 40 mm upsidence and 60 mm closure due to mining in all seams. These predicted values are expected to be conservative since the prediction curves for the 2002 ACARP method (Waddington and Kay, 2002) have been drawn above the empirical data (i.e. upperbound curve) and, therefore, there is an accumulation of survey tolerance when adding the incremental movements from each of the panels and longwalls.

The predicted valley closure and compressive strain have been further refined based on the analysis of ground monitoring lines for valleys with similar heights located at similar distances from previously extracted longwalls in the NSW coalfields, as for the Hunter River from the mining area. The maximum predicted total valley closure derived from this analysis is 30 mm based on the 95 % confidence level. The maximum predicted compressive strain due to valley closure effects is 1.1 mm/m based on the 95 % confidence level. It is noted that the predicted compressive strain comprises a component of survey tolerance in the order of 0.3 mm/m.

5.1.3. Comparison of the predictions for the Hunter River

The thalweg of the channel of the Hunter River is located outside the mining area at distances of 525 m based on the EIS Layout and 470 m based on the Modified Layout. While the distance of the river outside the mining area for the Modified Layout is less than the EIS Layout, this only occurs at the south-western corner of WHLW15 and near AFLW12 and BFLW12. The remaining longwalls based on the Modified Layout are located at minimum distances of 800 m or greater from the river.

A comparison of the maximum predicted total vertical subsidence and closure effects for the Hunter River, based on the EIS Layout and Modified Layout, is provided in Table 5.2. The values in this table represent the maximum cumulative movements for the river after the mining of all seams.

Table 5.2 Comparison of the maximum predicted subsidence effects for the Hunter River

Layout	After seam	Maximum predicted total vertical subsidence (mm)	Maximum predicted total closure based on 95 % confidence level (mm)	Maximum predicted total closure strain based on 95 % confidence level (mm/m)
EIS Layout (MSEC986)	WN, WH, AF and BF Seams	< 5	20	0.7
Modified Layout (MSEC1186)	WN, WH, AF and BF Seams	< 5	30	1.1

The maximum predicted total vertical subsidence for the Hunter River is less than 5 mm based on both the EIS Layout and Modified Layout. Only very low level conventional subsidence effects are predicted as the river is located well outside the 26.5° angle of draw for both layouts.

The maximum predicted total closure and compressive strain for the Hunter River, based on the Modified Layout, are greater than the maximum predicted values based on the EIS Layout. However, these maximum values only occur where the river is located closest to the south-western corner of WYLW15. Away from that location, the predicted closure and compressive strain for the Modified Layout are similar to or less than the maximum predicted values based on the EIS Layout.

The following section provides the updated impact assessments for the Hunter River based on the Modified Layout. The assessed impacts and recommended management strategies are the same as those presented in the EIS Subsidence Assessment (Report No. MSEC986) and the EIS.

5.1.4. Impact assessments for the Hunter River

The thalweg of the Hunter River is located at a minimum distance of 470 m from the modified mining area. At this distance, the predicted vertical subsidence at the river channel is expected to be negligible. The predicted conventional tilts, curvatures and strains are not expected to be measurable.

The river channel could experience very low-levels of valley-related upsidence and closure. The maximum predicted compressive strain is 1.1 mm/m based on the 95 % confidence level. These valley-related effects are not expected to be sufficient to result in fracturing of the bedrock beneath the river channel. Fracturing has not been observed at distances of 470 m outside of previous longwall mining in the NSW coalfields. While fracturing has been observed up to 400 m outside of longwall mining in the NSW coalfields, this has occurred in large and more deeply-incised river valleys in the Southern Coalfield.

The river channel itself is therefore not expected to experience adverse impacts resulting from the conventional or valley-related effects due to the Project (as modified).

It can be seen from Drawing No. MSEC1186-23 and Fig. 5.1, that the mapped limit of alluvium associated with the Hunter River and the 50 m buffer are located outside the 26.5° angles of draw lines from the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams. The alluvium is predicted to experience less than 20 mm vertical subsidence due to the Project (as modified). While the alluvium could experience very low-levels of vertical subsidence, it is not expected to experience measurable conventional tilts, curvatures or strains.

The potential impacts on the Hunter River, the alluvium and associated aquifer are discussed by the specialist surface water and groundwater consultants in the reports by *WRM Water and Environment* (2022) and *SLR* (2022), respectively.

5.1.5. Recommendations for the Hunter River

It is recommended that Extraction Plans for the Project include a subsidence effects monitoring program to monitor subsidence movements, including valley closure, and compare measured movements with predictions. Further recommendations for the Hunter River have been provided by the specialist surface water and groundwater consultants for the Project, including the development and implementation of a monitoring program.

5.2. Saddlers Creek

5.2.1. Description of Saddlers Creek

The location of Saddlers Creek and the extent of associated alluvial material as mapped by Fluvial Systems (2019) are shown in Drawing No. MSEC1186-23.

Saddlers Creek is located to the north of the modified mining area. A summary of the minimum distances of the thalweg (i.e. centreline) of the creek from the panels and longwalls within each seam is provided in Table 5.3. The minimum distances of the creek from the 26.5° angle of draw for each seam are also provided in this table.

Table 5.3 Minimum distances of Saddlers Creek from the panels and longwalls

Seam	Nearest panel or longwall	Minimum distance from the nearest panel or longwall (m)	Minimum distance from the 26.5° angle of draw (m)
Whynot Seam	WNP5	880	860
Woodlands Hill Seam	WHLW1	125	60
Arrowfield Seam	AFLW1	310	215
Bowfield Seam	BFLW1	340	235

The thalweg of the channel of Saddlers Creek is 125 m north of WHLW1, at its closest point to the modified mining area. The surveyed position at the top of the high bank of the creek is located 100 m from WHLW1, at its closest point to the mining area.

A section through Saddlers Creek and the longwalls, where the creek channel is located closest to the mining area, is shown in Fig. 5.3. The thalweg of the creek is located outside the 26.5° angles of draw from the panels and longwalls in each of the seams. The mapped limit of alluvium is also located outside the angles of draw.

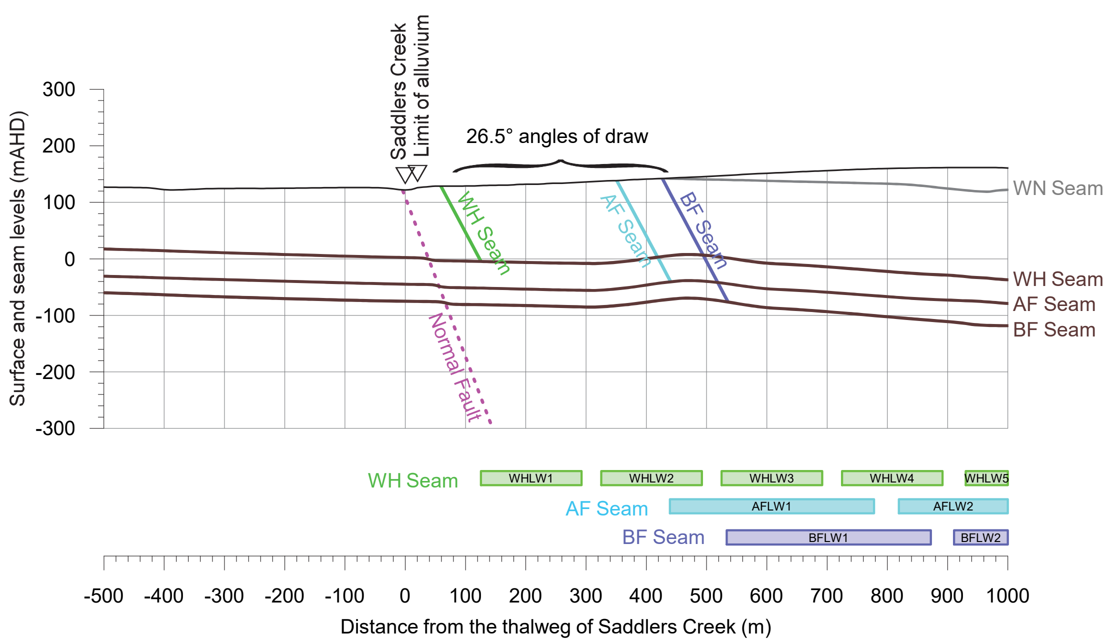


Fig. 5.3 Section through Saddlers Creek and the longwalls where the creek is located closest to the mining area

It is possible Saddlers Creek could be coincident with the surface expression of the fault that is located outside and adjacent to the modified mining area, as shown in Fig. 5.3. This north-east trending normal fault has a dip of approximately 70° and a throw of up to 5 m.

Saddlers Creek has a shallow incision into the alluvium. The banks of the creek are approximately 3 m to 5 m high. The natural ground rises up towards the modified mining area, on the southern side of the creek, with the elevation increasing by 10 m over a distance of approximately 100 m from the creek bank. The natural ground is flatter on the northern side of the creek, rising by less than 5 m over a distance of approximately 100 m from the creek bank.

Saddlers Creek flows towards the south-west and it joins the Hunter River more than 4 km outside of the modified mining area. Photographs of Saddlers Creek are provided in Fig. 5.4 near the crossing with Edderton Road (left side) and further upstream (right side).

Fig. 5.4 Photographs of Saddlers Creek

Further descriptions of Saddlers Creek are provided by the specialist surface water and groundwater consultants for the Project.

5.2.2. Predictions for Saddlers Creek

The thalweg of the Saddlers Creek is located at minimum distances of 125 m from the modified mining area and 60 m from the 26.5° angle of draw, at its closest point. At these distances, the creek channel itself is expected to experience negligible vertical subsidence, i.e. less than 5 mm. The creek channel is therefore not expected to experience measurable conventional tilts, curvatures or strains due to the Project (as modified).

The equivalent valley height for Saddlers Creek is equal to the average height of the two valley sides within a distance equal to half the depth of cover from the creek. The depth of cover to the Woodlands Hill Seam above the eastern end of WHLW1 (i.e. closest longwall to the creek) is 135 m. The equivalent valley height of Saddlers Creek is 8 m where it is located closest to the modified mining area.

The predicted total valley-related effects for Saddlers Creek are 20 mm upsidence and 30 mm closure due to the Project (as modified). The predicted compressive strain due to the valley-related effects is 0.5 mm/m based on the 95 % confidence level.

5.2.3. Comparison of the predictions for Saddlers Creek

The thalweg of the channel of Saddlers Creek is located outside the mining area at distances of 240 m based on the EIS Layout and 125 m based on the Modified Layout. While the distance of the creek outside the mining area for the Modified Layout is less than the EIS Layout, this only occurs at the north-western corner of WHLW1. The remaining panels and longwalls based on the Modified Layout are located at minimum distances of 310 m for the Arrowfield Seam, 340 m for the Bowfield Seam and 880 m for the Whynot Seam.

A comparison of the maximum predicted total vertical subsidence and closure effects for Saddler Creek, based on the EIS Layout and Modified Layout, is provided in Table 5.4. The values in this table represent the maximum cumulative movements for the creek after the mining of all seams.

Table 5.4 Comparison of the maximum predicted subsidence effects for Saddlers Creek

Layout	After seam	Maximum predicted total vertical subsidence (mm)	Maximum predicted total closure based on 95 % confidence level (mm)	Maximum predicted total closure strain based on 95 % confidence level (mm/m)
EIS Layout (MSEC986)	WN, WH, AF and BF Seams	< 20	20	< 0.5
Modified Layout (MSEC1186)	WN, WH, AF and BF Seams	< 20	30	0.5

The maximum predicted total vertical subsidence for Saddlers Creek is less than 20 mm based on both the EIS Layout and Modified Layout. Only very low level conventional subsidence effects are predicted as the creek is located outside the 26.5° angles of draw for both layouts.

The maximum predicted total closure and compressive strain for Saddlers Creek, based on the Modified Layout, are slightly greater than the maximum predicted values based on the EIS Layout. However, these maximum values only occur where the creek is located closest to the north-western corner of WYLW1. Away from that location, the predicted closure and compressive strain for the Modified Layout are similar to or less than the maximum predicted values based on the EIS Layout.

The following section provides the updated impact assessments for Saddlers Creek based on the Modified Layout. The assessed impacts and recommended management strategies are the same as those presented in the EIS Subsidence Assessment (Report No. MSEC986) and the EIS.

5.2.4. Impact assessments for Saddlers Creek

The thalweg of Saddlers Creek is located 125 m from the modified mining area, at its closest point. At this distance, the predicted vertical subsidence at the creek channel is expected to be negligible. The predicted conventional tilts, curvatures and strains are not expected to be measurable.

The creek channel could experience very low-levels of upsidence and closure. It is unlikely that the compressive strain due to these valley-related effects would be sufficient to result in fracturing in the bedrock beneath the creek. Even if fracturing were to occur in the bedrock beneath Saddlers Creek, it is unlikely that it would be visible at the surface due to the overlying alluvium.

The creek channel itself is therefore not expected to experience adverse impacts resulting from the conventional or valley-related effects due to the Project (as modified).

It is possible Saddlers Creek could be coincident with the surface expression of the fault that is located outside and adjacent to the modified mining area, as shown in Fig. 5.3. It is unlikely that localised movements would develop at the surface expression of this fault due to its distance from the modified mining area and due to its small size. Even if localised movements were to occur at the surface expression of the fault, it is unlikely that these low-level movements would be visible at the surface due to the alluvium.

The potential impacts on Saddlers Creek, the alluvium and associated aquifer are discussed by the specialist surface water and groundwater consultants in the reports by *WRM Water and Environment* (2022) and *SLR* (2022), respectively.

5.2.5. Recommendations for Saddlers Creek

It is recommended that Extraction Plans for the Project include periodic visual inspections of Saddlers Creek and surrounding areas during the mining period. Further recommendations for Saddlers Creek have been provided by the specialist surface water and groundwater consultants for the Project.

5.3. Drainage lines

5.3.1. Description of the drainage lines

The locations of the drainage lines within the Study Area are shown in Drawing No. MSEC1186-23. It appears from the CMA Map of the area, that there are no "named" drainage lines within the area.

The drainage lines in the southern part of the Study Area are tributaries to the Hunter River and the drainage lines in the northern part of the Study Area are tributaries to Saddlers Creek. The upper reaches are first and second order streams and some parts of the lower reaches are third order streams. The drainage lines are ephemeral, where surface water only flows during and for short periods after rainfall events, although some isolated natural ponding is evident along the flatter lower reaches.

The natural grades along the drainage lines typically vary between 30 mm/m and 70 mm/m (i.e. 3 % to 7 % or 1 in 33 to 1 in 14) along the upper reaches and typically between 10 mm/m and 30 mm/m (i.e. 1 % to 3 % or 1 in 100 to 1 in 33) along the lower reaches.

The drainage lines have shallow incisions into the natural surface soils, which are generally derived from the Jerrys Plains Subgroup of the Wittingham Coal Measures, as illustrated in Fig. 1.15. There is rock outcropping along the lower reaches of some of the drainage lines.

The features along the drainage lines have been mapped by *Fluvial Systems* (2019) and are described in the EIS Subsidence Assessment (Report No. MSEC986).

5.3.2. Predictions for the drainage lines

Drainage lines are located across the Study Area and, therefore, they are expected to experience the range of predicted subsidence effects. A summary of the maximum predicted conventional subsidence effects within the Study Area is provided in Chapter 4.

A summary of the maximum predicted vertical subsidence, tilt and curvatures for the drainage lines is provided in Table 5.5. The values are the maximum predicted subsidence effects within the Study Area due to mining in the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams.

Table 5.5 Maximum predicted conventional subsidence, tilt and curvature for the drainage lines

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})
Drainage lines	6500	50	2.0	2.0

The maximum predicted total conventional curvatures are 2.0 km^{-1} hogging and sagging, which represent a minimum radius of curvature of 0.5 km. The predicted conventional strains based on applying a factor of 10 to the predicted conventional curvatures are 20 mm/m tensile and compressive.

The distributions of strain above the mining area are provided in Section 4.4. The predicted strains due to multi-seam mining 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 predictions for the individual drainage lines vary depending on their locations relative to the approved panels and modified longwalls within each seam. To illustrate this variation, the predictions have been provided along four typical drainage lines above the mining area, referred to as Drainage Lines A, B, C and E. It is noted that these four drainage lines are only representative and are no more important than the other drainage lines within the Study Area. The locations of these representative drainage lines are shown in Drawing No. MSEC1186-23.

The predicted profiles of total vertical subsidence, tilt and curvature along Drainage Lines A, B, C and E are shown in Figs. C.04 to C.07, respectively, in Appendix C. The predicted profiles are shown after the completion of the Whynot Seam (red lines), Woodlands Hill Seam (green lines), Arrowfield Seam (cyan lines) and Bowfield Seam (blue lines). The maximum predicted tilts and curvatures after any panel or longwall in any seam are shown by the grey shading.

The drainage lines could also experience valley-related effects due to the Project (as modified). The drainage lines have shallow incisions into the natural surface soils and, therefore, the predicted upsidence and closure effects are not expected to be significant when compared with the predicted conventional effects.

5.3.3. Comparison of the predictions for the drainage lines

A comparison of the maximum predicted total conventional subsidence effects for the drainage lines, based on the EIS Layout and Modified Layout, is provided in Table 5.6. The values in this table represent the maximum cumulative movements for the drainage lines after the mining of all seams.

Table 5.6 Comparison of the maximum predicted subsidence effects for the drainage lines

Layout	After seam	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})
EIS Layout (MSEC986)	WN, WH, AF and BF Seams	5600	50	2.0	2.0
Modified Layout (MSEC1186)	WN, WH, AF and BF Seams	6500	50	2.0	2.0

The maximum predicted total vertical subsidence for the drainage lines of 6500 mm, based on the Modified Layout, is greater than the maximum predicted value based on the EIS Layout of 5600 mm. However, the potential for impacts does not result from absolute vertical subsidence but rather from the differential movements (i.e. differential subsidence, tilt, curvature and strain).

The predicted differential subsidence (i.e. difference between the greatest subsidence for areas directly above the longwalls and the lesser subsidence for areas above the chain pillars), based on the Modified Layout, is greater than that for the EIS Layout. The depths and extents of the potential ponding areas above the longwall mining area therefore increase.

The maximum predicted total tilt and curvatures for the drainage lines, based on the Modified Layout, are the same as the maximum predicted values based on the EIS Layout. The predicted subsidence effects will vary along each of the drainage lines, with locally higher values in some locations and locally lower values in other locations, depending on their positions relative to the panels and longwalls for each layout.

The surface area located within the predicted total 20 mm subsidence contour is 1892 ha based on the Modified Layout and 1805 ha based on the EIS Layout. The total length of the drainage lines located within the predicted limit of subsidence slightly increases; however, this represents a change of only approximately 5 %.

The following section provides the updated impact assessments for the drainage lines based on the Modified Layout. The assessed impacts and recommended management strategies are the same as those presented in the EIS Subsidence Assessment (Report No. MSEC986) and the EIS.

5.3.4. Impact assessments for the drainage lines

The impact assessments for the drainage lines are provided in the following sections.

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

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

The maximum predicted tilt for the drainage lines is 50 mm/m (i.e. 5 % or 1 in 20). The predicted changes in grade are similar to the natural gradients along the upper reaches and are greater than the natural gradients along the lower reaches of the drainage lines.

It is likely, therefore, that there would be areas that would experience increased ponding along the lower reaches of the drainage lines, predominately upstream of the chain pillars in the shallower seams and where the drainage lines exit the modified mining area. Other areas could also experience increased scouring of the stream beds, predominately downstream of the chain pillars in the shallower seams.

The locations within the Study Area that are predicted to experience increased potential for ponding are illustrated in Fig. 5.10. The natural and the predicted post-mining surface levels (i.e. prior to any surface remediation) along Drainage Lines A, B, C and E are also illustrated in Fig. 5.5 to Fig. 5.8. The estimated maximum depths and extents of the topographical depressions (prior to any remediation) along these drainage lines are also indicated in these figures.

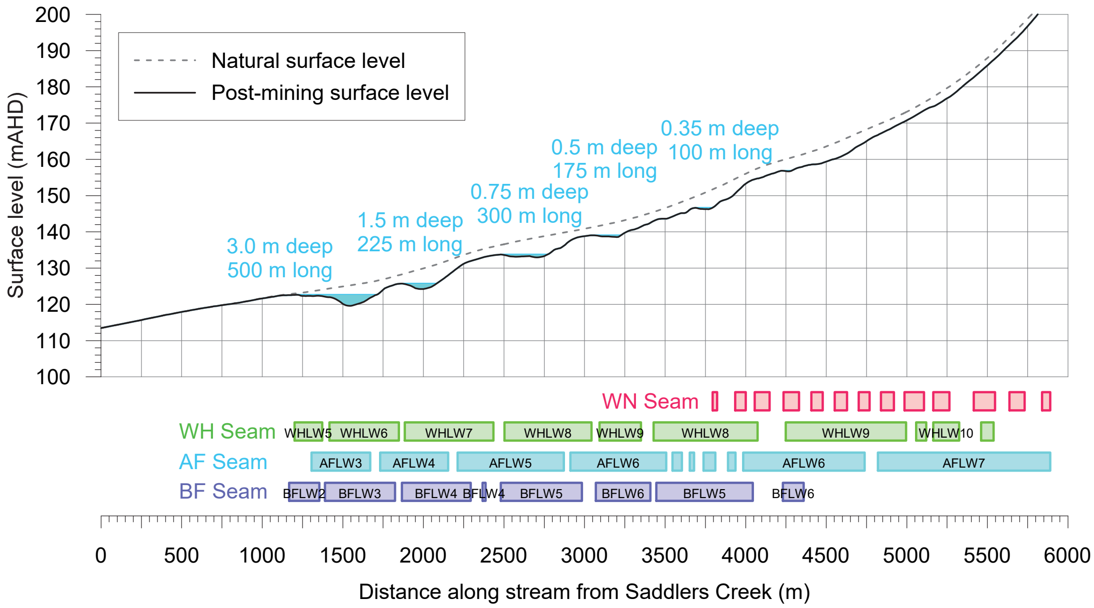


Fig. 5.5 Natural and predicted post-mining surface levels along Drainage Line A

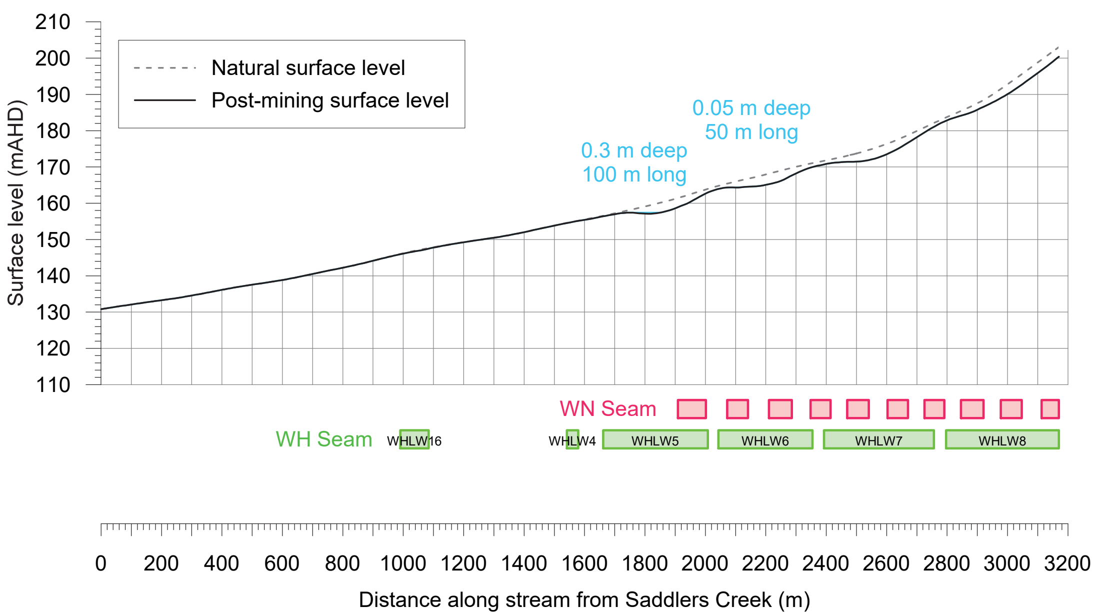


Fig. 5.6 Natural and predicted post-mining surface levels along Drainage Line B

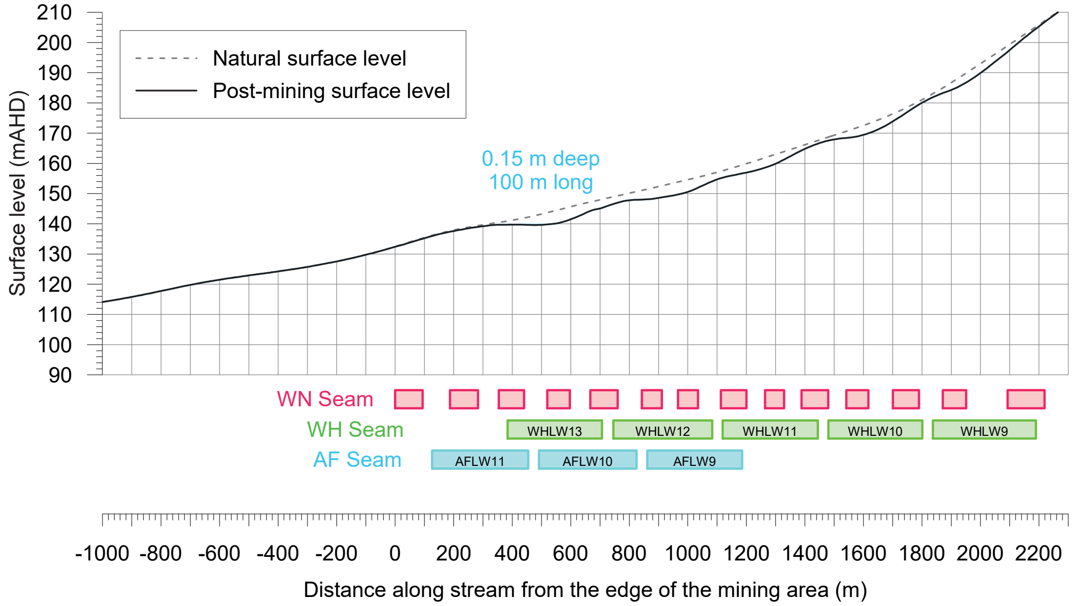


Fig. 5.7 Natural and predicted post-mining surface levels along Drainage Line C

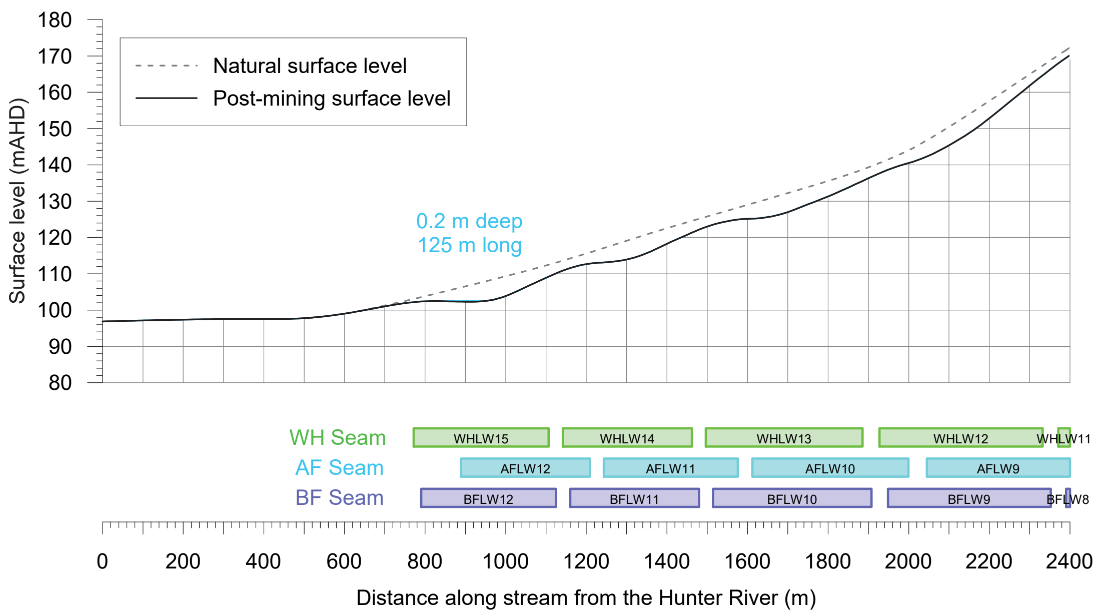


Fig. 5.8 Natural and predicted post-mining surface levels along Drainage Line E

The largest ponding areas are predicted to occur upstream of where the drainage lines exit the mining area. It is estimated that a topographical depression up to around 3.0 m deep and up to 500 m long will develop along the drainage lines, after the completion of all longwalls. Some deeper but more localised ponding could occur in the locations of the existing farm dams. The maximum predicted depth of the topographical depressions is greater than that assessed based on the EIS Layout of 2.3 m; however, the maximum extent does not change.

It is noted that the predicted ponding depths and extents are likely to be conservative, as these have been based on the predicted changes in surface levels along the original alignments of the drainage lines and, therefore, do not consider the natural grades across the alignments of the drainage lines. The mining will result in some changes in the stream alignments, due to the natural cross-grades and, in consequence, the actual ponding depths are expected to be less than those predicted.

The locations within the Study Area that are predicted to experience increased potential for ponding are illustrated in Fig. 5.10. That figure considers the changes along and across the alignments of the drainage lines and, therefore, provides a better indication for the extents of potential ponding as part of the discussions on land prone to flooding or inundation.

Potential for cracking in the drainage line beds and fracturing of the bedrock

Fracturing of the uppermost bedrock has been observed in the past, as a result of longwall mining, where the tensile strains have been greater than 0.5 mm/m. Buckling and dilation of the uppermost bedrock have also been observed where the compressive strains have been greater than 2 mm/m. It is likely, therefore, that fracturing, buckling and dilation would occur in the bedrock beneath the soil beds of the drainage lines based on the magnitudes of the predicted strains. Fracturing of the exposed bedrock is also expected.

The assessed surface deformations above the panels and longwalls are provided in Section 4.6. The largest impacts are expected to occur along the steeper sections of the drainage lines, on the sides of the ridgelines in the southern part of the mining area, and where the depths of cover are shallowest, in the northern part of the mining area.

The assessed impacts for the drainage lines, based on the Modified Layout, are similar to those based on the EIS Layout. The potential for surface cracking increases in some locations and decreases in other locations, depending on the locations relative to the panels and longwalls. It is considered that the overall level of potential impact does not significantly change. While the total length of the drainage lines located within the predicted limit of subsidence (i.e. 20 mm subsidence contour) slightly increases, this represents a change of only approximately 5 %.

The surface cracking in these areas is expected to be typically between 50 mm and 100 mm in approximately 60 % of cases, between 100 mm and 200 mm in approximately 25 % of cases, between 200 mm and 300 mm in approximately 10 % of cases and greater than 300 mm in approximately 5 % of cases. Multiple cracks resulting in deformations over several metres could also occur in some locations (i.e. less than 1 % of cases).

Rock slabs have been identified along the drainage lines in four locations above the mining area, as shown in Drawing No. MSEC1186-23 (after Fluvial Systems, 2019). The rock slab along Drainage Line C is located above the panels in the Whynot Seam, but it is outside the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams. The predicted vertical subsidence in this location is less than 200 mm and, therefore, the potential for significant fracturing in this rock slab is considered to be low.

Fracturing could develop in the other three rock slabs that are located directly above the longwalls. The two rock slabs along Drainage Line B are located at its upper reaches where the surface water flows are lower due to the limited tributary area. The exposed bedrock along Drainage Line E is confined to a narrow channel in the base on the stream. There are no standing pools at or upstream of these rock slabs.

The drainage lines 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, however, surface water flows could be diverted into the dilated strata below the beds where the bedrock is shallow or exposed.

It is likely that some remedial measures would be required at the completion of mining. Where necessary, any significant surface cracks in the drainage line beds could be remediated by infilling with the surface soil or other suitable materials or by locally regrading and recompacting the surface.

The multi-seam mining will result in the development of a network of fractures in the overburden above the extracted panels and longwalls. The changes in permeability and the potential hydrogeological impacts above panels and longwalls are discussed by the specialist groundwater consultant in the report by *SLR* (2022).

Experience from mining in the Hunter and Newcastle Coalfields indicates that impacts on ephemeral streams are low where the panels are subcritical or where the depths of cover are greater than the order of 200 m. The panels in the Whynot Seam are typically subcritical in width, except in the northern part of the mining area where the depths of cover are shallowest. The longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams are typically at depths of cover greater than 200 m.

For example, ephemeral drainage lines have been directly mined beneath at South Bulga and the Beltana No. 1 Underground Mine by the 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. Similar experience occurred where the North Wambo Underground Mine and United Collieries extracted longwalls in the Whybrow, Wambo and Woodlands Hill Seams (i.e. multi-seam) beneath a number of ephemeral streams, including North Wambo Creek.

Further discussions on the potential impacts on the drainage lines are provided by the specialist geomorphology, surface water and groundwater consultants in the reports by *WRM Water and Environment* (2022) and *SLR* (2022), respectively.

5.3.5. Recommendations for the drainage lines

Formation of topographical depressions along watercourses due to subsidence could create potential for erosion or knickpoint formation on the downstream sides of the hydraulic controls. Implementing earthworks to reinstate an even stream grade would potentially result in further adverse impacts to the stream channel and therefore a policy of routine earthworks is not recommended by Fluvial Systems (2019). Accordingly, Fluvial Systems (2019) recommends a process of adaptive management to address potential subsidence impacts on drainage lines. This process would involve:

- regular monitoring to detect if and where a potential geomorphic risk occurs;
- an assessment to determine the potential consequences of the observed risk; and
- development and implementation of appropriate control works.

If a significant increase is observed in the rate of knickpoint development or migration, these would be assessed by a suitably qualified geomorphologist in order to determine the most appropriate control measure in accordance with the Extraction Plan.

5.4. Aquifers and groundwater resources

There are groundwater resources associated with the Hunter River alluvial aquifer and other shallow and deeper aquifers within the Study Area. Detailed descriptions of these resources are provided by the specialist groundwater consultant in the report by *SLR* (2022).

Some groundwater bores within the region are used to extract groundwater for domestic, stock or irrigation use. Other groundwater bores are used for monitoring purposes. The locations of the groundwater bores within the Study Area are shown in Drawing No. MSEC1186-24 and their details are provided in Section 6.13.

5.5. Steep slopes

5.5.1. Description of the steep slopes

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

The areas identified as having steep slopes are shown in Drawing No. MSEC1186-23.

The steep slopes have been identified along the ridgelines predominately in the south-eastern part of the Study Area. The natural grades of the steep slopes are typically between 1 in 3 (i.e. 33 % or 18.3°) and 1 in 2 (i.e. 50 % or 26.6°), with isolated areas with natural grades up to approximately 1 in 1 (i.e. 100 % or 45°).

Photographs of the steep slopes within the Study Area are provided in Fig. 5.9.

Fig. 5.9 Steep slopes

5.5.2. Predictions for the steep slopes

Although predominantly located in the south-eastern part of the Study Area, the steep slopes are expected to experience the range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

A summary of the maximum predicted vertical subsidence, tilt and curvatures for the steep slopes is provided in Table 5.7. The values are the maximum predicted subsidence effects within the Study Area due to mining in the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams.

Table 5.7 Maximum predicted conventional subsidence, tilt and curvature for the steep slopes

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})
Steep slopes	6500	50	2.0	2.0

The maximum predicted tilt for the steep slopes is 50 mm/m (i.e. 5 % or 1 in 20). The maximum predicted total conventional curvatures are 2.0 km^{-1} hogging and sagging, which represent a minimum radius of curvature of 0.5 km. The predicted conventional strains based on applying a factor of 10 to the predicted conventional curvatures are 20 mm/m tensile and compressive.

The steep slopes in the south-eastern part of the Study Area near Drainage Line C are predicted to experience vertical subsidence up to 4700 mm, tilts up to 40 mm/m (i.e. 4 % or 1 in 25) and curvatures up to 1.0 km^{-1} (i.e. minimum radius of curvature of 1 km). The predicted conventional strains based on applying a factor of 10 to the predicted conventional curvatures are 10 mm/m tensile and compressive.

The distributions of strain above the mining area are provided in Section 4.4. The predicted strains due to the multi-seam mining 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.

5.5.3. Comparison of the predictions for the steep slopes

A comparison of the maximum predicted total conventional subsidence effects for the steep slopes, based on the EIS Layout and Modified Layout, is provided in Table 5.8. The values in this table represent the maximum cumulative movements for the steep slopes after the mining of all seams.

Table 5.8 Comparison of the maximum predicted subsidence effects for the steep slopes

Layout	After seam	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})
EIS Layout (MSEC986)	WN, WH, AF and BF Seams	5600	50	2.0	2.0
Modified Layout (MSEC1186)	WN, WH, AF and BF Seams	6500	50	2.0	2.0

The maximum predicted total vertical subsidence for the steep slopes of 6500 mm, based on the Modified Layout, is greater than the maximum predicted value based on the EIS Layout of 5600 mm. However, the potential for impacts does not result from absolute vertical subsidence but rather from the differential movements (i.e. tilt, curvature and strain). The maximum predicted total tilt and curvatures for the steep slopes, based on the Modified Layout, are the same as the maximum predicted values based on the EIS Layout.

The predicted subsidence effects will vary from place to place, with locally higher values in some locations and locally lower values in other locations, depending on their positions relative to the panels and longwalls for each layout. The overall levels of the predicted subsidence effects for the steep slopes, based on the Modified Layout, are similar to that based on the EIS Layout.

The surface area located within the predicted total 20 mm subsidence contour is 1892 ha based on the Modified Layout and 1805 ha based on the EIS Layout. The area of steep slopes located within the predicted limit of subsidence slightly increases; however, this represents a change of only approximately 5 %.

The following section provides the updated impact assessments for the steep slopes based on the Modified Layout. The assessed impacts and recommended management strategies are the same as those presented in the EIS Subsidence Assessment (Report No. MSEC986) and the EIS.

5.5.4. Impact assessments for the steep slopes

The maximum predicted tilt for the steep slopes within the Study Area is 50 mm/m (i.e. 5 % or 1 in 20). The predicted changes in grade are very small when compared to the natural surface grades, which are greater than 1 in 3. It is unlikely, therefore, that the mining-induced tilts would result in an adverse impact on the stability of the steep slopes. This is consistent with experience from mining in the NSW coalfields, where no instabilities have been observed previously when mining beneath similar types of steep slopes.

The steep slopes are more likely to be affected by curvature and strain, rather than tilt. The potential impacts would generally occur from the increased horizontal movements in the downslope direction. This will result 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 overall level of potential impacts on the steep slopes, based on the Modified Layout, is the same as that based on the EIS Layout.

The assessed surface deformations above the panels and longwalls are provided in Section 4.6. The surface cracking along the steep slopes is expected to be typically between 50 mm and 100 mm in approximately 60 % of cases, between 100 mm and 200 mm in approximately 25 % of cases, between 200 mm and 300 mm in approximately 10 % of cases and greater than 300 mm in approximately 5 % of cases. Multiple cracks resulting in deformations over several metres could also occur in some locations (i.e. less than 1 % of cases).

Compression heaving and stepping of the surface could also occur predominately towards the bases of the steep slopes. The heights of these deformations are expected to be typically less than 100 mm. However, vertical shear could also occur in some locations with height greater than 300 mm.

If large tension cracks were to develop along the steep slopes as a result of mining, it is possible that soil erosion could occur if these cracks were left untreated. It is likely, therefore, that some remediation would 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 on the slopes in the longer term.

The requirement and methodology for any erosion and sediment control and remediation techniques would be determined with consideration of the: potential impacts when unmitigated, including potential risks to safety and the potential for self-healing or long-term degradation; and potential impacts of the control/remediation technique, including site accessibility.

5.5.5. Recommendations for the steep slopes

The Land Management Plan component of the Extraction Plan should include more detailed consideration of slope stability, including input from a specialist geotechnical expert. It is recommended that the steep slopes are visually monitored throughout the mining period and until any necessary mitigation or rehabilitation measures are completed. In addition to this, it is recommended that the larger surface cracking be remediated, where it could result in increased erosion or restrict access to certain areas, by infilling with soil or other suitable materials, or by locally regrading and compacting the surface.

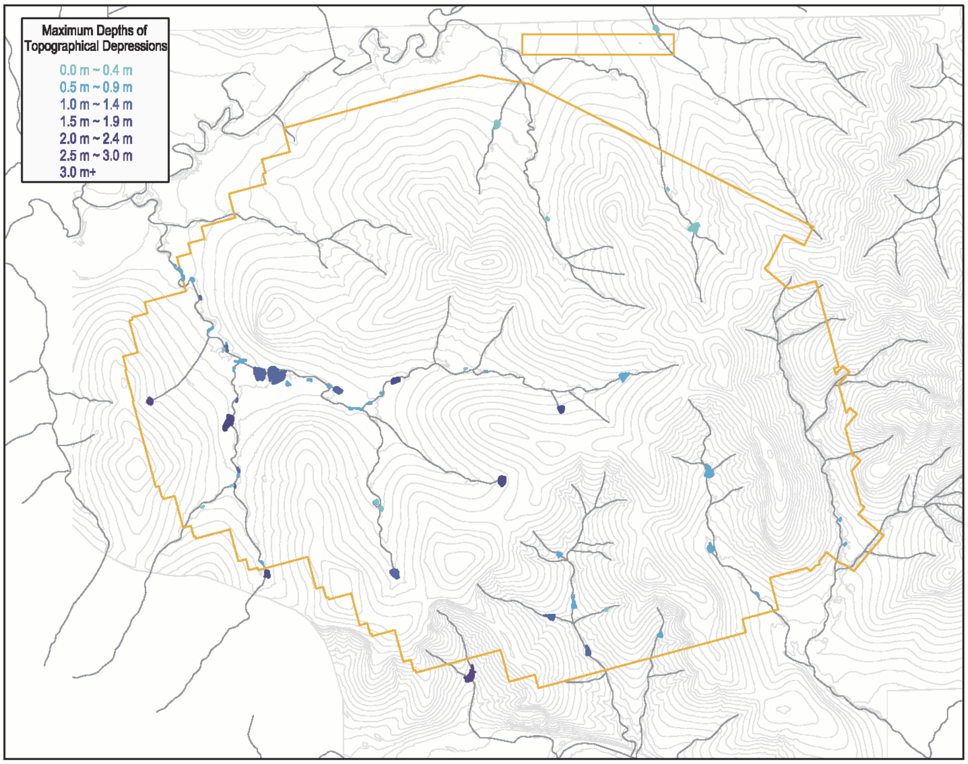
5.6. Land prone to flooding or inundation

The surface level contours within the mining area are shown in Drawing No. MSEC1186-06. The land generally falls towards the Hunter River to the south of the mining area and towards Saddlers Creek to the north of the mining area.

The drainage lines and the natural surface grades are illustrated in Drawing No. MSEC1186-23. The natural grades within the Study Area are typically less than 1 in 3 (i.e. 33 % or 18.4°), with areas on the ridgelines in the south-eastern part of the mining area having natural grades typically up to 1 in 2 (i.e. 50 % or 26.6°).

WRM Water and Environment (2022) has considered the potential effects of flooding for the Project based on the Modified Layout.

The natural and the predicted post-mining surface level contours are illustrated in Fig. 5.10. The maximum extents and depths of the topographical depressions are also illustrated in this figure and these are based on the geometry of the natural and post-mining surface level contours. The potential for increased ponding in these locations is dependent on a number of other factors including rainfall, catchment sizes, surface water runoff, permeation and evaporation and, therefore, the actual extents and depths of ponding are expected to be smaller than the topographical depressions.



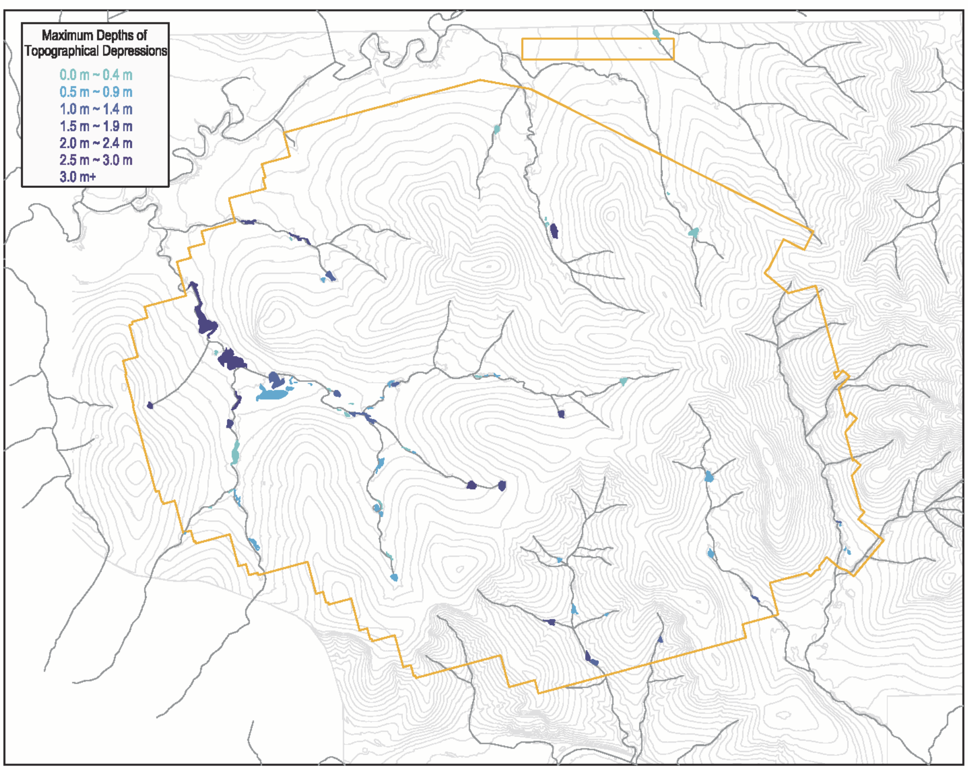


Fig. 5.10 Natural (top) and predicted post-mining (bottom) surface levels contours and the locations and depths of the topographical depressions

As shown at the top of Fig. 5.10, the land is naturally draining with only localised natural topographical depressions, i.e. localised areas where ponding can naturally develop. The majority of these topographical depressions are associated with the existing farm dams or are located along the natural drainage lines.

As shown at the bottom of this figure, additional topographical depressions (i.e. areas with increased potential for ponding) are expected to develop as a result of mining, primarily along the alignments of the natural drainage lines and away from the steep slopes.

Discussions on the management measures for the drainage lines and, therefore, the areas affected by post-mining ponding are provided in Section 5.3.5.

5.7. Swamp, wetlands and water-related ecosystems

There are no swamps or wetlands identified within the Study Area. There are water-related ecosystems within the Study Area, which are described in the report by *Hunter Eco* (2022).

5.8. Threatened, protected species and critical habitats

The descriptions and the discussions on the potential impacts on threatened and protected species within the Study Area are provided by the specialist ecology consultant in the report by *Hunter Eco* (2022).

5.9. Natural vegetation

The land has generally been cleared of overstory vegetation within the Study Area, with natural vegetation remaining on the steeper slopes along the ridgelines. The extent of natural vegetation can be seen from the aerial photograph provided in Fig. 2.3. A survey of the natural vegetation within the Study Area has been undertaken by the specialist ecology consultant and details are provided in the report by *Hunter Eco* (2022).

The Project is not located within a declared Mine Subsidence District (MSD). However, the former Muswellbrook MSD covered the Study Area prior to its revision on 1 July 2017.

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 Golden Highway

6.1.1. Description of the Golden Highway

The locations of the roads are shown in Drawing No. MSEC1186-24.

The Golden Highway (State Route 84) is located on the south-western boundary of the Study Area. A summary of the minimum distances of the centreline of the Golden Highway from the panels and longwalls within each seam is provided in Table 6.1. The minimum distances of the highway from the 26.5° angle of draw for each seam are also provided in this table.

Table 6.1 Minimum distances of the Golden Highway from the panels and longwalls

Seam	Nearest panel or longwall	Minimum distance from the nearest panel or longwall (m)	Minimum distance from the 26.5° angle of draw (m)
Whynot Seam	WNP1	1700	1650
Woodlands Hill Seam	WHLW11	190	70
Arrowfield Seam	AFLW8	200	50
Bowfield Seam	BFLW8	170	0

The section of the Golden Highway near the Study Area comprises a two lane single-carriageway with an asphaltic seal and grass verges with no kerb or guttering. There is a small cutting (less than 3 m in height) located approximately 300 m east of the intersection with Edderton Road and approximately 230 m south-west of the mining area.

The highway crosses the Hunter River approximately 750 m south of the mining area. The descriptions, predictions and impact assessments for the bridge are provided in Section 6.2.

A photograph of the Golden Highway at the intersection with Edderton Road is provided in Fig. 6.1.

Fig. 6.1 The Golden Highway at the intersection with Edderton Road

The Golden Highway is a NSW State owned road that is maintained by Transport for NSW (TfNSW).

6.1.2. Predictions for the Golden Highway

The Golden Highway is located outside of the mining area at a minimum distance of 170 m. The highway is also located outside the 26.5° angle of draw for the Whynot, Woodlands Hill and Arrowfield Seams and is located on the 26.5° angle of draw for the Bowfield Seam. At this distance, the highway is predicted to experience less than 20 mm vertical subsidence. While the highway could experience very low-levels of vertical subsidence, it is not expected to experience measurable tilts, curvatures or strains.

The highway is located at minimum distances between 170 m and 200 m from the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams. The depths of cover at the western ends of the nearest longwalls are 245 m above WHLW11, 305 m above AFLW8 and 335 m above BFLW8.

The range of potential strains for the Golden Highway resulting from the extraction of the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams, for multi-seam mining conditions, has been based on the strains measured for multi-seam mining in the Hunter and Newcastle Coalfields.

The frequency distribution of the maximum tensile and compressive strains measured in survey bays at distances between 100 m and 200 m from multi-seam longwall mining is provided in Fig. 6.2. The probability distribution functions, based on the fitted GPDs, are also shown in this figure. It is noted that some cases include survey bays above previously extracted goaf and, therefore, it provides some conservatism in the predictions for the Golden Highway which is located completely above solid coal.

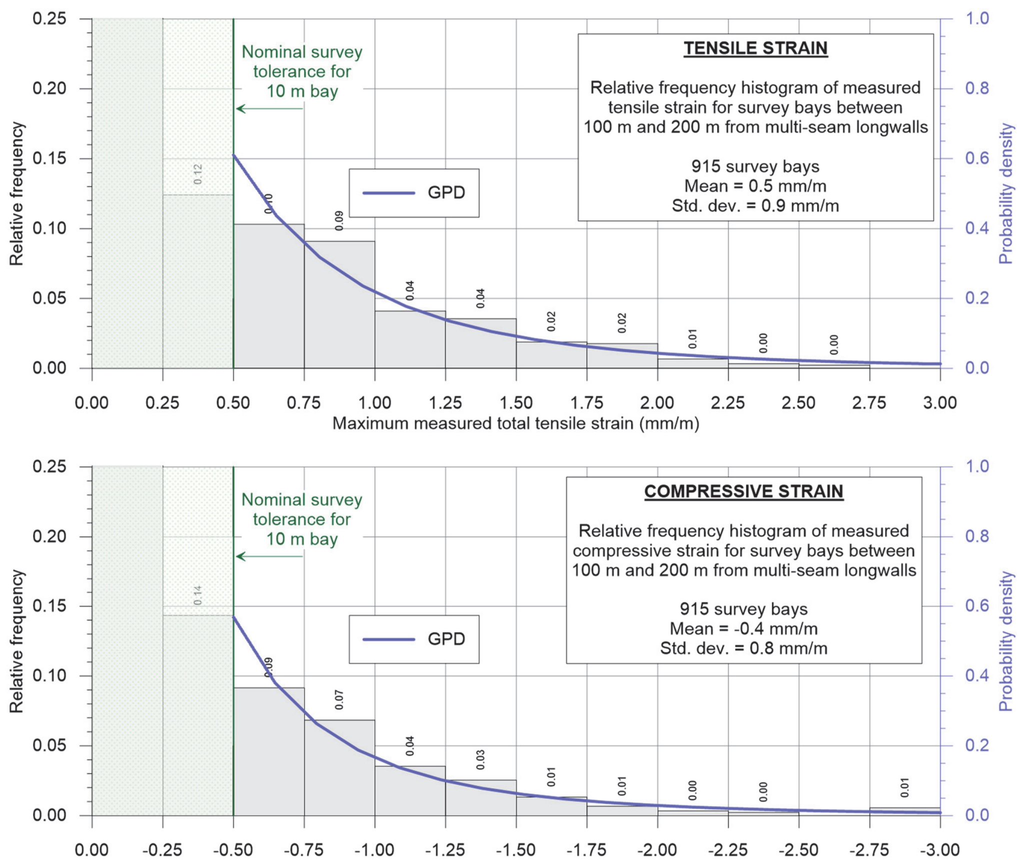


Fig. 6.2 Distributions of the measured tensile and compressive strains for multi-seam longwalls in the Hunter Coalfield

The mean measured strains are 0.5 mm/m or less tensile and compressive. It is expected, therefore, that the strains measured along the Golden Highway will be typically in the order of survey tolerance. The 95 % confidence levels for the maximum strains are 1.8 mm/m tensile and 1.5 mm/m compressive.

6.1.3. Comparison of the predictions for the Golden Highway

The Golden Highway is located outside the mining area at distances of 150 m based on the EIS Layout and 170 m based on the Modified Layout. The highway crosses and is located just inside the 26.5° angle of draw for the EIS Layout and it is located on the angle of draw for the Modified Layout. The Golden Highway is therefore located slightly further from the mining area based on the Modified layout compared with that for the EIS Layout.

A comparison of the maximum predicted total vertical subsidence and strain for the Golden Highway, based on the EIS Layout and Modified Layout, is provided in Table 6.2. The values in this table represent the maximum cumulative movements for the highway after the mining of all seams.

Table 6.2 Comparison of the maximum predicted subsidence effects for the Golden Highway

Layout	After seam	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tensile strain based on 95 % confidence level (mm/m)	Maximum predicted total comp. strain based on 95 % confidence level (mm/m)
EIS Layout (MSEC986)	WN, WH, AF and BF Seams	< 20	1.8	1.5
Modified Layout (MSEC1186)	WN, WH, AF and BF Seams	< 20	1.8	1.5

The maximum predicted total subsidence effects for the Golden Highway, based on the Modified Layout, are the same as the maximum predicted values based on the EIS Layout. The predicted subsidence effects for the Modified Layout are in fact slightly less, due to the slightly increased distance between the highway and the mining area; however, the differences are less than the order of accuracy of the prediction methods.

The following section provides the updated impact assessments for the Golden Highway based on the Modified Layout. The assessed impacts and recommended management strategies are the same as those presented in the EIS Subsidence Assessment (Report No. MSEC986) and the EIS.

6.1.4. Impact assessments for the Golden Highway

The Golden Highway is predicted to experience less than 20 mm vertical subsidence. While the highway could experience very low-levels of vertical subsidence, it is not expected to experience measurable tilts or curvatures. It is unlikely, therefore, that there would be adverse impacts on the profile or the serviceability of the highway due to vertical subsidence.

The strains along the Golden Highway are predicted to be generally in the order of survey tolerance. Low-level strains in the order of 1 mm/m to 2 mm/m could be measured along the section of highway that is located closest to the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams. However, it is unlikely that these low-level strains would result in adverse impacts on the highway.

The Golden Highway crosses the East Graben Fault approximately 1 km west of the intersection with Edderton Road. The surface projection of the fault crosses the highway at a distance of approximately 400 m south-west of the mining area. At this distance, it is unlikely that localised movements would develop at the highway due to the presence of the East Graben Fault.

It is expected that the Golden Highway would remain in safe and serviceable condition during and after the extraction of the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams.

6.1.5. Recommendations for the Golden Highway

It is recommended that a Built Features Management Plan (BFMP) be developed for the Golden Highway in consultation with TfNSW prior to mining within 500 m of the highway. The management plan could include ground monitoring and periodic visual inspections of the highway during the extraction of the longwalls closest to it. The monitoring and inspections should include the small cutting to the east of Edderton Road and the surface projection of the East Graben Fault.

6.2. Bridge at Bowmans Crossing

6.2.1. Description of the bridge at Bowmans Crossing

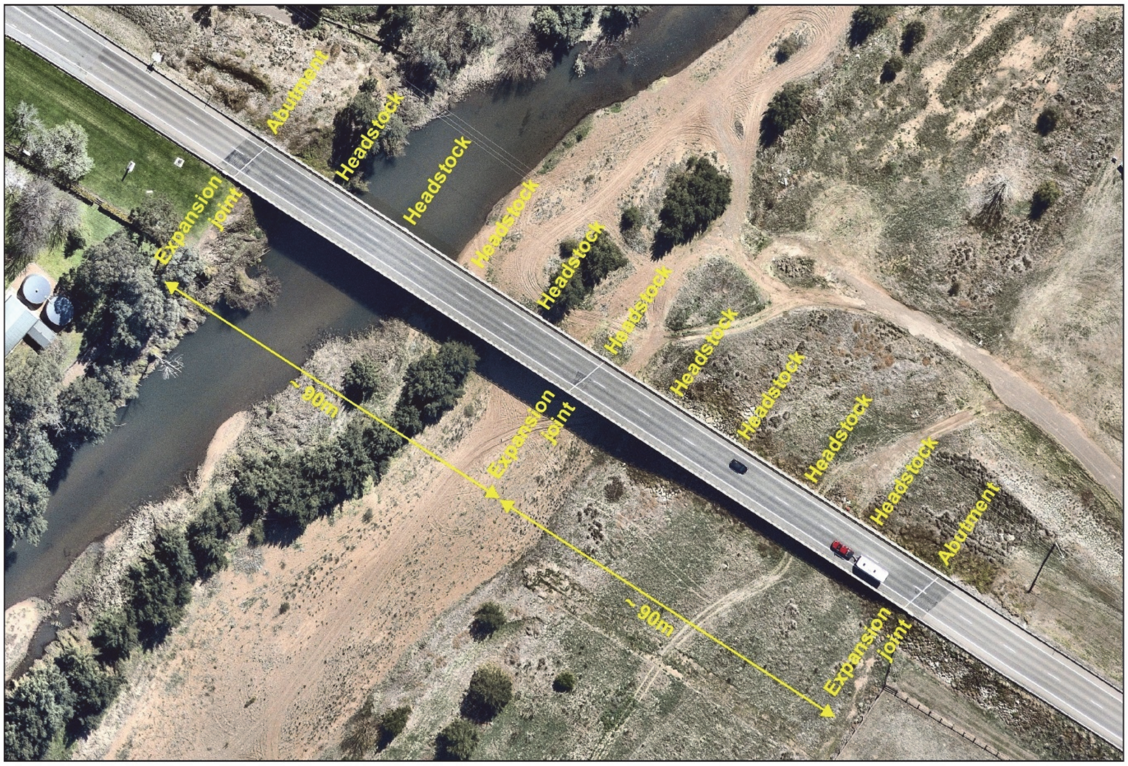
The Golden Highway crosses the Hunter River approximately 750 m south of the mining area. A bridge crosses the river and the adjacent floodplain, referred to as *Bowmans Crossing*. The location of the bridge along the Golden Highway is shown in Drawing No. MSEC1186-24.

The bridge comprises a suspended concrete deck supported on concrete abutment wingwalls and nine intermediate concrete headstocks on dual concrete columns. The spans between adjacent headstocks are approximately 18 m. The total length of the bridge between the two abutments is approximately 180 m. Expansion joints in the bridge deck are located at each abutment and above the central headstock. The lengths of the two deck segments between the expansion joints are both approximately 90 m.

Photographs of the bridge where the Golden Highway crosses the Hunter River and the adjacent floodplain are provided in Fig. 6.3 and Fig. 6.4. An aerial photograph showing the locations of the abutments, headstocks and expansion joints is provided in Fig. 6.5.

Fig. 6.3 Bridge where the Golden Highway crosses the Hunter River

Fig. 6.4 Bridge across the floodplain adjacent to the Hunter River



Courtesy of Nearmap

Fig. 6.5 Aerial photograph of the bridge

The bridge is maintained by TfNSW.

6.2.2. Predictions for the bridge at Bowmans Crossing

The bridge where the Golden Highway crosses the Hunter River is located approximately 750 m south of the mining area. At this distance, the bridge is predicted to experience negligible vertical subsidence, tilt, curvature and strain.

The bridge could experience small far-field horizontal movements due to mining. Total far-field horizontal movements in the order of 100 mm to 150 mm have been measured at distances of 700 m to 800 m from previous longwall mining. However, the potential for adverse impacts on the bridge does not result from absolute far-field horizontal movements, but rather from differential horizontal movements over the length of the structure.

Differential horizontal movements along the alignment of the bridge could potentially affect the widths of the expansion joints or the capacities of the support bearings. Differential horizontal movements across the alignment of the bridge could potentially induce eccentricities into the structure or affect the capacities of the support bearings.

The predicted differential horizontal movements at the bridge have been determined by statistically analysing the available 3D monitoring data from the NSW coalfields. The majority of the far-field horizontal movement data comes from the Southern Coalfield based on single-seam mining at depths of cover between 400 m and 600 m. The multi-seam mining at shallower depths of cover at the Project will result in greater movements above, but lesser movements outside, the mining area. The far-field horizontal movement data from the Southern Coalfield, therefore, should provide conservative predictions for the far-field horizontal movements at the Project.

The intermediate spans (i.e. distances between the supporting headstocks) for the bridge where the Golden Highway crosses the Hunter River are typically around 20 m. The analyses of differential horizontal movements, therefore, have been based on survey marks spaced at around 20 m.

The measured total differential longitudinal movements and total horizontal mid-ordinate deviations, for survey marks spaced at 20 m ±10 m relative to the distance from the longwall mining area, are shown in Fig. 6.6 and Fig. 6.7, respectively. The location of the bridge where the Golden Highway crosses the Hunter River relative to the mining area is also shown in these figures.

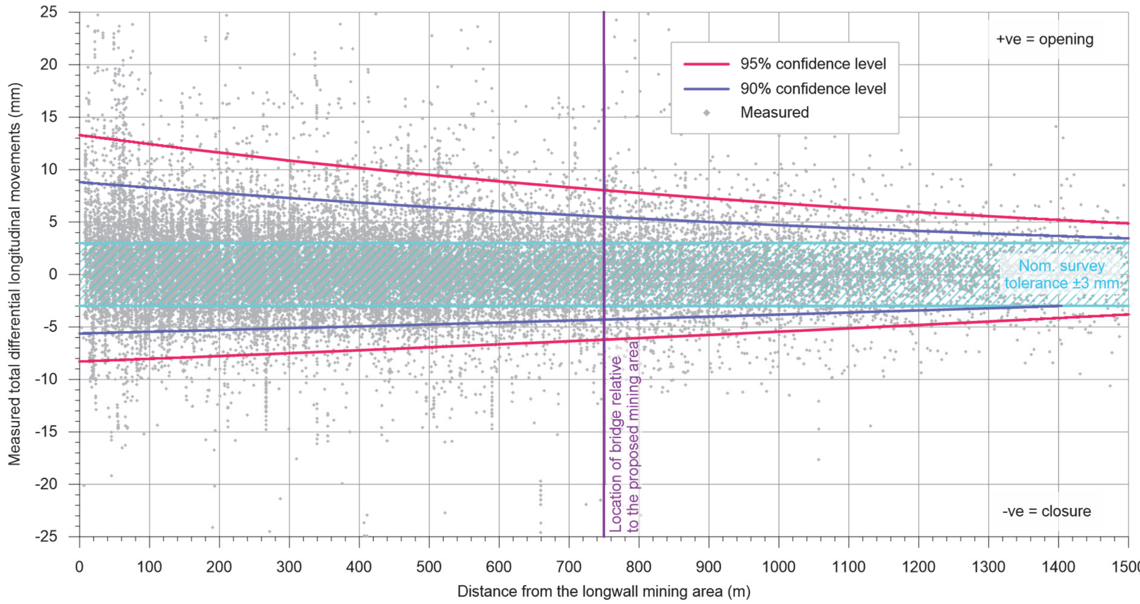


Fig. 6.6 Measured total differential horizontal movements versus distance from active longwall for marks spaced at 20 m ±10 m

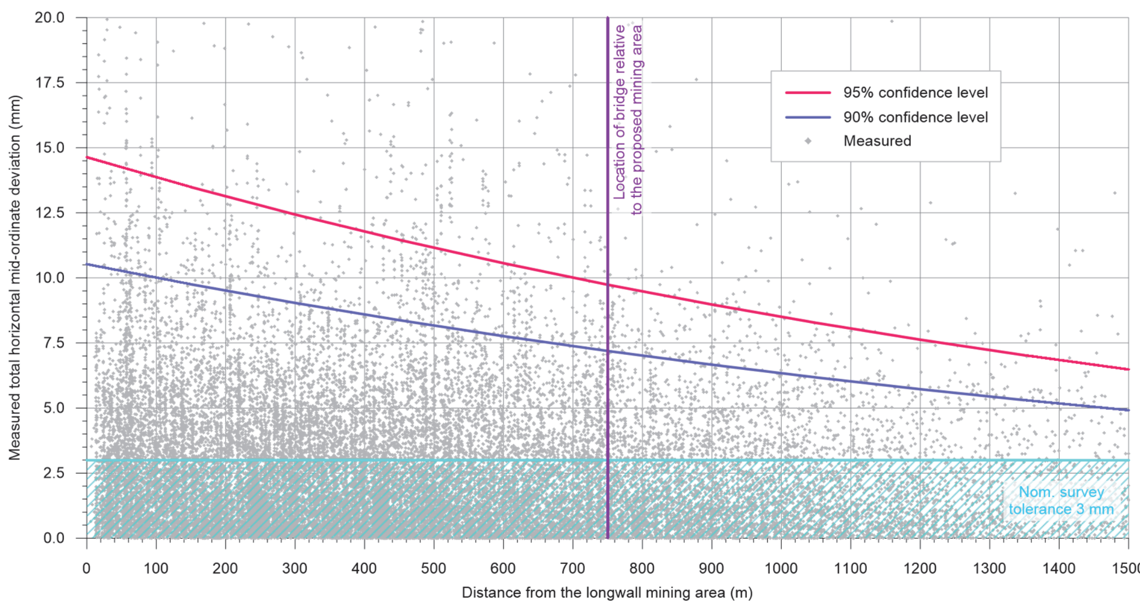


Fig. 6.7 Measured total horizontal mid-ordinate deviations versus distance from active longwall for marks spaced at 20 m ±10 m

The 95 % confidence levels have been determined from the empirical data using the fitted GPDs. In the cases where survey bays or marks were measured multiple times during a longwall extraction, the maximum opening, maximum closure and maximum mid-ordinate deviations were used in the analysis (i.e. single opening and single closure measurements per survey bay and single mid-ordinate deviation per survey mark).

The maximum predicted total differential longitudinal movements for the survey bays, at a distance of 750 m from the longwall mining area, are +8 mm opening and -6 mm closure based on the 95 % confidence levels. The maximum predicted total horizontal mid-ordinate deviation for the survey marks, at a distance of 750 m from the longwall mining area, is ±9 mm based on the 95 % confidence level. It is noted that a large proportion of these movements comprise the survey tolerance, which is around ±3 mm.

6.2.3. Comparison of the predictions for the bridge at Bowmans Crossing

The bridge at Bowmans Crossing is located outside the mining area at distances of 800 m based on the EIS Layout and 750 m based on the Modified Layout. The bridge is therefore located slightly closer to the mining area based on the Modified layout compared with that for the EIS Layout.

A comparison of the maximum predicted differential horizontal movements for the bridge at Bowmans Crossing, based on the EIS Layout and Modified Layout, is provided in Table 6.3. The values in this table represent the predicted movements based on the 95 % confidence levels.

Table 6.3 Comparison of the maximum predicted differential horizontal movements for the bridge at Bowmans Crossing

Layout	Minimum distance from longwall mining area (m)	Maximum predicted total opening over a 20 m bay based on 95 % confidence level (mm)	Maximum predicted total closure over a 20 m bay based on 95 % confidence level (mm)	Maximum predicted total horizontal mid-ordinate deviation over a 40 m bay based on 95 % confidence level (mm)
EIS Layout (MSEC986)	800	+8	-6	±9
Modified Layout (MSEC1186)	750	+8	-6	±9

The maximum predicted subsidence effects for the bridge at Bowmans Crossing, based on the Modified Layout, are the same as the maximum predicted values based on the EIS Layout. The predicted subsidence effects for the Modified Layout are in fact slightly greater, due to the slightly reduced distance between the bridge and the mining area; however, the differences are less than the order of accuracy of the prediction methods.

The following section provides the updated impact assessments for the bridge at Bowmans Crossing based on the Modified Layout. The assessed impacts and recommended management strategies are the same as those presented in the EIS Subsidence Assessment (Report No. MSEC986) and the EIS.

6.2.4. Impact assessments for the bridge at Bowmans Crossing

The maximum predicted differential total horizontal movements between the adjacent headstocks of the bridge vary between ±6 mm to ±9 mm based on the 95 % confidence levels. It is again noted that these movements include contributions due to survey tolerance, which is around ±3 mm. It is likely, therefore, that the differential horizontal movements due to mining will be very small and, in some cases, may not be measurable.

Differential horizontal movements between the concrete deck and the supports normally occur due to variations in the temperature of the structure. Typical horizontal movements due to temperature changes, based on a 90 m span (i.e. distance between the expansion joints), a coefficient of thermal expansion of $12x10^{-6}/^{o}C$ and a temperature variation of 20ºC, are around 20 mm.

The predicted mining-induced differential horizontal movements for the bridge, therefore, are less than the movements that normally occur due to the variation in ambient temperature. It is likely, therefore, that the bridge could tolerate the potential movements due to mining, without adverse impacts, provided that the expansion joints have sufficient redundant capacities. The structural engineers should assess the capacity of the bridge to accommodate the predicted mining-induced movements.

6.2.5. Recommendations for the bridge at Bowmans Crossing

Malabar has ongoing consultation with TfNSW on the bridge at Bowmans Crossing. It is recommended that structural engineers should assess the capacity of the bridge to accommodate the predicted mining-induced movements.

It is also recommended, that a BFMP is developed in consultation with TfNSW prior to mining within 1200 m of the bridge. The management strategies could include 3D monitoring points on the bridge structure, tell-tales across the expansion joints and periodic visual inspections during the extraction of the longwalls closest to it.

6.3. Edderton Road

6.3.1. Description of Edderton Road

The locations of the roads are shown in Drawing No. MSEC1186-24.

Edderton Road crosses the western part of the Study Area and it is located directly above the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams. In accordance with Condition B90 of NSW Development Consent SSD 9526, Malabar is required to construct the Edderton Road realignment before the commencement of secondary extraction in the Arrowfield and Bowfield Seams.

An indicative location for the potential realignment of Edderton Road is shown in Fig. 6.8. The section of road located within the Study Area will be realigned to the west of the mining area.

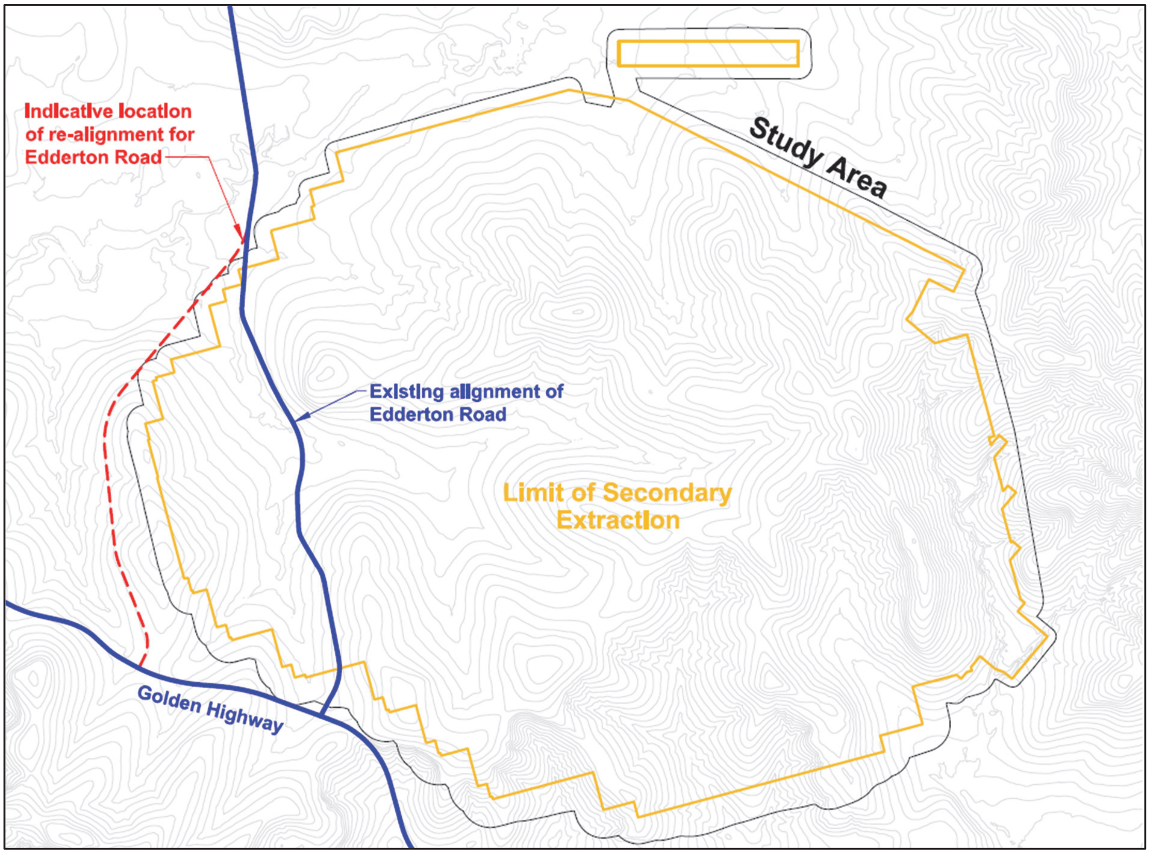


Fig. 6.8 Indicative location for the potential realignment of Edderton Road

The existing alignment of Edderton Road is located directly above WHLW4 to WHLW11. The total length of the existing road located above the longwalls in the Woodlands Hill Seam is 2.6 km. The existing alignment of Edderton Road is also located directly above AFLW2 to AFLW8 and BFLW2 to BFLW8; however, the realignment of the road will be completed before the commencement of secondary extraction in the Arrowfield and Bowfield Seams. The realignment of the road is located west of the mining area.

The section of Edderton Road within the Study Area comprises a two lane single-carriageway with a bitumen seal and grass verges with no kerb or guttering. The gross load limit is 14 tonnes.

There are circular concrete drainage culverts (Refs. ER-C1 to ER-C5) where the road crosses the drainage lines. The locations of the drainage culverts are shown in Drawing No. MSEC1186-24. The causeway where Edderton Road crosses Saddlers Creek is outside of the Study Area. The causeway is located 425 m north-west of the mining area.

Photographs of Edderton Road are provided in Fig. 6.9.


Fig. 6.9 Edderton Road

Edderton Road is owned and maintained by the Muswellbrook Shire Council.

6.3.2. Predictions for the current alignment of Edderton Road

The predicted profiles of vertical subsidence, tilt and curvature along the current alignment of Edderton Road are shown in Fig. C.08, in Appendix C. The predicted profiles are shown after the completion of the Woodlands Hill Seam (green lines), Arrowfield Seam (dashed cyan lines) and Bowfield Seam (dashed blue lines). The realignment of the road will be completed before the commencement of secondary extraction in the Arrowfield and Bowfield Seams.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvature for Edderton Road is provided in Table 6.4. The values are the maximum predicted subsidence effects anywhere along the current alignment of the road within the Study Area.

Table 6.4 Maximum predicted total vertical subsidence, tilt and curvature for the current alignment of Edderton Road

After seam	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})
Whynot Seam	< 20	< 0.5	< 0.01	< 0.01
Woodlands Hill Seam	1650	30	1.0	0.80

The maximum predicted tilt for the current alignment o Edderton Road after the completion of mining in the Woodlands Hill Seam is 30 mm/m (i.e. 3.0 % or 1 in 33). The maximum predicted curvatures for the road at that stage are 1.0 km^{-1} hogging and 0.8 km^{-1} sagging, which represent minimum radii of curvatures of 1.0 km and 1.3 km, respectively.

The current alignment of Edderton Road will experience additional subsidence effects due to mining in the Arrowfield and Bowfield Seams; however, the realignment of the road will be completed before the commencement of secondary extraction in those seams.

The maximum predicted conventional strains for the current alignment Edderton Road after the completion of mining in the Woodlands Hill Seam, based on applying a factor of 10 to the maximum predicted conventional curvatures, are 10 mm/m tensile and 8 mm/m compressive. The distribution of the predicted strains due to the extraction of the longwalls is described in Section 4.4. The predicted strains directly above the multi-seam longwalls 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.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvature for the drainage culverts is provided in Table 6.5. The values are the maximum predicted subsidence effects within 20 m of the mapped locations of each of the culverts after the completion of mining in the Woodlands Hill Seam.

Table 6.5 Maximum predicted total subsidence, tilt and curvature for the drainage culverts after the completion of mining in the Woodlands Hill Seam

Reference	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
ER-C1	< 20	< 0.5	< 0.01	< 0.01
ER-C2	950	16	0.20	< 0.01
ER-C3	175	6	0.18	< 0.01
ER-C4	1100	20	0.50	0.35
ER-C5	70	3	0.11	0.05

The maximum predicted tilt for the drainage culverts after the completion of mining in the Woodlands Hill Seam is 20 mm/m (i.e. 2.0 % or 1 in 50). The maximum predicted curvatures for the culverts at that stage are 0.5 km^{-1} hogging and 0.35 km^{-1} sagging, which represent minimum radii of curvatures of 2.0 km and 2.9 km, respectively.

The culverts will experience additional subsidence effects due to mining in the Arrowfield and Bowfield Seams; however, the realignment of the road will be completed before the commencement of secondary extraction in those seams.

The causeway where Edderton Road crosses Saddlers Creek is predicted to experience less than 20 mm vertical subsidence due to mining. While the causeway could experience very low-levels of vertical subsidence, it is not expected to experience measurable tilts, curvatures or strains. Malabar has agreed to upgrade this crossing as part of the Edderton road realignment.

The realignment of Edderton Road is located on or outside the Study Area. At this distance, it is predicted to experience less than 20 mm vertical subsidence. While the realignment of the road could experience very low-levels of vertical subsidence, it is not expected to experience measurable tilts, curvatures or strains.

6.3.3. Comparison of the predictions for Edderton Road

Edderton Road crosses directly above the mining area based on both the EIS Layout and Modified Layout. The total length of road above the longwalls in the Woodlands Hill Seam is 2.6 km for both the EIS Layout and Modified Layout.

A comparison of the maximum predicted total conventional subsidence effects for Edderton Road, based on the EIS Layout and Modified Layout, is provided in Table 6.6. The values in this table represent the maximum cumulative movements for the road after the completion of mining in the Woodlands Hill Seam. The current alignment of Edderton Road will experience additional subsidence effects due to mining in the Arrowfield and Bowfield Seams; however, the realignment of the road will be completed before the commencement of secondary extraction in those seams.

Table 6.6 Comparison of the maximum predicted subsidence effects for Edderton Road

Layout	After seam	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})
EIS Layout (MSEC986)	WN and WH Seams only	2300	35	1.4	0.90
Modified Layout (MSEC1186)	WN and WH Seams only	1650	30	1.0	0.80

The maximum predicted subsidence effects for Edderton Road, based on the Modified Layout, are less than the maximum predicted values based on the EIS Layout.

The following sections provide the updated impact assessments for current and realignment of Edderton Road based on the Modified Layout. The assessed impacts and recommended management strategies are the same as those presented in the EIS Subsidence Assessment (Report No. MSEC986) and the EIS.

6.3.4. Impact assessments for the current alignment of Edderton Road

The following impact assessments for Edderton Road are based on the predicted subsidence effects after the completion of mining in the Woodlands Hill Seam. The realignment of the road will be completed before the commencement of secondary extraction in the Arrowfield and Bowfield Seams.

The maximum predicted vertical subsidence along the current alignment of Edderton Road is 1650 mm. The predicted subsidence varies along the length of the road, with greater subsidence developing above the longwall voids and lesser subsidence developing near to the chain pillars in the Woodlands Hill Seam.

The maximum predicted change in grade (i.e. tilt) along the alignment of Edderton Road is 30 mm/m (i.e. 3.0 % or 1 in 33). The greater tilts occur towards the northern part of the mining area, where the depths of cover are shallower.

The existing and predicted post-mining surface levels and grades along the current alignment of Edderton Road, after the completion of mining in the Woodlands Hill Seam, are illustrated in Fig. 6.10.

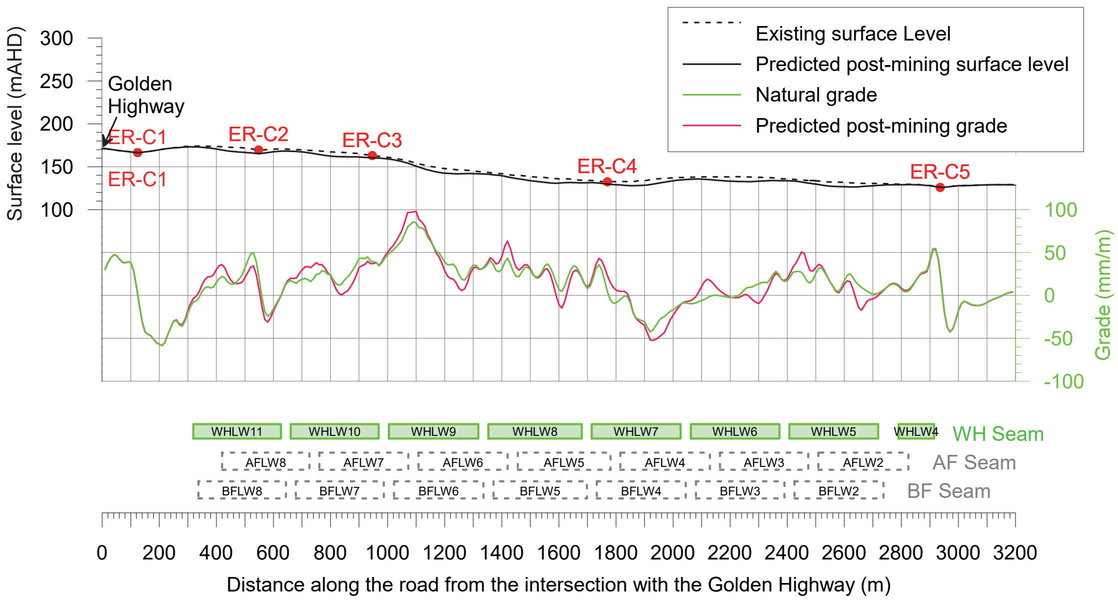


Fig. 6.10 Existing and predicted post-mining surface levels and grades along the current alignment of Edderton Road

The predicted post-mining grades along the current alignment of Edderton Road are reasonably similar to the existing grades. It is unlikely, therefore, that there would be large-scale changes in the surface drainage of the road due to mining. There is potential for increased ponding near the low-point along the road above the mining area (i.e. near culvert ER-C4) due to the locally increased subsidence in that location.

The maximum predicted curvatures for Edderton Road are 1.0 km^{-1} hogging and 0.8 km^{-1} sagging, which represent minimum radii of curvatures of 1.0 km and 1.3 km, respectively. The road could also experience strains typically between 10 mm/m and 20 mm/m, with some isolated strains greater than 20 mm/m. It is expected that cracking, heaving and possibly stepping of the road pavement would occur based on these levels of predicted curvature and strain.

The maximum predicted curvatures for Edderton Road are of similar orders of magnitude to the maximum predicted values where Blakefield South Longwalls 2 to 4 were extracted directly beneath Broke Road, which varied between 1.0 km^{-1} and 1.5 km^{-1}. These longwalls were extracted beneath the existing South Bulga longwalls in the Whybrow Seam and, therefore, were multi-seam mining conditions. The maximum predicted curvatures for Edderton Road are also less than the predicted values where Blakefield South Longwalls 1 to 4 were extracted beneath Charlton Road (also multi-seam conditions) and where the Beltana No. 1 Underground Mine Longwalls 1 to 10 were extracted beneath this road (shallow single-seam conditions), which were greater than 3.0 km^{-1}.

The impacts observed along Broke and Charlton Road should, therefore, provide a reasonable guide to the potential impacts that could occur along the current alignment of Edderton Road due to mining in the Woodlands Hill Seam.

Blakefield South Longwalls 1 to 4 had void widths of 330 m to 400 m and were extracted from the Blakefield Seam at depths of cover ranging between 150 m and 250 m beneath Broke Road and Charlton Roads. The longwalls were extracted beneath the existing South Bulga longwalls in the Whybrow Seam where the interburden thickness typically varied between 70 m and 90 m.

The crack widths observed along Broke and Charlton Roads at the Blakefield South Mine typically varied between 10 mm and 50 mm, with a maximum width of 220 mm. The compression heaving and step heights observed along these roads were typically less than 25 mm, with a maximum height of 50 mm. Examples of the impacts observed at the Blakefield South Mine are provided in Fig. 6.11 for Broke Road and in Fig. 6.12 for Charlton Road.

Fig. 6.11 Impacts observed along Broke Road at the Blakefield South Mine

Fig. 6.12 Impacts observed along Charlton Road at the Blakefield South Mine

Beltana Longwalls 1 to 10 had void widths of 275 m and were extracted from the Whybrow Seam at depths of cover ranging between 80 m and 115 m beneath Charlton Road. The crack widths observed along the road typically varied between 50 mm and 100 mm, with a maximum observed crack width around 380 mm. The heave and step heights observed along the road were typically in the order of 25 mm. Examples of the impacts observed along Charlton Road at the Beltana No. 1 Underground Mine are provided in Fig. 6.13.

Fig. 6.13 Impacts observed along Charlton Road at the Beltana No. 1 Underground Mine

The impacts on Broke and Charlton Roads were managed using visual monitoring and by undertaking temporary repairs of the road pavement during active subsidence. The management strategies required some temporary lane closures and speed restrictions while repairs were being undertaken. The final remediation of the road pavement was undertaken after the completion of active subsidence.

It is anticipated that the crack widths along the current alignment of Edderton Road due to mining would be typically between 25 mm and 50 mm, with isolated cracks greater than 300 mm. Stepping of the road pavement could also occur in the order of 25 mm to 50 mm, with isolated steps with heights greater than 100 mm. The potential impacts on Edderton Road could result in it becoming unsafe or unserviceable if preventive or remediation measures were not to be implemented.

The potential impacts on Edderton Road could be managed using visual monitoring and undertaking remediation of the road pavement during active subsidence. These strategies may require temporary lane closures to undertake the repairs and temporary speed restrictions along the section of the road that is impacted by mining.

Experience of mining beneath roads in the NSW coalfields indicates that the impacts on unbound pavements develop progressively, where the onset of impacts can be identified early by visual monitoring which, in most cases, allows for the remediation measures to be scheduled outside of peak traffic times. It is still possible that more rapidly developing impacts could occur, as a result of compressive buckling of the near surface bedrock, which may require temporary repairs to be undertaken during peak traffic times.

6.3.5. Impact assessments for the realignment of Edderton Road

An indicative location for the realignment of Edderton Road is shown in Fig. 6.8. The section of road located within the Study Area will be realigned to the west of the mining area.

The indicative road realignment is predicted to experience less than 20 mm vertical subsidence. While the road realignment could experience very low-levels of vertical subsidence, it is not expected to experience measurable tilts, curvatures or strains. It is unlikely, therefore, that the indicative realignment of Edderton Road would experience adverse impacts due to mining.

6.3.6. Recommendations for Edderton Road

It is recommended that a BFMP be developed for Edderton Road in consultation with the Muswellbrook Shire Council. The management measured for the road due to mining in the Woodlands Hill Seam could include strategies similar to those used to maintain Broke and Charlton Roads in safe and serviceable conditions during active subsidence at the Blakefield South Mine.

WHLW1 to WHLW3 do not mine directly beneath Edderton Road. Ground monitoring could be carried out above these earlier longwalls and the management measures could then be refined before WHLW4 to WYLW11 mine directly beneath the road.

6.4. Unsealed tracks

There are unsealed tracks located across the Study Area. Some of these tracks are shown in Drawing No. MSEC1186-24. The land above the mining area is owned by Malabar and, therefore, these tracks are not accessible to the public.

The unsealed tracks could experience the range of predicted subsidence movements. A summary of the maximum predicted mine subsidence effects within the Study Area was provided in Chapter 4. It is expected that cracking, rippling and stepping of the unsealed tracks would occur as each of the panels and longwalls are mined beneath them.

The assessed surface deformations above the panels and longwalls are provided in Section 4.6. The largest impacts are expected to occur along the tracks on the sides of the ridgelines, in the southern part of the mining area, and where the depths of cover are shallowest, in the northern part of the mining area.

The unsealed tracks within the Study Area can be maintained in safe and serviceable conditions throughout the mining period using normal road maintenance techniques. It is recommended that management strategies are developed to repair the unsealed tracks. It is also recommended that these tracks are periodically inspected during active subsidence.

The predictions, impact assessments and recommended management strategies for the unsealed tracks are the same as those presented in the EIS Subsidence Assessment (Report No. MSEC986) and the EIS.

6.5. Drainage culverts

Drainage culverts along Edderton Road are located within the Study Area and directly above the mining area. The descriptions, predictions and impact assessments for these culverts are provided in Section 6.3.

6.6. Electrical infrastructure

6.6.1. Description of the powerlines

The locations of the powerlines are shown in Drawing No. MSEC1186-24.

An 11 kilovolt (kV) powerline owned by Ausgrid crosses the western part of the Study Area. The powerline follows the alignment of Edderton Road and it is located directly above the longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams. A summary of the longwalls located directly beneath the powerline is provided in Table 6.7

Table 6.7 Longwalls located directly beneath the 11 kV powerline

Seam	Longwalls located directly beneath the powerline	Length of powerline above the mining areas (km)
Woodlands Hill Seam	WHLW4 to WHLW11	2.6
Arrowfield Seam	AFLW2 to AFLW8	2.4
Bowfield Seam	BFLW2 to BFLW8	2.4
All seams	As above	2.6

The 11 kV powerline comprises aerial copper conductors supported by timber poles. The power pole IDs (as provided by Ausgrid) are shown in Drawing No. MSEC1186-24. Photographs of the powerline along Edderton Road are provided in Fig. 6.14.

Fig. 6.14 11 kV voltage powerline along Edderton Road

6.6.2. Predictions for the powerline

The predicted profiles of vertical subsidence, tilt along and tilt across the alignment of the 11 kV powerline are shown in Fig. C.09, in Appendix C. The predicted profiles are shown after the completion of the Woodlands Hill Seam (green lines), Arrowfield Seam (cyan lines) and Bowfield Seam (blue lines). The maximum predicted tilts after any panel or longwall in any seam are shown by the grey shading.

A summary of the maximum predicted values of total vertical subsidence, tilt along the alignment and tilt across the alignment of the 11 kV powerline is provided in Table 6.8. The values are the maximum predicted subsidence effects anywhere along the powerline (i.e. not necessarily at the pole locations) within the Study Area.

Table 6.8 Maximum predicted total subsidence and tilt for the 11 kV powerline

After seam	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt along alignment (mm/m)	Maximum predicted total tilt across alignment (mm/m)
Whynot	< 20	< 0.5	< 0.5
Woodlands Hill	1650	30	10
Arrowfield	3500	30	45
Bowfield	5750	40	50

The maximum predicted conventional tilts for the powerline are 40 mm/m (i.e. 4.0 % or 1 in 25) along the alignment and 50 mm/m (i.e. 5.0 % or 1 in 20) across the alignment of the powerline. The maximum predicted total tilt in any direction is 60 mm/m (i.e. 6.0 % or 1 in 17).

The maximum predicted horizontal movement of the ground associated with the maximum predicted tilt is 600 mm. The maximum predicted horizontal movement at the tops of the poles (assuming a height of 15 m) therefore is 1500 mm.

The mining-induced tilts and horizontal movements along the alignment of the powerline will result in net opening and net closure between the tops of the adjacent power poles. A summary of the maximum predicted values of total opening and total closure between the tops of the power poles is provided in Table 6.9. The values are the maximum predicted subsidence effects that occur at the completion of the longwalls in each of the seams. Higher transient movements could occur as the longwalls are extracted directly beneath the powerline.

Table 6.9 Maximum predicted total opening and total closure movements between the tops of the power poles of the 11 kV powerline

Span	Final predicted opening (+ve) or closure (-ve) at the completion of mining within each seam (mm)			Maximum predicted total opening after completion of any longwall (mm)	Maximum predicted total closure after completion of any longwall (mm)
	After WH Seam	After AF Seam	After BF Seam		
AN-10006 to AN-10005	+20	+40	+150	+150	< -20
AN-10005 to AN-10004	+325	+525	+725	+725	< -20
AN-10004 to AN-10003	-575	-475	-900	< +20	-900
AN-10003 to AN-10002	+175	-425	-500	+175	-500
AN-10002 to AN-10001	+400	+625	+1100	+1100	< -20
AN-10001 to AM-70114	-70	+200	+150	+200	-70
AM-70114 to AM-70113	-625	-775	-1400	< +20	-1400
AM-70113 to AM-70112	+350	-30	+275	+350	-30
AM-70112 to AM-70111	+400	+700	+1100	+1100	< -20
AM-70111 to AM-70110	-525	-125	-525	< +20	-525
AM-70110 to AM-70109	-175	-575	-900	< +20	-900
AM-70109 to AM-70108	+325	< ±20	+425	+425	< -20
AM-70108 to AM-70107	+175	+625	+975	+975	< -20
AM-70107 to AM-70106	-375	-150	-650	< +20	-650
AM-70106 to AM-70105	+50	-450	-650	+50	-650
AM-70105 to AM-70104	+575	+700	+1350	+1350	< -20
AM-70104 to AM-70103	-500	-100	-375	< +20	-500
AM-70103 to AM-70102	-325	-775	-1200	< +20	-1200
AM-70102 to AM-70101	+550	+350	+875	+875	< -20
AM-70101 to AM-70100	-150	+425	+475	+475	-150
AM-70100 to AM-70099	-650	-925	-1500	< +20	-1500
AM-70099 to AM-70098	+700	+325	+775	+775	< -20
AM-70098 to AM-70097	-30	+375	+600	+600	-30
AM-70097 to AM-70095	-225	+30	-550	+30	-550
AM-70095 to AM-70094	+125	-475	-425	+125	-475
AM-70094 to AM-70093	+30	+275	+500	+500	< -20
AM-70093 to AM-70092	< ±20	+50	+80	+80	< -20

The maximum predicted total differential movements between the tops of the adjacent poles are 1350 mm opening and 1500 mm closure. Higher transient values could occur as the longwalls are mined directly beneath the powerline.

6.6.3. Comparison of the predictions for the 11 kV powerline

The 11 kV powerline crosses directly above the mining area based on both the EIS Layout and Modified Layout. The total length of powerline above the mining area is 2.6 km for both the EIS Layout and Modified Layout.

A comparison of the maximum predicted total conventional subsidence effects for the 11 kV powerline, based on the EIS Layout and Modified Layout, is provided in Table 6.10. The values in this table represent the maximum cumulative movements for the powerline after the mining of all seams.

Table 6.10 Comparison of the maximum predicted subsidence effects for the 11 kV powerline

Layout	After seam	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt along alignment (mm/m)	Maximum predicted total tilt across alignment (mm/m)
EIS Layout (MSEC986)	WN, WH, AF and BF Seams	5100	45	30
Modified Layout (MSEC1186)	WN, WH, AF and BF Seams	5750	40	50

The maximum predicted total vertical subsidence for the 11 kV powerline of 5750 mm, based on the Modified Layout, is greater than the maximum predicted value based on the EIS Layout of 5100 mm. The potential for impacts does not result from absolute vertical subsidence but rather from the differential movements (i.e. tilt).

The maximum predicted total tilt for the powerline, based on the Modified Layout, is less along the alignment but greater across the alignment compared with the EIS Layout. The maximum predicted tilt in any direction is 60 mm/m based on the Modified Layout and 50 mm/m based on the EIS Layout. The maximum tilt in any direction, based on the Modified Layout, is greater than that based on the EIS Layout.

The following section provides the updated impact assessments for the 11 kV powerline based on the Modified Layout. The assessed impacts and recommended management strategies are the same as those presented in the EIS Subsidence Assessment (Report No. MSEC986) and the EIS.

6.6.4. Impact assessments for the powerline

The powerline will not be directly affected by the ground strains, as the cables are supported by the power poles above ground level. However, the cables may be affected by the changes in bay lengths, i.e. the distances between the poles at the levels of the cables, resulting from the differential subsidence, horizontal movements and tilt at the pole locations. The stabilities of the poles and the cable clearances may also be affected by the mining-induced tilts and the changes in the catenary profiles of the cables.

The maximum predicted tilt in any direction for the 11 kV powerline along Edderton Road is 60 mm/m (i.e. 6.0 % or 1 in 17). A rule of thumb used by some electrical engineers is that the tops of the poles may displace up to two pole diameters horizontally before remediation works are considered necessary. Based on pole heights of 15 m and pole diameters of 250 mm, the maximum tolerable tilt at the pole locations is in the order of 20 mm/m.

It is likely, therefore, that the powerline could experience impacts due to the extraction of the longwalls directly beneath it. The impacts could include increased cable tensions and lateral loads on the power poles and/or reduced cable clearances.

The potential for impacts could be managed with the implementation of preventive measures, such as the provision of cable rollers, guy wires or additional poles. Alternatively, the potential impacts could be avoided by realigning the powerline around the area of active subsidence.

Powerlines have been successfully mined beneath in the NSW coalfields where the mine subsidence movements were similar to those predicted for the longwalls. It is expected, therefore, that the powerline along Edderton Road could be maintained in a safe and serviceable condition with the development and implementation of the necessary management and monitoring measures.

6.6.5. Recommendations for the powerline

It is recommended that a BFMP is developed with Ausgrid prior to longwall extraction within 500 m of the powerline. Preventative measures that could be implemented in advance of mining include the realignment of the powerline around the mining area or the installation of cable rollers, guy wires or additional poles, or the adjustment of cable catenaries. It is recommended that powerlines are visually monitored during active subsidence, to maintain them in a safe and serviceable condition at all times.

6.7. Telecommunications infrastructure

There is no telecommunications infrastructure located within the Study Area. Optical fibre and copper telecommunications cables follow the alignment of the Golden Highway and Edderton Road outside of the Study Area. The locations of these cables are shown in Drawing No. MSEC1186-24.

The optical fibre and copper telecommunications cables are located at minimum distances of 680 m and 350 m, respectively, outside of the mining area at their closest points. At these distances, the cables are predicted to experience negligible vertical subsidence. While the copper cables located closest to the mining area could experience very low-levels of vertical subsidence, they are not expected to experience measurable tilts, curvatures or strains.

The optical fibre and copper telecommunications cables are supported by the bridge where the Golden Highway crosses the Hunter River approximately 750 m south of the mining area. The predicted far-field horizontal movements at this bridge are discussed in Section 6.2.

It is recommended that the management plan for the bridge includes strategies to maintain the optical fibre and copper telecommunications cables in serviceable conditions.

6.8. Plashett Reservoir

There are no public dams, reservoirs or associated works within the Study Area. Plashett Reservoir is located outside and to the east of the Study Area. The reservoir is shown in Drawing No. MSEC1186-24.

Plashett Reservoir serves as an off-river water storage for the Bayswater Power Station, operated by AGL, and also supplies water to Jerrys Plains township. The reservoir is fed by pumps located on the Hunter River and Saltwater Creek and it has a total storage capacity of 67 GL. Plashett Reservoir is a prescribed dam (gazettal date 8 August 1997, gazettal no. 88) that is managed by Dams Safety NSW (DS NSW). The DS NSW Notification Area is shown in Drawing No. MSEC1186-24. There is no mining within the Notification Area.

Plashett Reservoir is located at a minimum distance of 2 km outside of the modified mining area. The dam wall is at the south-western corner of the reservoir and it is more than 2 km from the modified mining area. At these distances, the vertical subsidence at the reservoir and dam wall are expected to be negligible.

The reservoir and dam wall could experience very small far-field horizontal movements due to mining. The total far-field horizontal movements are typically less than 25 mm (i.e. in the order of survey tolerance) at distances of 2000 m from previous longwall mining. The potential for adverse impacts on the dam wall does not result from absolute far-field horizontal movements, but rather from differential horizontal movements over the length of the structure. It is unlikely that the differential horizontal movements (i.e. strains) at the dam wall would be measurable.

The distance of Plashett Reservoir from the mining area, based on the Modified Layout, is the same as that based on the EIS Layout. The predicted far-field horizontal movements and, therefore, the assessed potential for impacts does not change.

Longwall mining has been previously carried out near other prescribed dams in the NSW coalfields, including Lake Liddell and the Avon, Cataract, Cordeaux and Nepean Reservoirs. This previous mining has not resulted in adverse impacts on these structures. For example, the longwalls at Dendrobium Mine have been extracted within 0.9 km of the Upper Cordeaux No. 1 and No. 2 Dam Walls. The detailed ground monitoring indicated that the measured movements were very small and were within the order of survey tolerance (i.e. not measurable).

It is unlikely, therefore, that the Plashett Reservoir and the associated dam wall would experience adverse impacts due to mining. The panels and longwall series within each seam are progressively mined towards the reservoir and dam wall. This will allow the movements at these features to be measured and reviewed as the mining progresses towards them, if required.

It is recommended that Malabar continue to consult with DS NSW and AGL throughout the life of the Project in relation to Plashett Reservoir. The predictions, impact assessments and recommended management strategies for Plashett Reservoir are the same as those presented in the EIS Subsidence Assessment (Report No. MSEC986) and the EIS.

6.9. Agricultural utilisation

All land above the mining area is owned by Malabar and it is primarily used for cattle grazing with small areas of opportunistic fodder cropping (under favourable conditions). The agricultural improvements include fences, farm dams, land contours and cattle yards. The potential impacts on the fences and farm dams are discussed in Sections 6.11 and 6.12, respectively. Photographs of the land contouring and cattle yards are provided in Fig. 6.15 and Fig. 6.16, respectively.

Fig. 6.15 Land contouring within the Study Area

Fig. 6.16 Cattle yard and fences within the Study Area

The main risk to the light cattle grazing within the Study Area is the potential for the mining-induced surface cracking and deformations to injure the cattle or workers. The assessed surface deformations above the panels and longwalls are provided in Section 4.6.

Management strategies can be developed for this agricultural utilisation, which could include:

- visual monitoring of the surface in the active subsidence zone, to identify any surface cracking and deformations that could potentially injure the stock or people;
- consider the installation of temporary fencing and/or the temporary relocation of stock to areas outside the active subsidence zone;
- establish methods of remediation, which could include infilling of surface cracks with soil or other suitable materials, or by locally regrading and recompacting the surface; and
- develop management plans detailing the appropriate methods to manage surface cracking and deformations within the Study Area.

These management strategies should be developed in consultation with the lessee, as required. The discussions of the potential impacts on the built features and surface improvements associated with the agricultural utilisation are included in the following sections.

The predictions, impact assessments and recommended management strategies for the agricultural utilisation are the same as those presented in the EIS Subsidence Assessment (Report No. MSEC986) and the EIS.

6.10. Rural structures and tanks

The locations of the rural structures (i.e. sheds) and tanks within the Study Area are shown in Drawing No. MSEC1186-24.

A disused shearers hut, sheep yards and associated structures are located above the mining area. This site is directly above the WHLW9, AFLW6 and BFLW6 and it is south-west of the panels in the Whynot Seam. The structures are timber framed with corrugated metal sheeting. The stockyard has a concrete ground slab and a shallow well with a concrete surround. There is a brick fire pit next to the shearers hut. The structures are in varying states of disrepair.

A summary of the maximum predicted total vertical subsidence, tilt and curvatures for the disused shearers hut, sheep yards and associated structures is provided in Table 6.11. The values are the maximum predicted subsidence effects within 20 m of the identified location of this site.

Table 6.11 Maximum predicted total vertical subsidence, tilt and curvatures for the disused shearers hut, sheep yards and associated structures

After seam	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})
Whynot	< 20	< 0.5	< 0.01	< 0.01
Woodlands Hill	275	8	0.20	< 0.01
Arrowfield	2700	14	0.20	0.11
Bowfield	4050	25	0.20	0.11

The disused shearers hut, sheep yards and associated structures are predicted to experience a maximum curvature of 0.20 km^{-1} and strains of 8 mm/m tensile and 9 mm/m compressive based on the 95 % confidence levels. The maximum predicted subsidence effects based on the Modified Layout are the same or less than the maximum predicted values based on the EIS Layout.

The ground movements are expected to result in considerable deformation of the structures at this site. These structures are of lightweight construction and in varying states of disrepair. The conditions of the timber framing and corrugated sheeting are unlikely to change due to mining. Cracking could develop in the concrete slab, concrete surround and brickwork.

The rural structures (Refs. A01r01 to A01r04) and tanks (Refs. A01t01 to A01t03) are located outside the southern boundary of the Study Area. These structures are owned by Malabar. The structures are located at distances greater than 200 m from the mining area at their closest points.

It is unlikely that the rural structures and tanks located outside the mining area would experience adverse impacts due to mining. All structures are expected to remain in safe and serviceable conditions throughout the mining period. Similarly, all other structures located outside the Study Area are predicted to experience negligible vertical subsidence and are not expected to experience adverse impacts due to mining.

The impact assessments and recommended management strategies for the rural structures are the same as those presented in the EIS Subsidence Assessment (Report No. MSEC986) and the EIS.

6.11. Fences

Fences are located across the Study Area and, therefore, are expected to experience the range of predicted subsidence movements. 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 adverse impacts.

It is expected, at the predicted magnitudes of tilt, curvature and strain, that some sections of the fences within the Study Area would be impacted due to mining. Impacts on the fences could be remediated by re-tensioning the fencing wire, straightening the fence posts, and if necessary, replacing the affected sections of fencing.

The impact assessments and recommended management strategies for the fences are the same as those presented in the EIS Subsidence Assessment (Report No. MSEC986) and the EIS.

6.12. Farm dams

6.12.1. Description of the farm dams

The locations of the farm dams are shown in Drawing No. MSEC1186-24.

There are 21 farm dams within the Study Area. These dams are all located on land owned by Malabar. Part of the land within the Study Area is leased and is used for cattle grazing. The farm dams provide sources of water for this agricultural utilisation.

The dams are of earthen construction and have been established by localised cut and fill operations within the natural drainage lines. The farm dams are shallow, with the dam walls generally being less than 3 m in height.

Photographs of typical farm dams within the Study Area are provided in Fig. 6.17.

Fig. 6.17 Farm dams

The largest farm dam above the mining area has a surface area of 13,000 m^2 and a maximum planar dimension of 140 m. The majority of the remaining dams within the Study Area have surface areas less than 4000 m^2 and maximum planar dimensions of less than 80 m.

6.12.2. Predictions for the farm dams

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

A summary of the maximum predicted vertical subsidence, tilt and curvatures for the farm dams is provided in Table 6.12. The values are the maximum predicted subsidence effects within the Study Area due to mining in the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams.

Table 6.12 Maximum predicted conventional subsidence, tilt and curvature for the farm dams

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})
Farm dams	6500	50	2.0	2.0

The maximum predicted total conventional curvatures are 2.0 km^{-1} hogging and sagging, which represent a minimum radius of curvature of 0.5 km. The predicted conventional strains based on applying a factor of 10 to the predicted conventional curvatures are 20 mm/m tensile and compressive.

The distributions of strain above the mining area are provided in Section 4.4. The predicted strains due to the multi-seam mining 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 farm dams are located along the natural drainage lines and, therefore, could also experience valley-related effects due to mining. The drainage lines have shallow incisions into the natural surface soils and, therefore, the predicted upsidence and closure effects are not expected to be significant when compared with the predicted conventional effects.

6.12.3. Comparison of the predictions for the farm dams

A comparison of the maximum predicted total conventional subsidence effects for the farm dams, based on the EIS Layout and Modified Layout, is provided in Table 6.13. The values in this table represent the maximum cumulative movements for the farm dams after the mining of all seams.

Table 6.13 Comparison of the maximum predicted subsidence effects for the steep slopes

Layout	After seam	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})
EIS Layout (MSEC986)	WN, WH, AF and BF Seams	5600	50	2.0	2.0
Modified Layout (MSEC1186)	WN, WH, AF and BF Seams	6500	50	2.0	2.0

The maximum predicted total vertical subsidence for the farm dams of 6500 mm, based on the Modified Layout, is greater than the maximum predicted value based on the EIS Layout of 5600 mm. The potential for impacts does not result from absolute vertical subsidence but rather from the differential movements (i.e. differential subsidence, tilt, curvature and strain). The maximum predicted total tilt and curvatures for the farm dams, based on the Modified Layout, are the same as the maximum predicted values based on the EIS Layout.

The predicted subsidence effects will vary from place to place, with locally higher values for some dams and locally lower values in other dams, depending on their positions relative to the panels and longwalls for each layout. The overall levels of the predicted subsidence effects for the farm dams, based on the Modified Layout, are similar to that based on the EIS Layout.

The following section provides the updated impact assessments for the farm dams based on the Modified Layout. The assessed impacts and recommended management strategies are the same as those presented in the EIS Subsidence Assessment (Report No. MSEC986) and the EIS.

6.12.4. Impact assessments for the farm dams

The maximum predicted final tilt for the farm dams within the Study Area is 50 mm/m (i.e. 5 % or 1 in 20). The individual dams will experience varying tilts up to this value, depending on their locations relative to the panels and longwalls in each seam.

Mining-induced tilts can affect the water levels around the perimeters of farm dams, with the freeboard increasing on one side, and decreasing on the other. Tilt can potentially reduce the storage capacity of farm dams, by causing them to overflow, or can affect the stability of the dam walls.

The maximum predicted changes in freeboard occur at the two largest farm dams located adjacent to Edderton Road and above the western part of the mining area. The predicted changes in freeboard for these dams are 1.2 m. The predicted changes in freeboard for the remaining farm dams located above the mining area vary up to approximately 0.5 m.

It is likely that the storage capacities of the farm dams predicted to experience the greatest changes in freeboard would reduce due to mining. If the storage capacities of any farm dams were adversely affected, they could be re-established by raising the earthen walls. In some cases, the dam walls may also need to be lengthened on the downslope side. In some cases, the storage capacities of the farm dams could increase due to mining. It is recommended that, during active mining, Malabar should confirm that any increase in storage capacity remains within harvestable rights and/or water licensing constraints.

The maximum predicted curvatures at the farm dams are 2.0 km^{-1} hogging and sagging, which represents a minimum radius of curvature of 0.5 km. The farm dams will also experience strains typically up to 10 mm/m, with localised and isolated strains up to 20 mm/m.

It is expected, at these magnitudes of predicted curvatures and strains, that many of the farm dams would be affected by cracking, heaving or stepping in the bases of the dam walls. It is also likely that fracturing and buckling of the uppermost bedrock would occur beneath the farm dams. The farm dams which are at higher risk from surface cracking are those located in the final tensile zones, i.e. located at distances around 0.1 times the depth of cover from the longwall edges.

There is also a possibility that high concentrations of strain could occur at faults, fissures and other geological features, or points of weaknesses in the strata, and such occurrences could be coupled with localised stepping in the surface. If this type of phenomenon coincided with a farm dam wall, then, there is a possibility that cracking could occur in the dam wall or base resulting in loss of the stored water.

Surface cracking or leakages in the farm dams could be identified by visual inspections and remediated by re-instating the bases and walls of the dams with cohesive materials. Any loss of stored water from the farm dams would flow into the drainage line in which the dam was formed. Consultation should occur with the lessee during mining to manage any temporary impacts on stock water supply.

6.12.5. Recommendations for the farm dams

Monitoring and management measures for each farm dam should be developed as part of the Extraction Plan process. It is recommended that the stored water levels in the larger farm dams are lowered prior to active subsidence. It is also recommended that farm dams are visually monitored, during active subsidence at the dam, such that any impacts can be identified and remediated accordingly.

6.13. Groundwater bores

The locations of groundwater bores are shown in Drawing No. MSEC1186-24.

A summary of groundwater bores located within the Study Area is provided in Table 6.14. These groundwater bores are located on Malabar-owned land. There are also additional groundwater bores that are located outside the Study Area, as shown in Drawing No. MSEC1186-24.

Table 6.14 Details of the groundwater bores within the Study Area

Reference	Approximate easting (m)	Approximate northing (m)	Depth (m)
DD1004	299800	6410925	106
DD1005	298800	6410900	139
DD1014	296800	6410875	90
DD1015	298825	6409900	163
DD1016	297800	6410875	126
DD1025	298775	6411900	45
DD1032	297150	6412500	276
DD1041 – Deep	296200	6409475	387
DD1041 – Shallow	296200	6409475	N/A
DD1043	295200	6409450	203
DD1052	296275	6408525	127
DD1057	295175	6410450	188
RBD1	295175	6409250	111
RD1192	296100	6409050	149
Shearers Well	296900	6410275	N/A
Shearers Well Bore	296925	6410250	N/A
WND16	298125	6408850	126
WND26	299475	6409050	152

There are 18 groundwater bores located within the Study Area based on the Modified Layout. There is one additional bore (DD1032) within the Study Area compared with that for the EIS Layout.

The groundwater bores are located across the Study Area and, therefore, are expected to experience the range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4. The maximum predicted subsidence effects for the groundwater bores, based on the Modified Layout, are the same as the maximum predicted values based on the EIS Layout.

The predicted subsidence effects will vary from place to place, with locally higher values for some bores and locally lower values in other bores, depending on their positions relative to the panels and longwalls for each layout. The overall levels of the predicted subsidence effects for the groundwater bores, based on the Modified Layout, are similar to that based on the EIS Layout.

It is likely that the groundwater bores will experience impacts as the result of mining, particularly those located directly above the mining area. Impacts would include lowering of the piezometric surface, blockage of the bore due to differential horizontal displacements at different horizons within the strata and changes to groundwater quality. Such impacts on the groundwater bores can be managed and, if required, the bores can be reinstated. The predictions, impact assessments and recommended management strategies for the groundwater bores are the same as those presented in the EIS Subsidence Assessment (Report No. MSEC986) and the EIS.

The potential impacts on the bores and groundwater resources are provided by the specialist groundwater consultant for the EIS in the report by *SLR* (2022).

6.14. Business and commercial establishments

There are no business or commercial establishments within the Study Area. There are business and commercial establishments located along the Golden Highway to the south of the Study Area, including horse studs and a vineyard. The establishments near the Study Area are shown in Drawing No. MSEC1186-24.

These properties located outside the Study Area will not be affected by mining-induced surface cracking and deformations, nor changes in surface water drainage. The potential impacts on the bores and groundwater resources in the vicinity of the Study Area are provided by the specialist groundwater consultant for the EIS in the report by *SLR* (2022).

The building structures, surface infrastructure and improvements on the properties located outside the Study Area are predicted to experience negligible vertical subsidence, tilts, curvatures and strains. It is unlikely that these features would experience adverse impacts due to mining. All structures, infrastructure and improvements on the private properties are expected to remain in safe and serviceable conditions throughout the mining period.

The predictions, impact assessments and recommended management strategies for the business and commercial establishments are the same as those presented in the EIS Subsidence Assessment (Report No. MSEC986) and the EIS.

6.15. Aboriginal heritage sites

6.15.1. Descriptions of the Aboriginal heritage sites

The locations of known Aboriginal heritage sites are shown in Drawing No. MSEC1186-25. The details of these sites have been provided by *AECOM* (2022).

The Aboriginal heritage sites located within the Study Area and surrounds comprise stone quarries and other open artefact sites, i.e. isolated artefacts, artefact scatters and an artefact scatter with an associated potential archaeological deposit (PAD). The locations of these sites relative to the mining areas are provided in Table D.01, in Appendix D. The locations provided in Table D.01 are based on an amalgamation of the sites and estimated extents due to the proximity of neighbouring sites.

Further details on the Aboriginal heritage sites are provided by *AECOM* (2022).

6.15.2. Predictions for the Aboriginal heritage sites

The maximum predicted total conventional subsidence effects for each of the Aboriginal heritage sites are provided in Table D.01, in Appendix D. The predictions provided in Table D.01 are based on the maximum values within the amalgamation of the sites and estimated extents.

Summaries of the maximum predicted total vertical subsidence, tilt and curvatures for the stone quarries and the other open artefact sites (i.e. isolated artefacts, isolated artefacts, artefact scatters and artefact scatter with PAD) are provided in Table 6.15 and Table 6.16, respectively.

Stone quarry site ‘SC-QS-1/Quarry’ (Ref. 37-2-1955) recorded by Mills (2000) within the Modification Study Area was not located during AECOM’s 2012 and 2018 surveys (AECOM, 2022). Notwithstanding, predictions for Site 37-2-1955 are presented in Table 6.16 for completeness.

Table 6.15 Maximum predicted total vertical subsidence, tilt and curvatures for the stone quarries

Site	After seam	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})
37-2-1954	Whynot	< 20	< 0.5	< 0.01	< 0.01
	Woodlands Hill	< 20	< 0.5	< 0.01	< 0.01
	Arrowfield	< 20	< 0.5	< 0.01	< 0.01
	Bowfield	< 20	< 0.5	< 0.01	< 0.01
37-2-1955	Whynot	< 20	< 0.5	< 0.01	< 0.01
	Woodlands Hill	50	1.0	0.02	< 0.01
	Arrowfield	50	1.0	0.02	< 0.01
	Bowfield	50	1.0	0.02	< 0.01

Table 6.16 Maximum predicted total vertical subsidence, tilt and curvatures for the other open artefact sites

Sites	After seam	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Open artefact sites	Whynot	325	15	0.5	1.0
	Woodlands Hill	3300	35	1.5	1.5
	Arrowfield	4600	40	2.0	2.0
	Bowfield	6400	50	2.0	2.0

Following the completion of initial subsidence predictions, Malabar revised the lengths of the longwalls in the Woodlands Hill and Arrowfield Seams to avoid mining beneath the previously recorded Aboriginal stone quarry Site 37-2-1954 in order to reduce potential subsidence-related impacts. As a result, the stone quarry is located outside the mining area and it is predicted to experience less than 20 mm vertical subsidence. While this stone quarry could experience very low-levels of vertical subsidence, it is not expected to experience measurable tilts, curvatures or strains.

The previously reported stone quarry 37-2-1955 is located outside the mining area but adjacent to WHLW16. This site is predicted to experience vertical subsidence of 50 mm. This site could experience low-level subsidence effects up to 1.0 mm/m tilt (i.e. 0.1 % or 1 in 1000), hogging curvature of 0.02 km^{-1} (i.e. minimum radius of curvature of 50 km) and sagging curvature of less than 0.01 km^{-1} (i.e. minimum radius of curvature greater than 100 km).

The maximum predicted total conventional curvatures for the other open artefact sites are 2.0 km^{-1} hogging and sagging, which represent a minimum radius of curvature of 0.5 km. The predicted conventional strains based on applying a factor of 10 to the predicted conventional curvatures are 20 mm/m tensile and compressive.

The distributions of strain above the mining area are provided in Section 4.4. The predicted strains due to the multi-seam mining 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.

6.15.3. Comparison of the predictions for the Aboriginal heritage sites

Comparisons of the maximum predicted total conventional subsidence effects for stone quarries and the other open artefact sites, based on the EIS Layout and Modified Layout, are provided in Table 6.17 to Table 6.19. The values in these tables represent the maximum cumulative movements for the sites after the mining of all seams.

Table 6.17 Comparison of the maximum predicted subsidence effects for stone quarry 37-2-1954

Layout	After seam	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})
EIS Layout (MSEC986)	WN, WH, AF and BF Seams	< 20	< 0.5	< 0.01	< 0.01
Modified Layout (MSEC1186)	WN, WH, AF and BF Seams	< 20	< 0.5	< 0.01	< 0.01

Table 6.18 Comparison of the maximum predicted subsidence effects for stone quarry 37-2-1955

Layout	After seam	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})
EIS Layout (MSEC986)	WN, WH, AF and BF Seams	< 20	< 0.5	< 0.01	< 0.01
Modified Layout (MSEC1186)	WN, WH, AF and BF Seams	50	1.0	0.02	< 0.01

Table 6.19 Comparison of the maximum predicted subsidence effects for the other open artefact sites

Layout	After seam	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})
EIS Layout (MSEC986)	WN, WH, AF and BF Seams	5450	50	2.0	2.0
Modified Layout (MSEC1186)	WN, WH, AF and BF Seams	6400	50	2.0	2.0

The maximum predicted vertical subsidence for the stone quarry 37-2-1954 is less than 20 mm based on both the EIS Layout and Modified Layout. While this site could experience very low-levels of vertical subsidence, it is not expected to experience measurable tilts, curvatures or strains.

The maximum predicted subsidence effects for stone quarry 37-2-1955 slightly increase as it is now located outside but adjacent to WHLW16. However, that site was not located during AECOM's 2012 and 2018 surveys (AECOM, 2022).

The maximum predicted total vertical subsidence for the open artefact sites, based on the Modified Layout, is greater than the maximum predicted value based on the EIS Layout. However, the potential for adverse impacts is not directly related to absolute vertical subsidence, but to the maximum predicted differential movements, i.e. tilt, curvature and strain. The maximum predicted total tilt, curvature and strain for the other open artefact sites, based on the Modified Layout, are the same as the maximum predicted values based on the EIS Layout.

The predicted subsidence effects will vary from place to place, with higher values for some sites and lower values for other sites, depending on their positions relative to the panels and longwalls for each layout. The overall levels of the predicted subsidence effects for the other open artefact sites, based on the Modified Layout, are similar to those based on the EIS Layout.

The following section provides the updated impact assessments for Aboriginal heritage sites based on the Modified Layout. The assessed impacts and recommended management strategies are the same as those presented in the EIS Subsidence Assessment (Report No. MSEC986) and the EIS.

6.15.4. Impact assessments for the Aboriginal heritage sites

The Aboriginal heritage sites are located across the mining area and, therefore, they could experience the range of the predicted mine subsidence movements. These sites can potentially be affected by cracking and heaving of the surface soils due to mining.

The assessed surface deformations above the panels and longwalls are provided in Section 4.6.

The surface cracking in the flatter areas and at higher depths of cover is expected to be typically between 25 mm and 50 mm in approximately 50 % of cases, between 50 mm and 100 mm in approximately 30 % of cases, between 100 mm and 150 mm in approximately 15 % of cases and greater than 150 mm in approximately 5 % of cases.

The surface cracking in the steeper areas and at shallower depths of cover is expected to be typically between 50 mm and 100 mm in approximately 60 % of cases, between 100 mm and 200 mm in approximately 25 % of cases, between 200 mm and 300 mm in approximately 10 % of cases and greater than 300 mm in approximately 5 % of cases. Multiple cracks resulting in deformations over several metres could also occur in some locations (i.e. less than 1 % of cases).

It is unlikely that the finds, 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 Aboriginal heritage sites.

It is recommended that Malabar develop appropriate protocols in the event that remediation of the surface is required in the locations of the isolated finds, artefact scatters and deposits. Further assessments of the potential impacts on these sites are provided by *AECOM* (2022).

6.15.5. Recommendations for the Aboriginal heritage sites

Recommendations for Aboriginal heritage sites have been provided by the specialist Aboriginal cultural heritage consultant for the Project in the report by *AECOM* (2022). It is recommended that the Aboriginal Cultural Heritage Management Plan (ACHMP) include visual inspection of sites prior to mining within 500 m of the site and following the completion of active subsidence at the site. Protocols should be developed to manage sites that may be directly impacted by surface cracking or that may be disturbed during surface remediation activities.

6.16. Historic heritage sites

The locations of the historic heritage sites are shown in Drawing No. MSEC1186-25. The details of these sites have been provided by *Extent Heritage* (2022).

Historic heritage sites identified by *Extent Heritage (*2022*)* are located outside the Study Area. The sites in the region include the Arrowfield Homestead, Bowfield Homestead, Edderton Homestead, Plashett Homestead, Randwick Homestead, Strowan Homestead, Woodlands Homestead and a stockyard.

The historic heritage sites are located at distances between 0.7 km and 5 km outside the mining area. At these distances, these sites are predicted to experience negligible ground movements due to mining. The potential for mining-induced impacts on these historic heritage sites is considered to be negligible.

Further assessments of the historic heritage sites are provided by *Extent Heritage* (2022).

6.17. Survey control marks

The survey control marks are shown in Drawing No. MSEC1186-24. The locations and details of the survey control marks were obtained from *Spatial Services* using the *SCIMS Online* website (SCIMS, 2018).

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

The survey control marks located outside the Study Area are also expected to experience small amounts of subsidence and small far-field horizontal movements. It is possible that the survey control marks could be affected by far-field horizontal movements at distances of 1 km to 2 km outside 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.

Malabar should manage the impacts of mine subsidence on survey marks in consultation with NSW Spatial Services, including lodging relevant applications under the NSW *Surveying and Spatial Information Regulation, 2017* as required by the *Surveyor-General's Direction No. 11 Preservation of Survey Infrastructure*.

The assessed impacts and recommended management strategies for the survey control marks are the same as those presented in the EIS Subsidence Assessment (Report No. MSEC986) and the EIS.

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 thickness	The thickness of coal that is extracted. The extracted seam thickness is normally given as an average over the area of the panel.
Effective extracted seam thickness (T)	The extracted seam thickness modified to account for the percentage of coal left as pillars within the panel.
Face length	The width of the coalface measured across the longwall panel.
Far-field movements	The measured horizontal movements at pegs that are located beyond the longwall panel edges and over solid unmined coal areas. Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low-levels of strain.
Goaf	The void created by the extraction of the coal into which the immediate roof layers collapse.
Goaf end factor	A factor applied to reduce the predicted incremental subsidence at points lying close to the commencing or finishing ribs of a panel.
Horizontal displacement	The horizontal movement of a point on the surface of the ground as it settles above an extracted panel.
Inflection point	The point on the subsidence profile where the profile changes from a convex curvature to a concave curvature. At this point the strain changes sign and subsidence is approximately one half of S max.
Incremental subsidence	The difference between the subsidence at a point before and after a panel is mined. It is therefore the additional subsidence at a point resulting from the excavation of a panel.
Panel	The plan area of coal extraction.
Panel length (L)	The longitudinal distance along a panel measured in the direction of mining from the commencing rib to the finishing rib.
Panel width (Wv)	The transverse distance across a panel, usually equal to the face length plus the widths of the roadways on each side.
Panel centre line	An imaginary line drawn down the middle of the panel.
Pillar	A block of coal left unmined.
Pillar width (Wpi)	The shortest dimension of a pillar measured from the vertical edges of the coal pillar, i.e. from rib to rib.

Shear deformations	The horizontal displacements that are measured across monitoring lines and these can be described by various parameters including; horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index.
Strain	The change in the horizontal distance between two points divided by the original horizontal distance between the points, i.e. strain is the relative differential displacement of the ground along or across a subsidence monitoring line. Strain is dimensionless and can be expressed as a decimal, a percentage or in parts per notation. **Tensile Strains** are measured where the distance between two points or survey pegs increases and **Compressive Strains** where the distance between two points decreases. While mining-induced **strains** are measured **along** monitoring lines, ground **shearing** can occur both vertically, and horizontally **across** the directions of the monitoring lines.
Subcritical 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.
Subsidence effects	The deformations of the ground mass surrounding a mine, sometimes referred to as 'components' or 'parameters' of mine subsidence induced ground movements, including vertical and horizontal displacements, tilts, curvatures, strains, upsidence and closure.
Subsidence impacts	The physical changes or damage to the fabric or structure of the ground, its surface and natural features, or built structures that are caused by the subsidence effects. These impacts considerations can include tensile and shear cracking of the rock mass, localised buckling of strata, bed separation, rock falls, collapse of overhangs, failure of pillars, failure of pillar floors, dilation, slumping and also include subsidence depressions or troughs.
Subsidence consequences	The knock-on results of subsidence impacts, i.e. any change in the amenity or function of a natural feature or built structure that arises from subsidence impacts. Consequence considerations include public safety, loss of flows, reduction in water quality, damage to artwork, flooding, draining of aquifers, the environment, community, land use, loss of profits, surface improvements and infrastructure. Consequences related to natural features are referred to as environmental consequences.
Supercritical 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 term uplift is used for the cases where the ground level is raised above the pre-mining level, i.e. when the upsidence is greater than the subsidence. 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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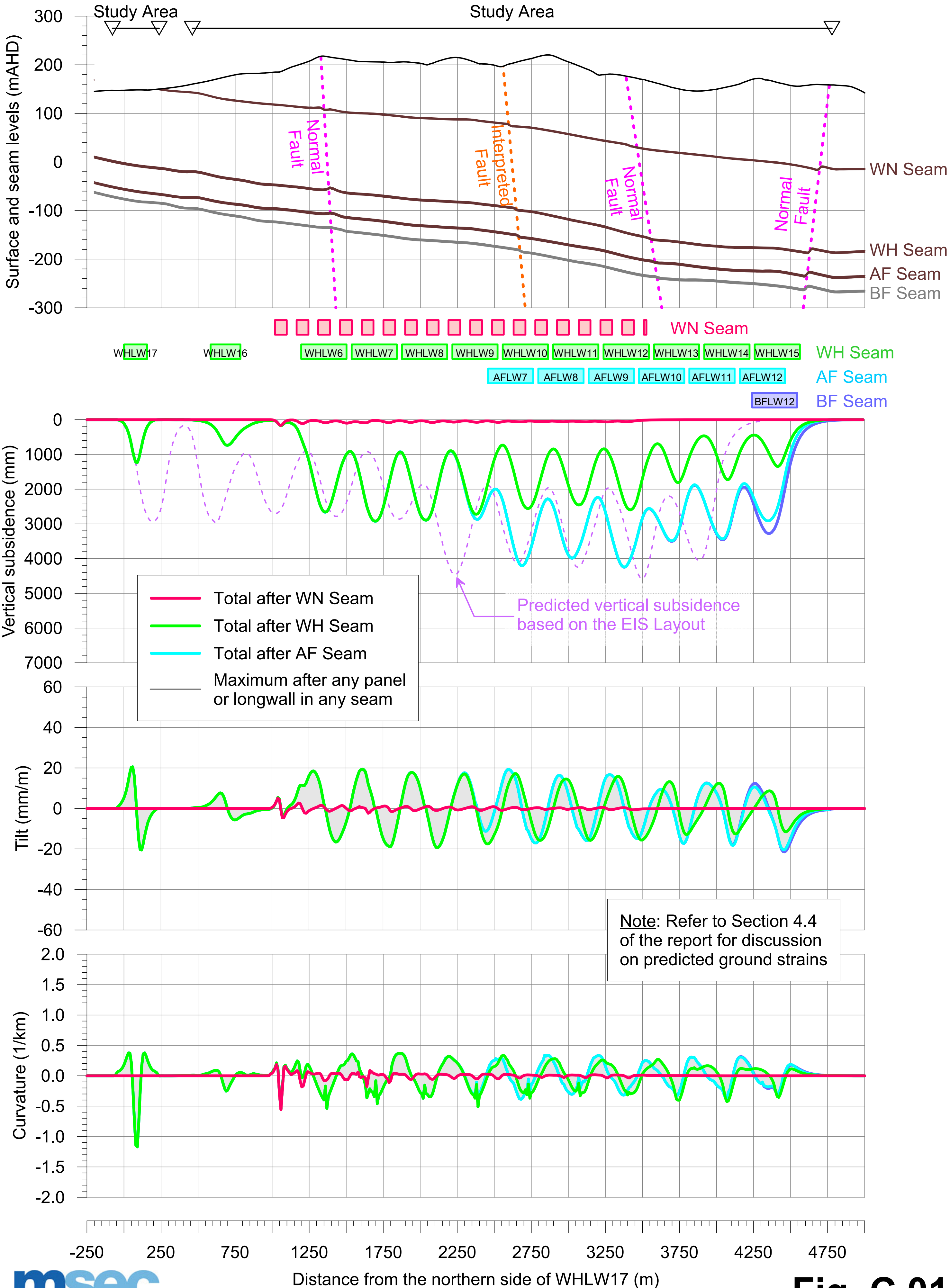
APPENDIX C. FIGURES

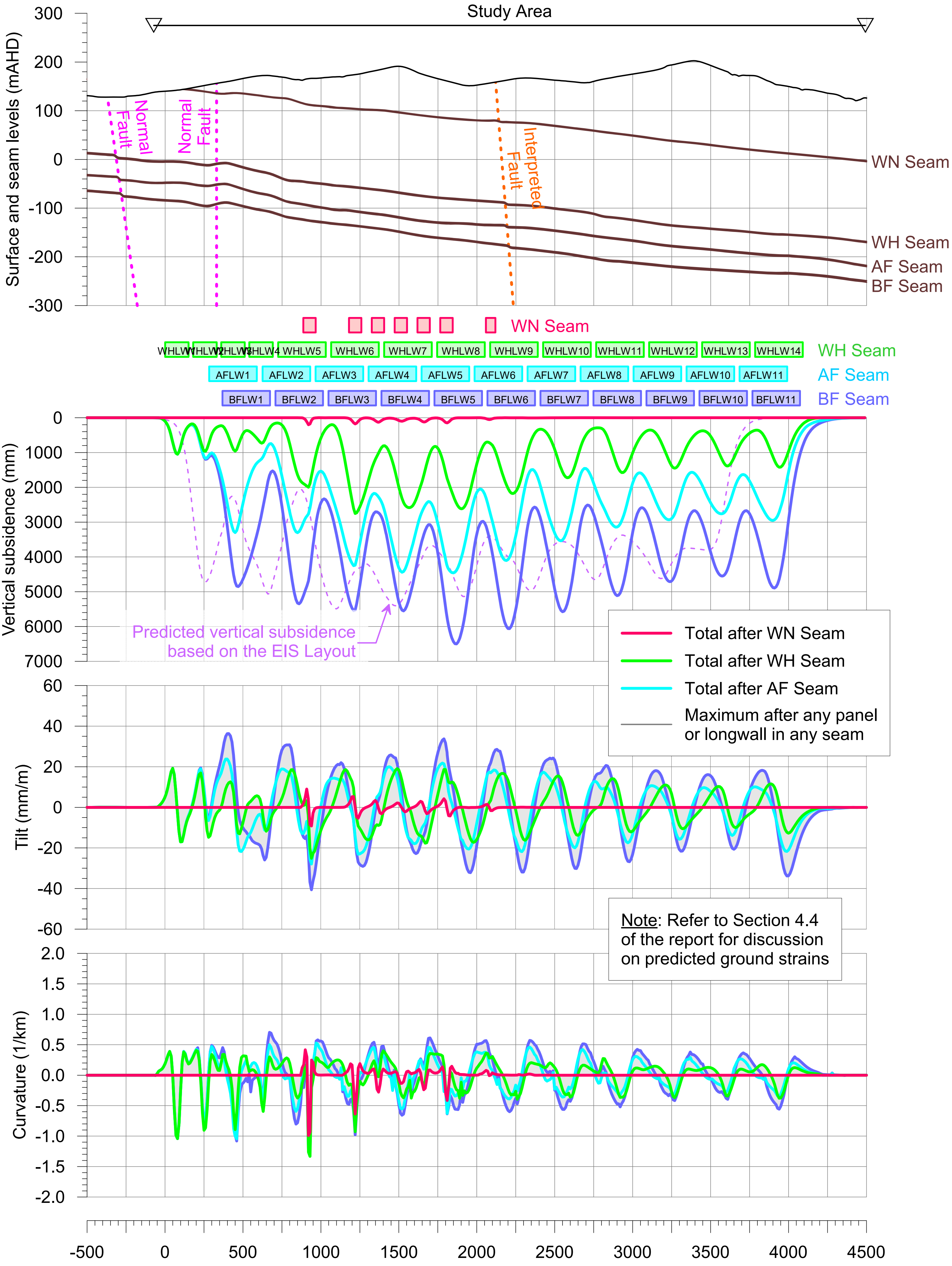
Predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 1 due to the extraction of the WN, WH, AF and BF Seams



msec

Fig. C.01

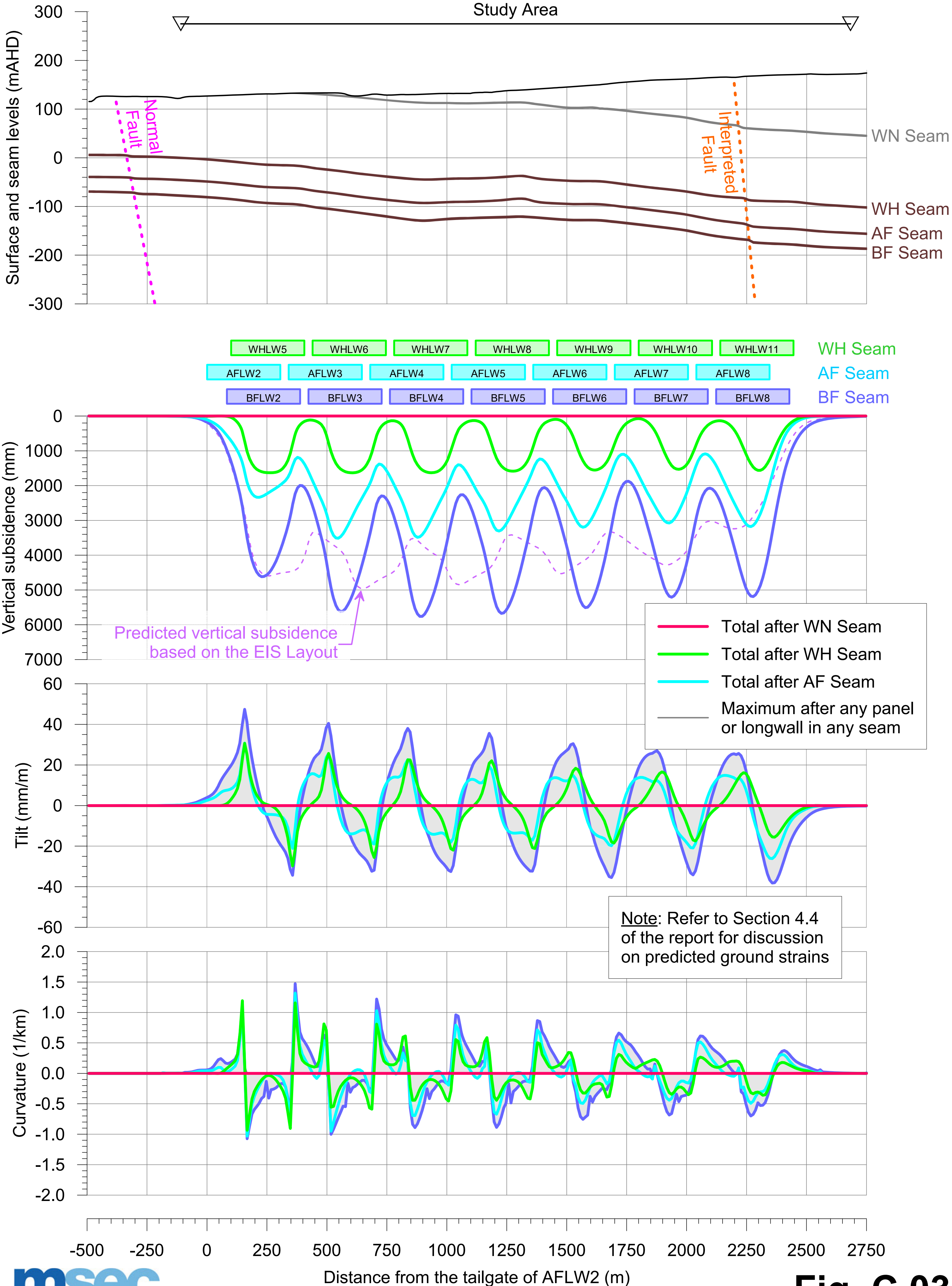
Predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 2 due to the extraction of the WN, WH, AF and BF Seams



msec

Fig. C.02

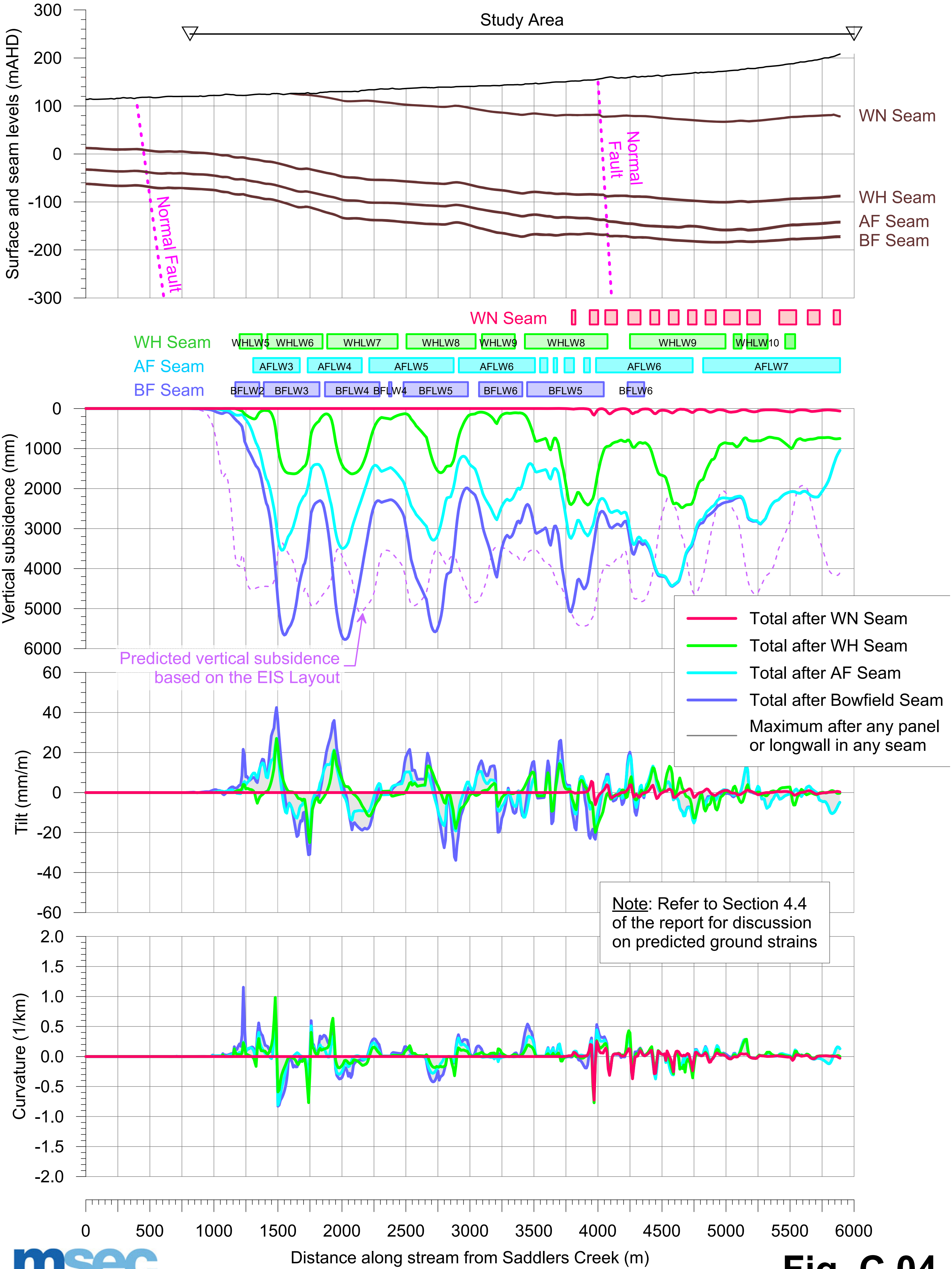
Predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 3 due to the extraction of the WN, WH, AF and BF Seams



msec

Fig. C.03

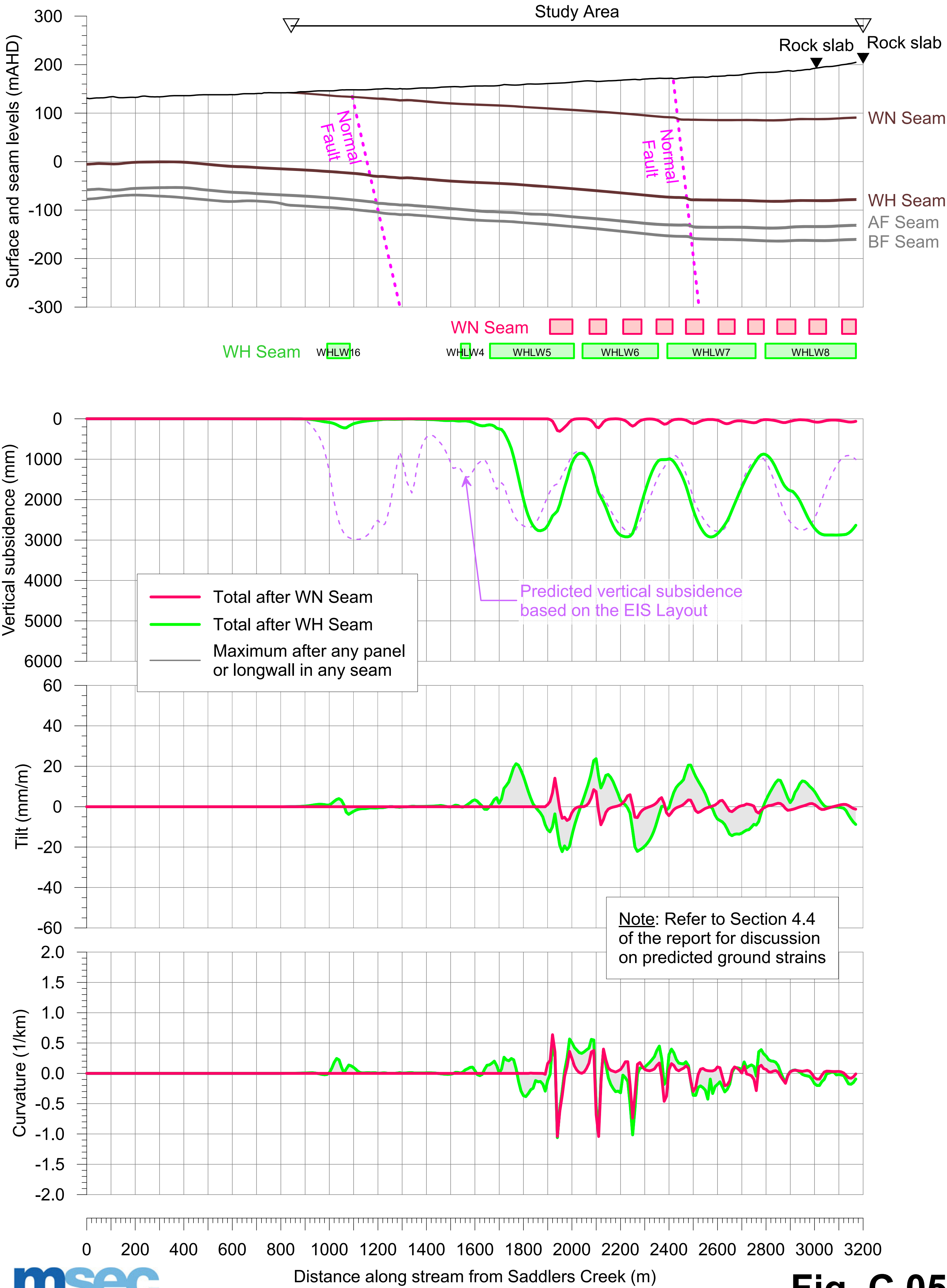
Predicted profiles of vertical subsidence, tilt and curvature along Drainage Line A due to the extraction of the WN, WH, AF and BF Seams



msec

Fig. C.04

Predicted profiles of vertical subsidence, tilt and curvature along Drainage Line B due to the extraction of the WN, WH, AF and BF Seams



msec

Fig. C.05

Predicted profiles of vertical subsidence, tilt and curvature along Drainage Line C due to the extraction of the WN, WH, AF and BF Seams

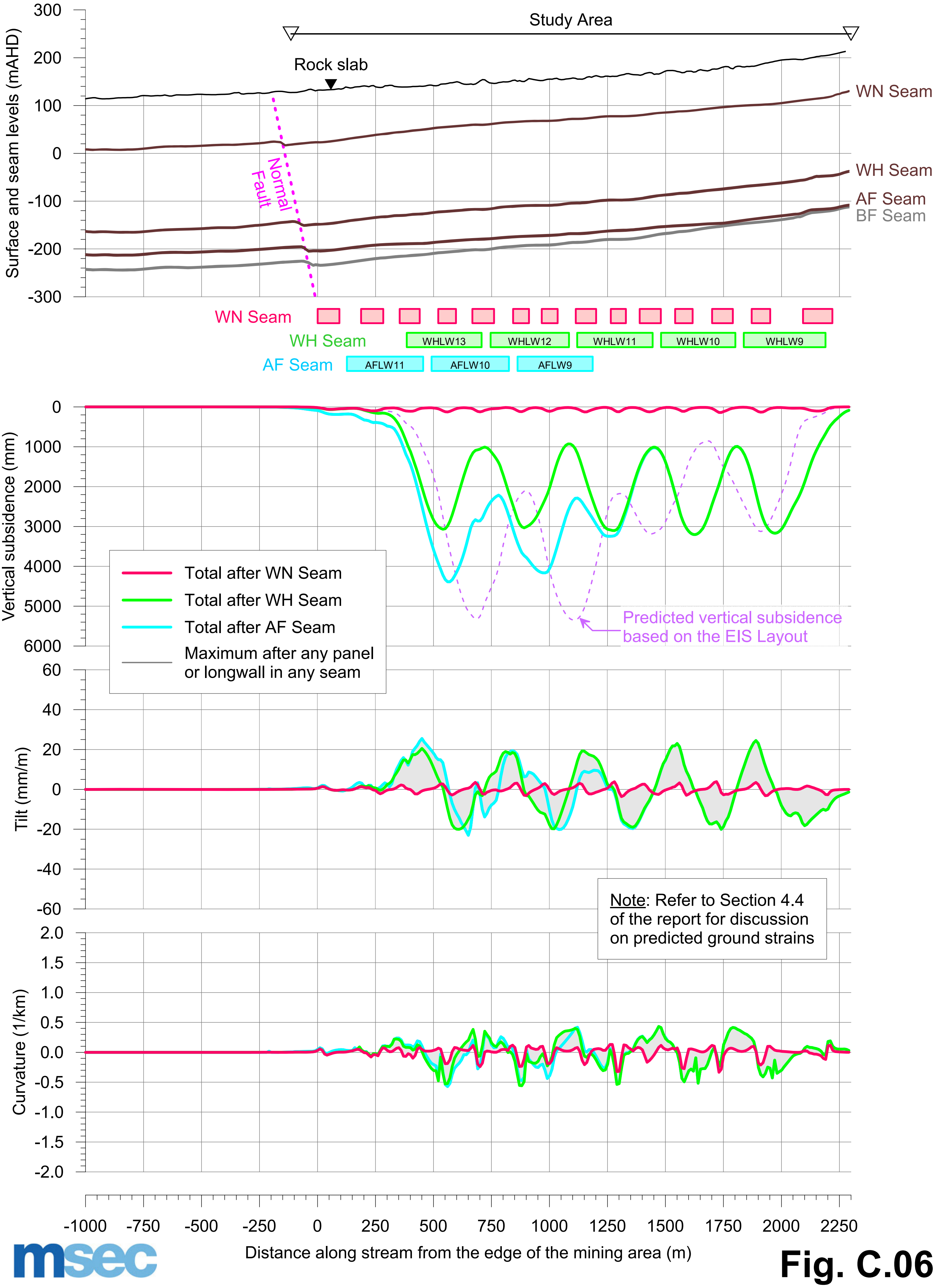


Fig. C.06

Predicted profiles of vertical subsidence, tilt and curvature along Drainage Line E due to the extraction of the WN, WH, AF and BF Seams

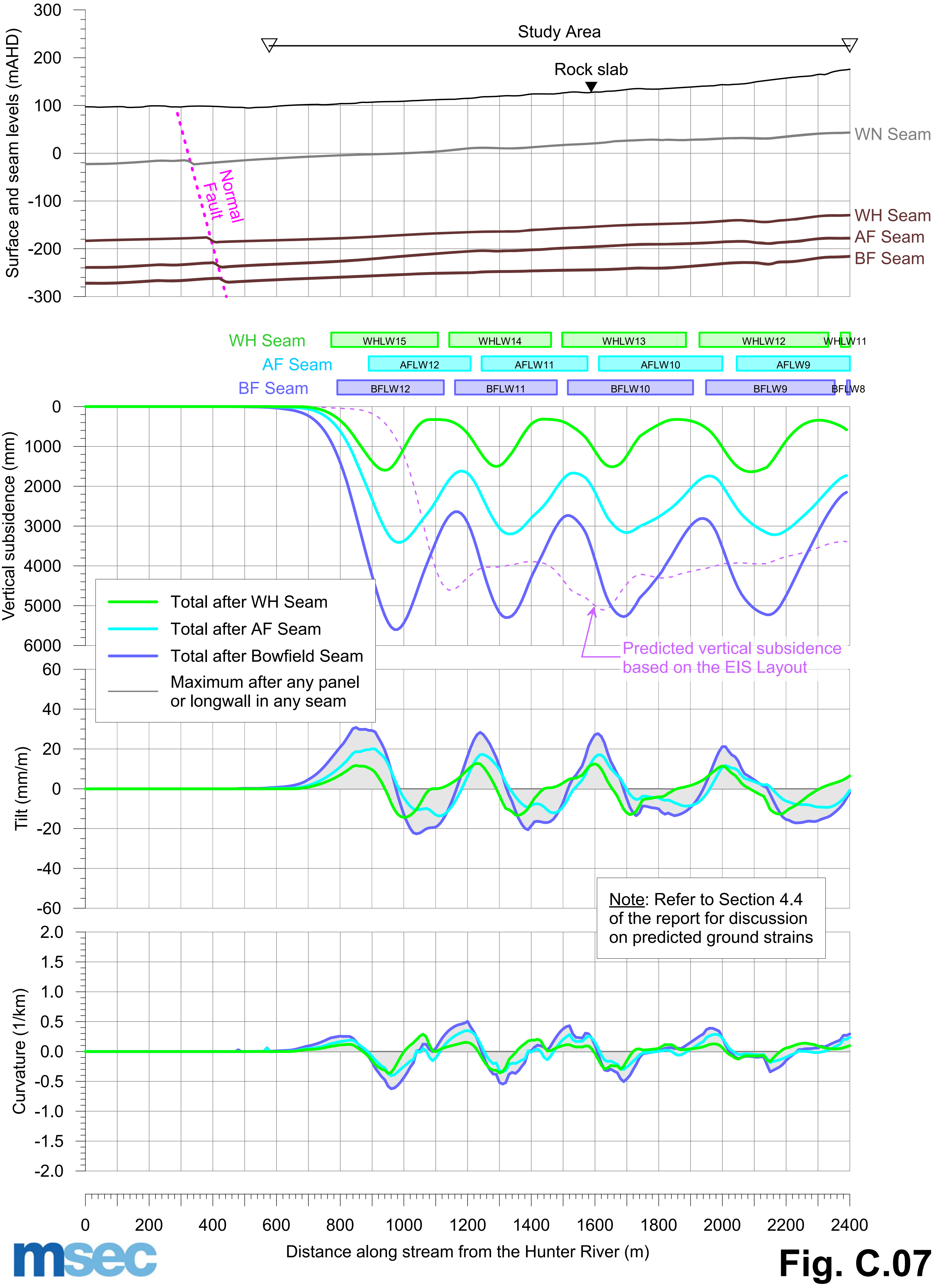
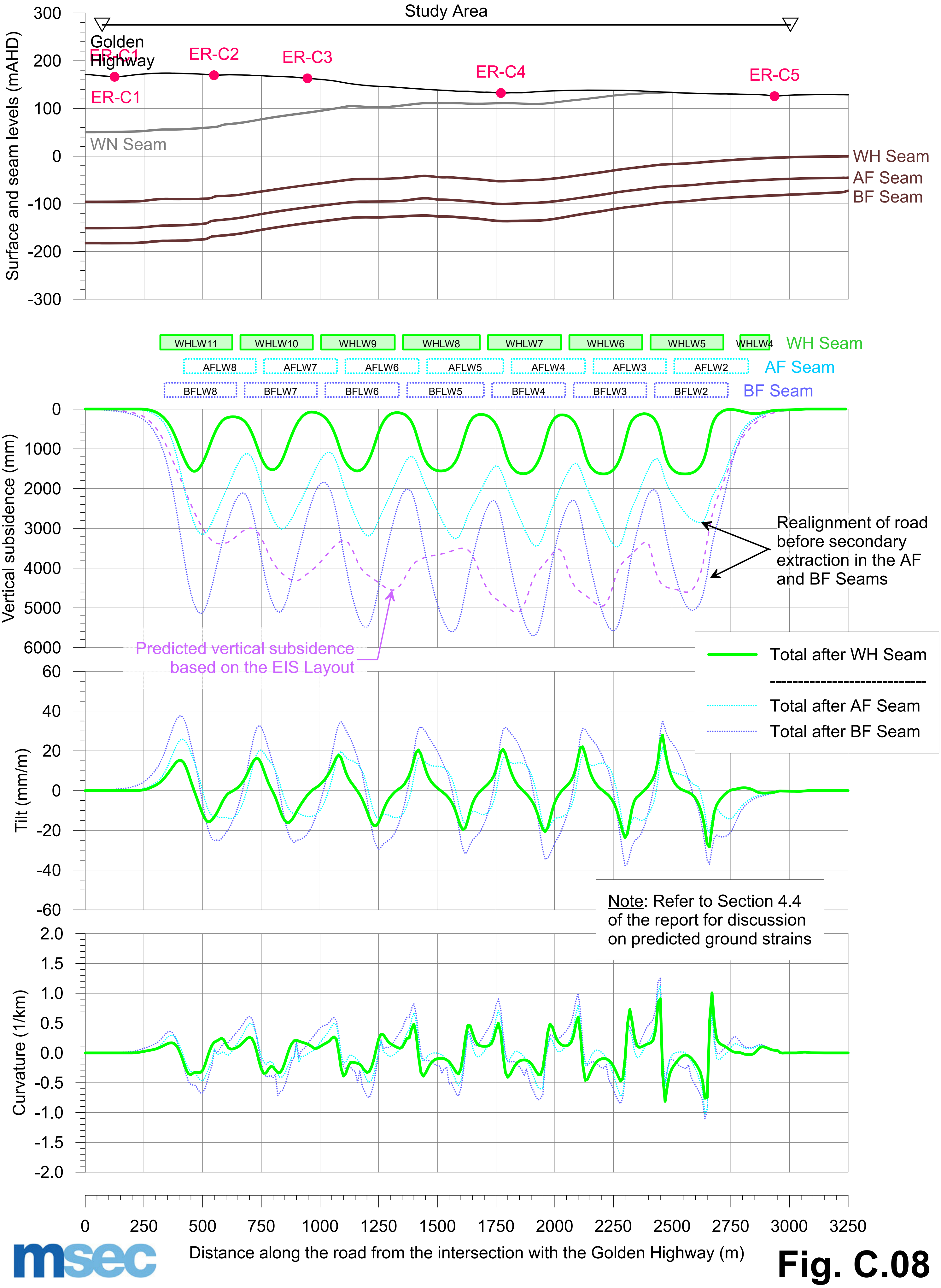


Fig. C.07

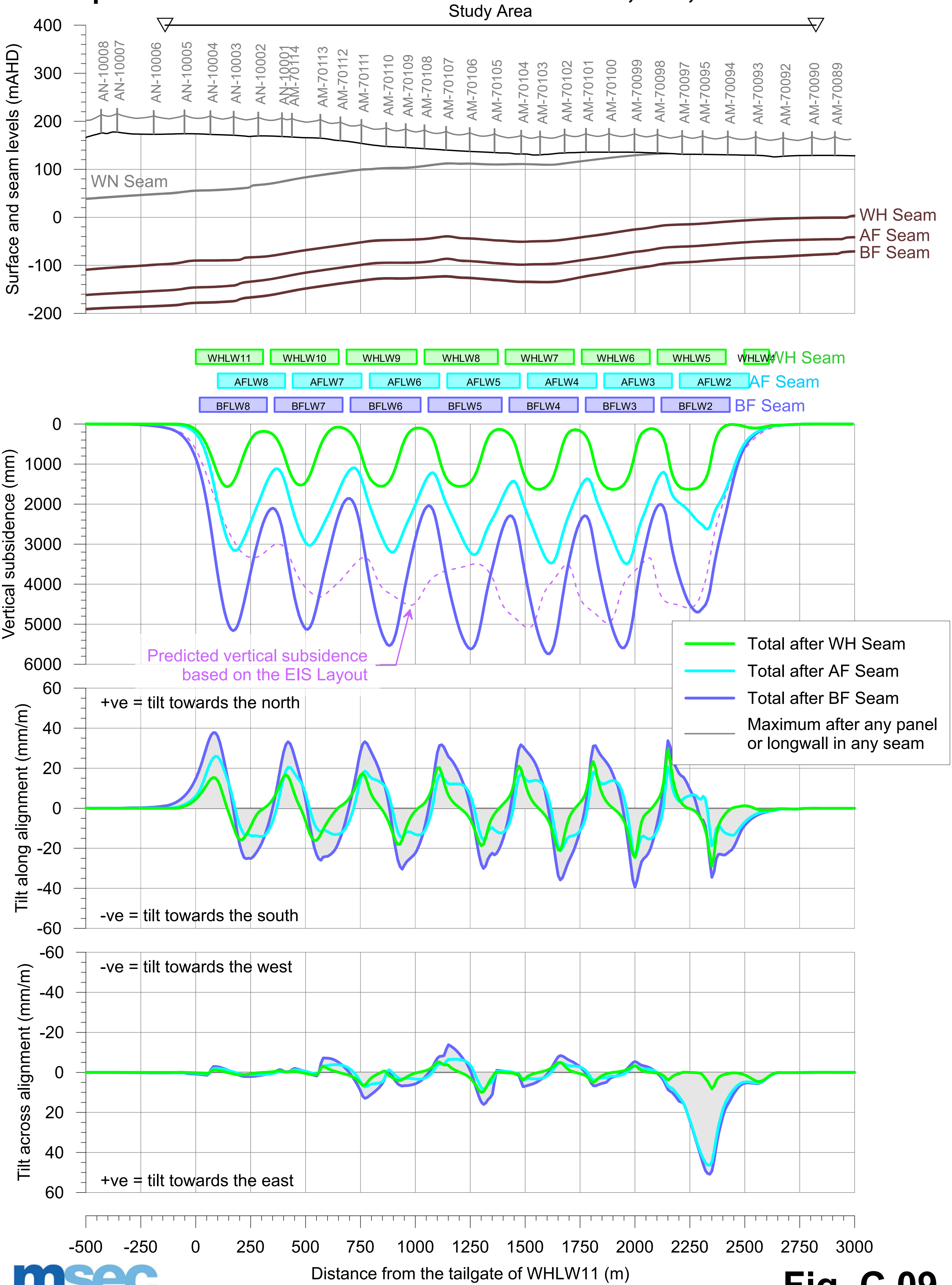
Predicted profiles of vertical subsidence, tilt and curvature along Edderton Road due to the extraction of the WN, WH, AF and BF Seams



msec

Fig. C.08

Predicted profiles of vertical subsidence, tilt along and tilt across the 11 kV powerline due to the extraction of the WN, WH, AF and BF Seams



msec

Fig. C.09

APPENDIX D. TABLES

Table D.01 - Details and maximum predicted subsidence effects for the Aboriginal heritage sites within the Study Area

AHIMS	Site type	Located within Study Area	Located above WN Seam mining area	Located above WH Seam mining area	Located above AF Seam mining area	Located above BF Seam mining area	Located outside of the mining areas	Maximum predicted total vertical subsidence after WN Seam (mm)	Maximum predicted total vertical subsidence after WH Seam (mm)	Maximum predicted total vertical subsidence after AF Seam (mm)	Maximum predicted total vertical subsidence after BF Seam (mm)	Maximum predicted total tilt after BF Seam (mm/m)	Maximum predicted total hogging curvature after BF Seam (1/km)	Maximum predicted total sagging curvature after BF Seam (1/km)
37-2-0004	Artefact Scatter	1		1	1	1		< 20	1650	3550	5700	50	2.00	2.00
37-2-0006	Artefact Scatter	1		1	1	1		< 20	1650	3550	5700	50	2.00	2.00
37-2-0053	Artefact Scatter	1		1	1	1		< 20	1650	3550	5700	50	2.00	2.00
37-2-0069	Artefact Scatter	1		1				< 20	300	325	325	11	0.35	0.01
37-2-0073	Artefact Scatter	1		1	1	1		< 20	1800	3450	5700	40	0.90	0.90
37-2-0074	Artefact Scatter	1		1	1	1		< 20	1650	2800	5050	35	0.70	0.45
37-2-0075	Artefact Scatter	1		1	1	1		< 20	1600	3350	5600	35	0.90	0.80
37-2-0076	Artefact Scatter	1		1	1	1		< 20	1650	3550	5700	50	2.00	2.00
37-2-0077	Artefact Scatter	1		1				< 20	1000	1000	1000	18	0.40	0.90
37-2-0078	Artefact Scatter	1	1	1				175	3000	3000	3000	20	0.50	1.10
37-2-0080	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-0082	Artefact Scatter	1	1	1				125	3100	3100	3100	20	0.25	0.40
37-2-0089	Artefact Scatter	1	1		1			100	200	400	400	5.5	0.11	0.16
37-2-0090	Artefact Scatter	1	1		1			100	200	400	400	5.5	0.11	0.16
37-2-0289	Artefact Scatter	1		1	1	1		< 20	1650	3550	5700	50	2.00	2.00
37-2-0362	Artefact Scatter	1		1	1	1		< 20	1650	3550	5700	50	2.00	2.00
37-2-0363	Artefact Scatter	1		1	1	1		< 20	1650	3550	5700	50	2.00	2.00
37-2-0364	Artefact Scatter	1		1	1	1		< 20	1650	3550	5700	50	2.00	2.00
37-2-0365	Artefact Scatter	1		1	1	1		< 20	1650	3550	5700	50	2.00	2.00
37-2-0366	Artefact Scatter	1		1	1	1		< 20	1650	3550	5700	50	2.00	2.00
37-2-0367	Artefact Scatter	1		1	1	1		< 20	1650	3500	5750	40	1.00	0.90
37-2-0368	Artefact Scatter	1		1	1	1		< 20	1650	3500	5750	40	1.00	0.90
37-2-0369	Artefact Scatter	1		1	1	1		< 20	1600	3350	5600	35	0.90	0.80
37-2-0370	Artefact Scatter	1		1	1	1		< 20	1600	3350	5600	35	0.90	0.80
37-2-0371	Artefact Scatter	1		1	1	1		< 20	1600	3300	5500	40	0.60	0.80
37-2-0372	Artefact Scatter	1		1	1	1		< 20	1600	3300	5500	40	0.60	0.80
37-2-0373	Artefact Scatter	1		1	1	1		< 20	1600	3300	5500	40	0.60	0.80
37-2-0374	Artefact Scatter	1		1	1	1		< 20	175	650	975	25	0.45	0.01
37-2-0375	Artefact Scatter	1		1	1	1		< 20	575	2800	4000	40	0.30	0.70
37-2-0376	Artefact Scatter	1		1	1	1		< 20	1600	3350	5600	35	0.90	0.80
37-2-0377	Artefact Scatter	1		1	1	1		< 20	275	2400	3650	25	0.60	0.04
37-2-0378	Artefact Scatter	1		1	1	1		< 20	1600	3350	5600	35	0.90	0.80
37-2-0379	Artefact Scatter	1		1	1	1		< 20	1600	3350	5600	35	0.90	0.80
37-2-0380	Artefact Scatter	1		1	1	1		< 20	1650	3500	5750	40	1.00	0.90
37-2-0381	Artefact Scatter	1		1	1	1		< 20	1650	3500	5750	40	1.00	0.90
37-2-0382	Artefact Scatter	1		1	1	1		< 20	1650	3500	5750	40	1.00	0.90
37-2-0383	Artefact Scatter	1		1	1	1		< 20	1650	3550	5700	50	2.00	2.00
37-2-0396	Artefact Scatter	1		1				< 20	300	325	325	11	0.35	0.01
37-2-0397	Artefact Scatter	1		1	1	1		< 20	1800	3450	5700	40	0.90	0.90
37-2-0398	Artefact Scatter	1		1	1	1		< 20	1550	3250	5550	25	< 0.01	0.80
37-2-0399	Artefact Scatter	1	1	1	1	1		175	2800	4600	6400	35	0.70	1.10
37-2-0400	Artefact Scatter	1	1	1	1	1		175	2800	4600	6400	35	0.70	1.10
37-2-0401	Artefact Scatter	1	1	1	1	1		175	2800	4600	6400	35	0.70	1.10
37-2-0402	Artefact Scatter	1	1	1	1	1		175	2800	4600	6400	35	0.70	1.10
37-2-0403	Artefact Scatter	1	1	1	1	1		175	2800	4600	6400	35	0.70	1.10
37-2-0404	Artefact Scatter	1	1	1	1	1		175	2800	4600	6400	35	0.70	1.10
37-2-0405	Artefact Scatter	1	1	1	1	1		175	2800	4600	6400	35	0.70	1.10
37-2-0406	Artefact Scatter	1	1	1	1	1		175	2800	4600	6400	35	0.70	1.10
37-2-0407	Artefact Scatter	1	1	1	1	1		175	2800	4600	6400	35	0.70	1.10
37-2-0408	Artefact Scatter	1		1	1	1		< 20	1600	3200	5150	20	0.20	0.50

Table D.01 - Details and maximum predicted subsidence effects for the Aboriginal heritage sites within the Study Area

AHIMS	Site type	Located within Study Area	Located above WN Seam mining area	Located above WH Seam mining area	Located above AF Seam mining area	Located above BF Seam mining area	Located outside of the mining areas	Maximum predicted total vertical subsidence after WN Seam (mm)	Maximum predicted total vertical subsidence after WH Seam (mm)	Maximum predicted total vertical subsidence after AF Seam (mm)	Maximum predicted total vertical subsidence after BF Seam (mm)	Maximum predicted total tilt after BF Seam (mm/m)	Maximum predicted total hogging curvature after BF Seam (1/km)	Maximum predicted total sagging curvature after BF Seam (1/km)
37-2-0409	Artefact Scatter	1	1	1				175	3000	3000	3000	20	0.50	1.10
37-2-0410	Artefact Scatter	1		1				< 20	950	950	950	14	0.25	0.80
37-2-0411	Artefact Scatter	1		1				< 20	700	700	700	20	0.45	0.12
37-2-0412	Artefact Scatter	1		1				< 20	700	700	700	20	0.45	0.12
37-2-0413	Artefact Scatter	1		1				< 20	1250	1250	1250	20	0.45	1.30
37-2-0414	Artefact Scatter	1		1				< 20	1250	1250	1250	20	0.45	1.30
37-2-0415	Artefact Scatter	1		1				< 20	1250	1250	1250	20	0.45	1.30
37-2-0416	Artefact Scatter	1	1	1				275	875	875	875	25	2.00	1.70
37-2-0417	Artefact Scatter	1		1				< 20	700	700	700	20	0.45	0.12
37-2-0418	Artefact Scatter with PAD	1	1	1				125	3300	3300	3300	25	0.50	0.70
37-2-0419	Artefact Scatter with PAD	1	1	1				125	3300	3300	3300	25	0.50	0.70
37-2-0505	Artefact Scatter	1		1	1	1		< 20	1650	3550	5700	50	2.00	2.00
37-2-1923	Artefact Scatter	1		1	1	1		< 20	1500	3150	5000	25	0.40	0.50
37-2-1928	Artefact Scatter	1	1	1	1	1		175	2800	4600	6400	35	0.70	1.10
37-2-1929	Artefact Scatter	1		1	1	1		< 20	1450	2850	4650	25	0.35	0.45
37-2-1930	Artefact Scatter	1		1	1	1		< 20	1550	3250	5400	30	0.50	0.60
37-2-1931	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-1932	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-1933	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-1934	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-1935	Artefact Scatter	1		1				< 20	1250	1250	1250	20	0.45	1.30
37-2-1936	Artefact Scatter	1		1	1	1		< 20	1800	3450	5700	40	0.90	0.90
37-2-1937	Artefact Scatter	1		1				< 20	1250	1250	1250	20	0.45	1.30
37-2-1938	Artefact Scatter	1		1				< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-1939	Artefact Scatter	1					1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-1940	Artefact Scatter	1	1	1	1			125	3000	3000	3000	35	0.50	0.80
37-2-1941	Artefact Scatter	1		1	1	1		< 20	1500	3200	5250	30	0.45	0.50
37-2-1942	Artefact Scatter	1	1	1	1			80	2250	3350	3350	20	0.30	0.10
37-2-1943	Artefact Scatter	1	1	1	1	1		175	2800	4600	6400	35	0.70	1.10
37-2-1946	Artefact Scatter	1		1				< 20	1250	1250	1250	20	0.45	1.30
37-2-1947	Artefact Scatter	1		1				< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-1954	Stone Quarry	1					1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-1955	Stone Quarry	1					1	< 20	50	50	50	1	0.02	< 0.01
37-2-1956	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-1957	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-1960	Artefact Scatter	1		1	1	1		< 20	1500	3150	5000	25	0.40	0.50
37-2-1961	Artefact Scatter	1		1	1	1		< 20	650	2300	3400	16	0.40	0.01
37-2-1986	Artefact Scatter	1		1				< 20	950	950	950	14	0.25	0.80
37-2-2035	Artefact Scatter	1		1	1	1		< 20	650	2300	3400	16	0.40	0.01
37-2-2329	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-2330	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4226	Artefact Scatter	1		1	1	1		< 20	125	225	375	9.5	0.40	0.01
37-2-4227	Artefact Scatter	1		1	1	1		< 20	225	425	675	20	1.00	0.07
37-2-4228	Artefact Scatter							< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4234	Artefact Scatter	1		1	1	1		< 20	1300	1750	2600	35	1.10	0.70
37-2-4235	Artefact Scatter	1		1	1	1		< 20	900	3150	4850	35	0.60	0.50
37-2-4236	Artefact Scatter	1		1	1	1		< 20	1400	3350	5700	35	0.45	0.90
37-2-4237	Artefact Scatter							< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4239	Artefact Scatter	1		1	1	1		< 20	1600	3250	5400	30	0.25	0.80
37-2-4240	Artefact Scatter	1		1	1	1		< 20	1000	1950	3100	35	0.90	0.02

Table D.01 - Details and maximum predicted subsidence effects for the Aboriginal heritage sites within the Study Area

AHIMS	Site type	Located within Study Area	Located above WN Seam mining area	Located above WH Seam mining area	Located above AF Seam mining area	Located above BF Seam mining area	Located outside of the mining areas	Maximum predicted total vertical subsidence after WN Seam (mm)	Maximum predicted total vertical subsidence after WH Seam (mm)	Maximum predicted total vertical subsidence after AF Seam (mm)	Maximum predicted total vertical subsidence after BF Seam (mm)	Maximum predicted total tilt after BF Seam (mm/m)	Maximum predicted total hogging curvature after BF Seam (1/km)	Maximum predicted total sagging curvature after BF Seam (1/km)
37-2-4241	Artefact Scatter	1		1	1	1		< 20	1050	1150	2650	25	0.70	0.90
37-2-4242	Artefact Scatter	1			1			< 20	40	70	275	8	0.25	< 0.01
37-2-4243	Artefact Scatter	1		1	1	1		< 20	475	2550	3450	40	0.60	0.80
37-2-4245	Artefact Scatter	1					1	< 20	50	70	70	4	0.12	0.06
37-2-4246	Artefact Scatter	1		1	1	1		< 20	900	2700	4700	25	0.50	0.50
37-2-4247	Artefact Scatter	1	1	1	1	1		250	2400	4300	5350	30	1.00	1.40
37-2-4248	Artefact Scatter	1	1	1	1	1		275	2500	3950	5750	40	0.90	1.50
37-2-4249	Artefact Scatter	1	1	1	1	1		30	2450	3900	5800	25	0.01	0.70
37-2-4250	Artefact Scatter	1	1	1	1	1		175	2700	3750	5450	35	0.60	1.20
37-2-4251	Artefact Scatter	1	1	1	1	1		175	2700	3750	5450	35	0.60	1.20
37-2-4252	Artefact Scatter	1		1	1	1		< 20	1600	3300	5600	30	0.14	0.80
37-2-4253	Artefact Scatter	1		1	1	1		< 20	1550	2700	4950	35	0.70	0.40
37-2-4254	Artefact Scatter	1		1	1	1		< 20	1550	3250	5300	35	0.25	0.60
37-2-4255	Artefact Scatter	1		1	1	1		< 20	625	2600	3850	18	0.25	0.25
37-2-4256	Artefact Scatter	1		1	1	1		< 20	1550	3050	4950	30	0.50	0.50
37-2-4257	Artefact Scatter	1		1	1	1		< 20	1350	2900	4800	20	0.11	0.50
37-2-4258	Artefact Scatter	1		1		1		< 20	1150	1850	3550	35	0.30	0.11
37-2-4259	Artefact Scatter	1		1		1		< 20	1100	1800	3450	40	0.35	0.01
37-2-4260	Artefact Scatter	1		1	1	1		< 20	1500	3200	5250	30	0.45	0.50
37-2-4262	Artefact Scatter	1					1	< 20	20	90	125	2	0.04	< 0.01
37-2-4264	Artefact Scatter	1	1	1	1			100	2800	3450	3450	35	0.25	0.45
37-2-4265	Artefact Scatter	1	1	1	1	1		125	2500	4350	6150	30	0.14	0.70
37-2-4266	Artefact Scatter	1		1	1	1		< 20	1600	3050	4900	25	0.45	0.50
37-2-4267	Artefact Scatter	1	1	1	1			70	2550	3550	3550	20	0.35	0.40
37-2-4268	Artefact Scatter	1	1	1				70	2700	2850	2850	18	0.35	0.40
37-2-4269	Artefact Scatter	1	1	1	1			90	2450	3400	3400	25	0.30	0.30
37-2-4270	Artefact Scatter	1	1	1				80	2650	2950	2950	16	0.10	0.45
37-2-4271	Artefact Scatter	1	1	1				90	1900	1900	1900	19	0.35	0.20
37-2-4272	Artefact Scatter	1	1	1				90	3000	3000	3000	18	0.06	0.70
37-2-4274	Artefact Scatter	1	1	1	1			125	2700	4550	4550	20	0.20	0.60
37-2-4275	Artefact Scatter	1	1	1	1			125	2700	4450	4550	30	0.40	0.70
37-2-4276	Artefact Scatter	1	1	1	1			80	2600	2850	2850	18	0.35	0.45
37-2-4277	Artefact Scatter	1		1				< 20	500	525	525	11	0.25	< 0.01
37-2-4278	Artefact Scatter	1	1	1				200	2900	2900	2900	20	0.45	1.30
37-2-4279	Artefact Scatter	1	1	1				70	2550	2600	2600	17	0.25	0.30
37-2-4280	Artefact Scatter	1	1	1				250	2800	2800	2800	30	0.60	1.40
37-2-4281	Artefact Scatter	1		1	1			< 20	650	2100	2100	35	0.80	0.60
37-2-4282	Artefact Scatter	1		1	1			< 20	875	975	975	12	0.30	0.60
37-2-4283	Artefact Scatter	1		1				< 20	875	875	875	11	0.45	0.60
37-2-4284	Artefact Scatter	1		1				< 20	975	975	975	16	0.30	0.90
37-2-4285	Artefact Scatter	1		1				< 20	950	950	950	14	0.35	0.90
37-2-4286	Artefact Scatter	1		1				< 20	1100	1100	1100	9.5	0.30	0.60
37-2-4287	Artefact Scatter	1	1	1				275	2850	2850	2850	25	1.30	1.40
37-2-4288	Artefact Scatter	1	1	1				325	3150	3150	3150	50	1.40	1.80
37-2-4289	Artefact Scatter	1					1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4290	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4291	Artefact Scatter	1		1				< 20	30	30	30	1	0.03	0.02
37-2-4292	Artefact Scatter	1		1				< 20	750	750	750	20	0.40	< 0.01
37-2-4293	Artefact Scatter	1		1				< 20	100	100	100	4.5	0.20	0.02
37-2-4294	Artefact Scatter	1		1				< 20	275	275	275	10	0.25	0.17

Table D.01 - Details and maximum predicted subsidence effects for the Aboriginal heritage sites within the Study Area

AHIMS	Site type	Located within Study Area	Located above WN Seam mining area	Located above WH Seam mining area	Located above AF Seam mining area	Located above BF Seam mining area	Located outside of the mining areas	Maximum predicted total vertical subsidence after WN Seam (mm)	Maximum predicted total vertical subsidence after WH Seam (mm)	Maximum predicted total vertical subsidence after AF Seam (mm)	Maximum predicted total vertical subsidence after BF Seam (mm)	Maximum predicted total tilt after BF Seam (mm/m)	Maximum predicted total hogging curvature after BF Seam (1/km)	Maximum predicted total sagging curvature after BF Seam (1/km)
37-2-4296	Artefact Scatter	1		1				< 20	800	800	800	10	0.15	0.50
37-2-4297	Artefact Scatter	1	1					125	150	150	150	20	2.00	0.45
37-2-4298	Artefact Scatter	1		1				< 20	1050	1050	1050	10	0.14	0.35
37-2-4299	Artefact Scatter	1	1	1				175	1050	1050	1050	12	0.35	0.50
37-2-4300	Artefact Scatter	1					1	< 20	90	90	90	2	0.06	< 0.01
37-2-4301	Artefact Scatter	1	1	1				125	550	550	550	17	0.50	0.35
37-2-4302	Artefact Scatter	1	1	1				200	200	200	200	7.5	0.30	1.00
37-2-4303	Artefact Scatter	1					1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4307	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4310	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4311	Artefact Scatter	1		1				< 20	150	150	150	3.5	0.07	< 0.01
37-2-4312	Artefact Scatter	1	1	1				175	2150	2150	2150	25	0.30	0.80
37-2-4313	Artefact Scatter	1		1				< 20	325	325	325	10	0.25	0.02
37-2-4317	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4318	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4327	Isolated Find							< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4328	Isolated Find						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4329	Isolated Find	1		1	1	1		< 20	40	1700	2300	30	0.50	0.05
37-2-4330	Isolated Find	1		1	1	1		< 20	250	2000	2450	40	0.70	0.25
37-2-4331	Isolated Find	1					1	< 20	< 20	20	60	1	0.03	< 0.01
37-2-4332	Isolated Find	1					1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4333	Isolated Find	1		1	1	1		< 20	325	2550	3900	30	0.60	0.04
37-2-4334	Isolated Find	1		1	1	1		< 20	525	2600	3350	40	0.50	< 0.01
37-2-4335	Isolated Find	1	1	1	1	1		150	2100	3300	5450	35	0.70	0.50
37-2-4336	Isolated Find	1	1	1	1	1		100	2650	4150	6150	30	0.45	0.50
37-2-4337	Isolated Find	1		1	1	1		< 20	1550	2600	4800	35	0.70	0.30
37-2-4338	Isolated Find	1		1	1	1		< 20	850	1850	2950	25	0.50	< 0.01
37-2-4339	Isolated Find	1		1	1	1		< 20	1400	3100	4950	25	0.25	0.60
37-2-4340	Isolated Find	1		1	1	1		< 20	1400	2600	4150	30	0.25	0.50
37-2-4341	Isolated Find	1		1	1	1		< 20	475	2500	3650	18	0.45	< 0.01
37-2-4342	Isolated Find	1		1	1	1		< 20	1350	2700	4450	20	0.40	0.45
37-2-4343	Isolated Find	1					1	< 20	150	275	675	12	0.19	< 0.01
37-2-4344	Isolated Find	1	1	1	1	1		40	2450	4150	5450	20	< 0.01	0.45
37-2-4345	Isolated Find	1	1	1	1	1		< 20	1100	2600	3400	18	0.40	0.03
37-2-4346	Isolated Find	1		1	1	1		< 20	1650	3300	5250	25	0.40	0.45
37-2-4347	Isolated Find	1	1	1	1			70	2650	3050	3050	18	0.20	0.45
37-2-4348	Isolated Find	1	1	1				70	2700	2850	2850	18	0.02	0.40
37-2-4349	Isolated Find	1	1	1				70	2700	2850	2850	11	0.07	0.40
37-2-4350	Isolated Find	1	1	1				100	2400	2400	2400	20	0.35	0.16
37-2-4351	Isolated Find	1	1	1				175	3100	3100	3100	19	0.50	0.90
37-2-4352	Isolated Find	1	1	1	1			125	2700	2950	2950	19	0.25	0.50
37-2-4353	Isolated Find	1	1	1				150	2850	2850	2850	20	0.18	0.80
37-2-4354	Isolated Find	1	1	1				125	1500	1500	1500	19	0.40	0.40
37-2-4355	Isolated Find	1		1				< 20	650	650	650	9.5	0.30	< 0.01
37-2-4356	Isolated Find	1		1				< 20	675	675	675	16	0.30	0.30
37-2-4357	Isolated Find	1	1					200	200	200	200	8	0.35	0.90
37-2-4358	Isolated Find	1		1				< 20	525	525	525	9	0.14	0.05
37-2-4359	Isolated Find						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4361	Isolated Find						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4362	Isolated Find						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01

Table D.01 - Details and maximum predicted subsidence effects for the Aboriginal heritage sites within the Study Area

AHIMS	Site type	Located within Study Area	Located above WN Seam mining area	Located above WH Seam mining area	Located above AF Seam mining area	Located above BF Seam mining area	Located outside of the mining areas	Maximum predicted total vertical subsidence after WN Seam (mm)	Maximum predicted total vertical subsidence after WH Seam (mm)	Maximum predicted total vertical subsidence after AF Seam (mm)	Maximum predicted total vertical subsidence after BF Seam (mm)	Maximum predicted total tilt after BF Seam (mm/m)	Maximum predicted total hogging curvature after BF Seam (1/km)	Maximum predicted total sagging curvature after BF Seam (1/km)
37-2-4364	Isolated Find	1		1				< 20	550	550	550	6.5	0.08	0.25
37-2-4367	Isolated Find						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4370	Isolated Find						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4371	Isolated Find	1	1	1				80	2850	2850	2850	20	0.25	0.35
37-2-4372	Isolated Find	1	1	1				80	1800	1800	1800	30	0.50	0.50
37-2-4373	Isolated Find	1	1	1	1			125	2000	2100	2100	35	0.70	0.50
37-2-4376	Isolated Find						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4377	Isolated Find						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4378	Isolated Find						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4379	Isolated Find						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-4426	Isolated Find	1		1				< 20	975	975	975	20	0.40	0.30
37-2-4427	Artefact Scatter	1		1				< 20	1200	1200	1200	20	0.40	1.00
37-2-4428	Isolated Find	1		1	1	1		< 20	925	950	2700	5	0.20	0.80
37-2-4432	Artefact Scatter	1	1	1	1	1		175	2700	3750	5450	35	0.60	1.20
37-2-4512	Artefact Scatter	1					1	< 20	50	50	50	1.5	0.05	< 0.01
37-2-4536	Isolated Find	1		1				< 20	1150	1150	1150	20	0.40	0.90
37-2-4537	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5002	Artefact Scatter	1			1			< 20	80	2500	2550	15	0.14	0.25
37-2-5003	Artefact Scatter	1		1	1			< 20	825	1900	1900	17	0.30	0.20
37-2-5004	Artefact Scatter	1		1	1			< 20	825	3000	3050	14	0.25	0.13
37-2-5005	Artefact Scatter	1		1	1	1		< 20	1100	2300	2750	17	0.30	0.03
37-2-5006	Artefact Scatter	1		1	1	1		< 20	1650	3200	4800	20	0.13	0.35
37-2-5007	Artefact Scatter	1	1	1	1	1		175	2800	4600	6400	35	0.70	1.10
37-2-5008	Artefact Scatter	1		1	1			< 20	250	1800	1950	14	0.25	0.18
37-2-5014	Artefact Scatter	1					1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5016	Isolated Find						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5022	Isolated Find						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5023	Isolated Find	1					1	< 20	< 20	175	175	3	0.04	0.02
37-2-5024	Isolated Find	1		1	1			< 20	1150	2200	2200	17	0.35	< 0.01
37-2-5035	Isolated Find	1		1	1	1		< 20	675	2650	3900	20	0.45	< 0.01
37-2-5036	Isolated Find	1		1	1	1		< 20	1550	2900	4650	25	0.40	0.40
37-2-5043	Artefact Scatter	1	1	1	1			70	2700	4350	4350	20	0.35	0.40
37-2-5469	Artefact Scatter	1		1	1	1		< 20	1600	3300	5500	40	0.60	0.80
37-2-5470	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5787	Isolated Artefact	1					1	< 20	< 20	50	125	2	0.04	< 0.01
37-2-5840	Artefact Scatter	1					1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5841	Artefact Scatter	1					1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5842	Artefact Scatter	1					1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5843	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5844	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5845	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5846	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5847	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5848	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5849	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5850	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5851	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5852	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5853	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5854	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01

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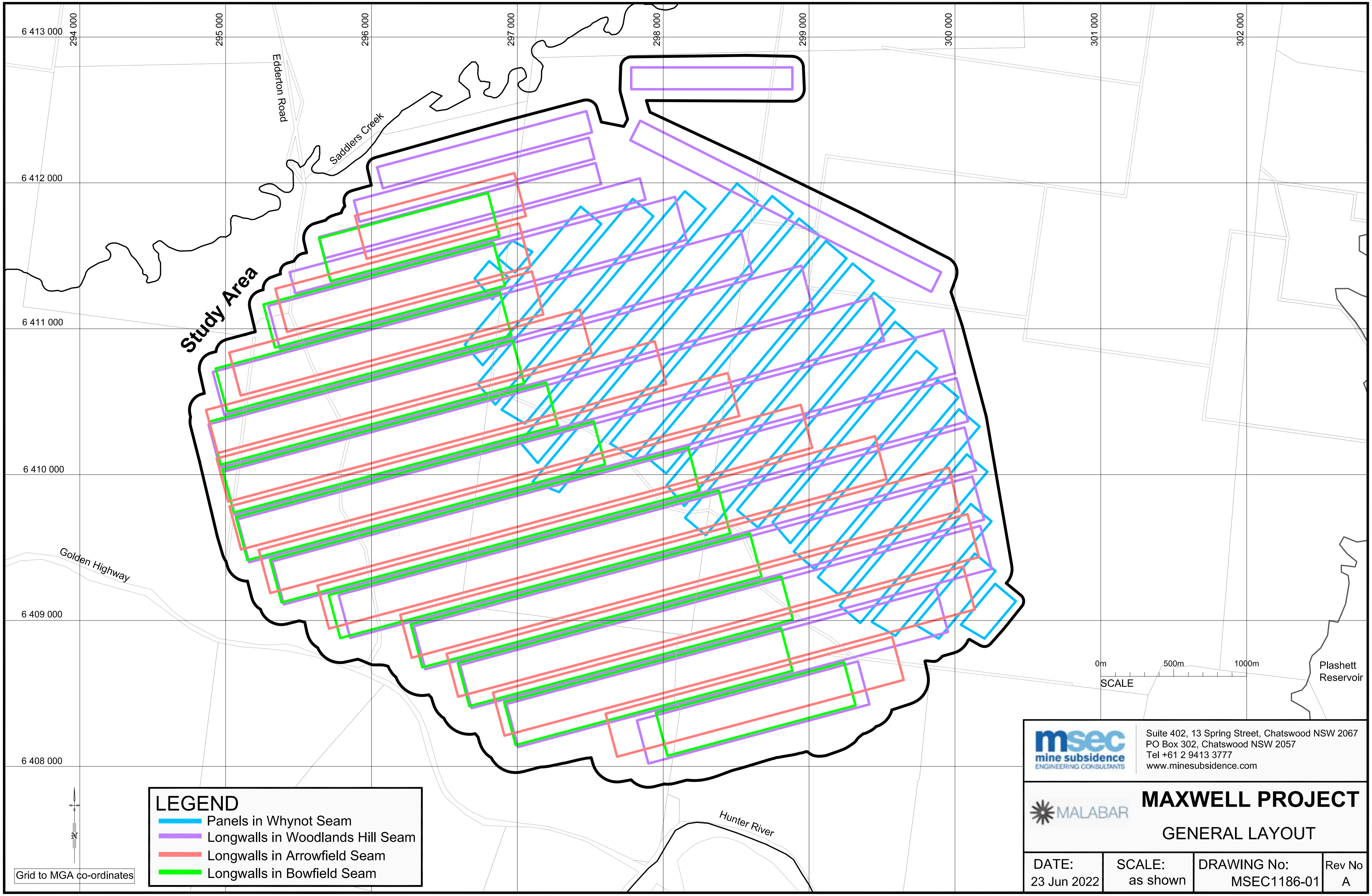
AHIMS	Site type	Located within Study Area	Located above WN Seam mining area	Located above WH Seam mining area	Located above AF Seam mining area	Located above BF Seam mining area	Located outside of the mining areas	Maximum predicted total vertical subsidence after WN Seam (mm)	Maximum predicted total vertical subsidence after WH Seam (mm)	Maximum predicted total vertical subsidence after AF Seam (mm)	Maximum predicted total vertical subsidence after BF Seam (mm)	Maximum predicted total tilt after BF Seam (mm/m)	Maximum predicted total hogging curvature after BF Seam (1/km)	Maximum predicted total sagging curvature after BF Seam (1/km)
37-2-5861	Isolated Artefact	1			1			< 20	20	200	300	6	0.15	< 0.01
37-2-5862	Artefact Scatter	1	1	1	1			80	2500	4450	4450	20	0.40	0.45
37-2-5863	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5864	Artefact Scatter	1	1	1	1			70	2600	4400	4400	19	0.04	0.35
37-2-5865	Artefact Scatter	1	1	1	1			70	2650	4350	4350	20	0.30	0.40
37-2-5866	Artefact Scatter	1	1	1	1			60	1900	3950	4000	17	0.35	0.25
37-2-5867	Artefact Scatter	1	1	1	1			80	2500	3850	3850	18	0.40	0.13
37-2-5868	Isolated Artefact	1	1	1	1			80	1400	3750	3750	17	0.35	0.08
37-2-5869	Artefact Scatter	1		1	1			< 20	1850	3400	3450	17	0.30	0.35
37-2-5870	Artefact Scatter	1	1	1	1			70	2600	4000	4000	16	0.35	0.25
37-2-5871	Artefact Scatter	1		1	1	1		< 20	1650	3200	4150	20	0.40	0.40
37-2-5872	Artefact Scatter	1		1	1	1		< 20	1500	3350	5350	20	0.07	0.60
37-2-5873	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5874	Artefact Scatter	1		1	1	1		< 20	1550	3350	5400	35	0.50	0.60
37-2-5875	Artefact Scatter	1		1	1	1		< 20	1600	3200	5200	20	0.04	0.50
37-2-5876	Artefact Scatter	1		1	1	1		< 20	1450	3150	5100	30	0.45	0.60
37-2-5877	Artefact Scatter	1		1	1			< 20	250	2450	2650	7.5	0.25	0.16
37-2-5878	Artefact Scatter	1					1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5879	Artefact Scatter	1					1	< 20	< 20	< 20	60	1	0.05	< 0.01
37-2-5880	Artefact Scatter	1					1	< 20	< 20	125	225	3.5	0.04	< 0.01
37-2-5881	Artefact Scatter	1		1	1	1		< 20	1500	3100	5250	35	0.40	0.60
37-2-5882	Artefact Scatter	1					1	< 20	< 20	30	50	1.5	0.02	< 0.01
37-2-5883	Artefact							< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5884	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5885	Artefact Scatter	1					1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5886	Isolated Artefact	1	1	1	1			60	1550	3050	3050	20	0.25	0.16
37-2-5887	Isolated Artefact	1	1	1	1			70	2100	3050	3050	16	0.35	0.03
37-2-5888	Isolated Artefact	1		1	1	1		< 20	1450	3000	4450	25	< 0.01	0.35
37-2-5889	Isolated Artefact	1					1	< 20	40	80	250	4.5	0.07	< 0.01
37-2-5890	Isolated Artefact	1		1	1	1		< 20	1600	3250	5200	25	0.05	0.50
37-2-5891	Isolated Artefact	1					1	< 20	30	70	200	4	0.07	< 0.01
37-2-5892	Isolated Artefact	1		1	1	1		< 20	1450	2350	4250	40	0.35	0.35
37-2-5893	Isolated Artefact	1		1	1	1		< 20	550	2900	4500	20	0.35	0.04
37-2-5894	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
37-2-5895	Isolated Artefact	1					1	< 20	< 20	< 20	20	0.5	< 0.01	< 0.01
37-2-5896	Isolated Artefact	1		1	1	1		< 20	1350	2300	3950	35	0.25	0.45
37-2-5897	Isolated Artefact	1		1	1	1		< 20	275	900	1350	25	0.30	0.06
37-2-5898	Artefact Scatter						1	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
							Maximum	**325**	**3300**	**4600**	**6400**	**50**	**2.00**	**2.00**

APPENDIX E.   DRAWINGS

I:\Projects\Maxwell Project\MSEC1186 - Modified Longwall Layout\AcadData\MSEC1186-01 General Layout.dwg



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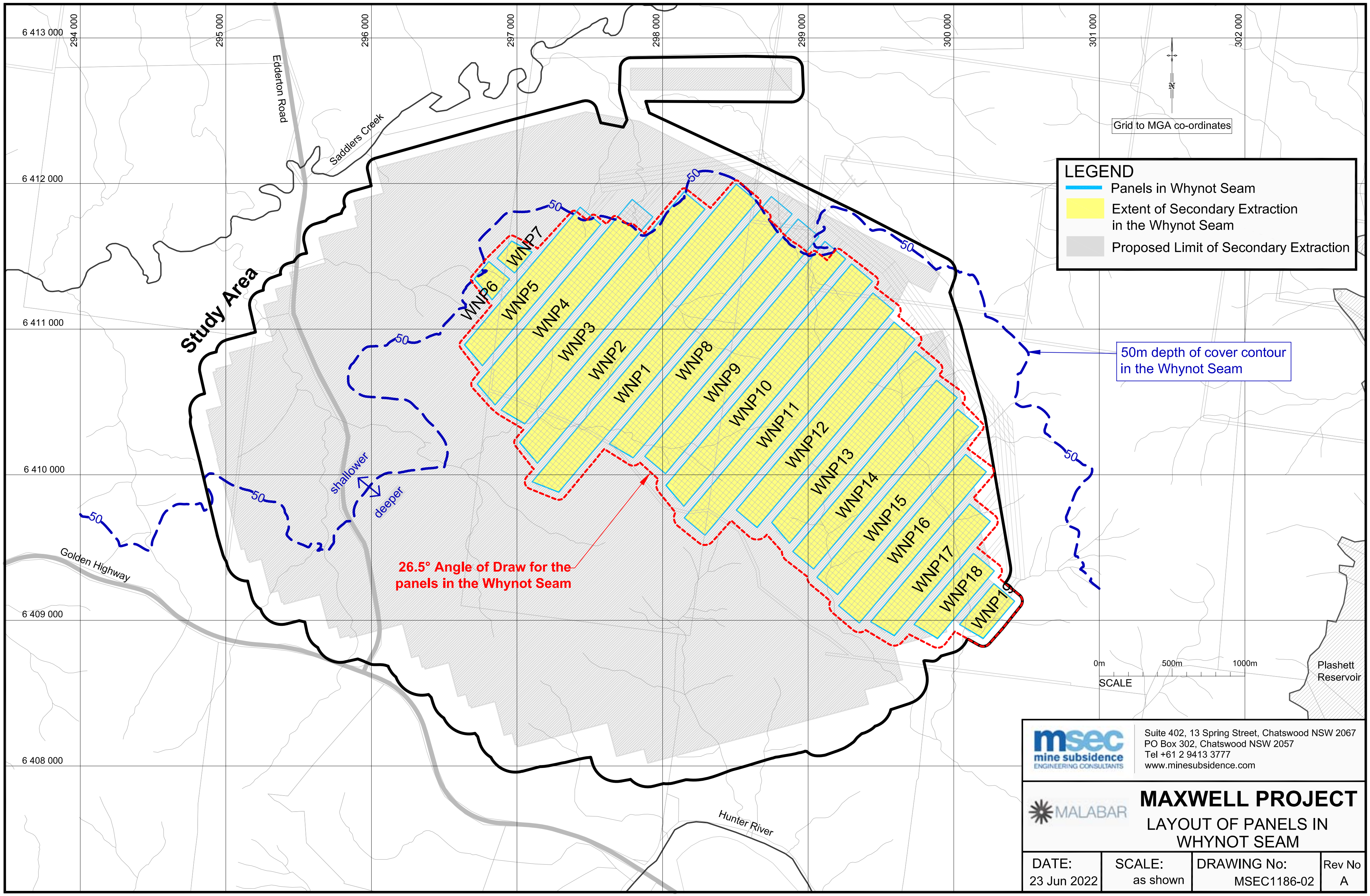
MAXWELL PROJECT

GENERAL LAYOUT

DATE:	SCALE:	DRAWING No:	Rev No
23 Jun 2022	as shown	MSEC1186-01	A

I:\Projects\Maxwell Project\MSEC1186 - Modified Longwall Layout\AcadData\MSEC1186-02 Panels in Whynot Seam.dwg



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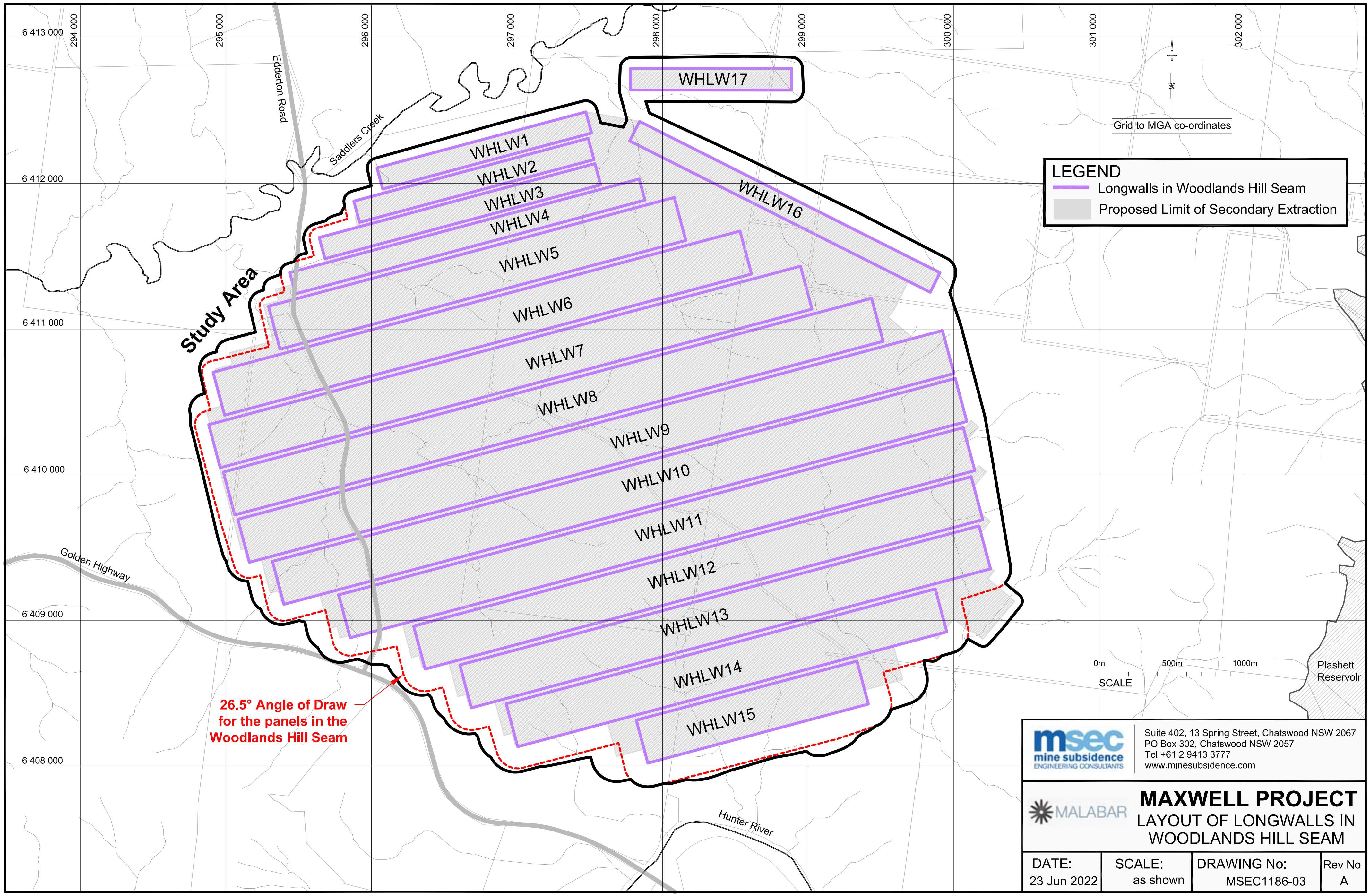
MAXWELL PROJECT

LAYOUT OF PANELS IN WHYNOT SEAM

DATE:	SCALE:	DRAWING No:	Rev No
23 Jun 2022	as shown	MSEC1186-02	A

I:\Projects\Maxwell Project\MSEC1186 - Modified Longwall Layout\AcadData\MSEC1186-03 Longwalls in Woodlands Hill Seam.dwg



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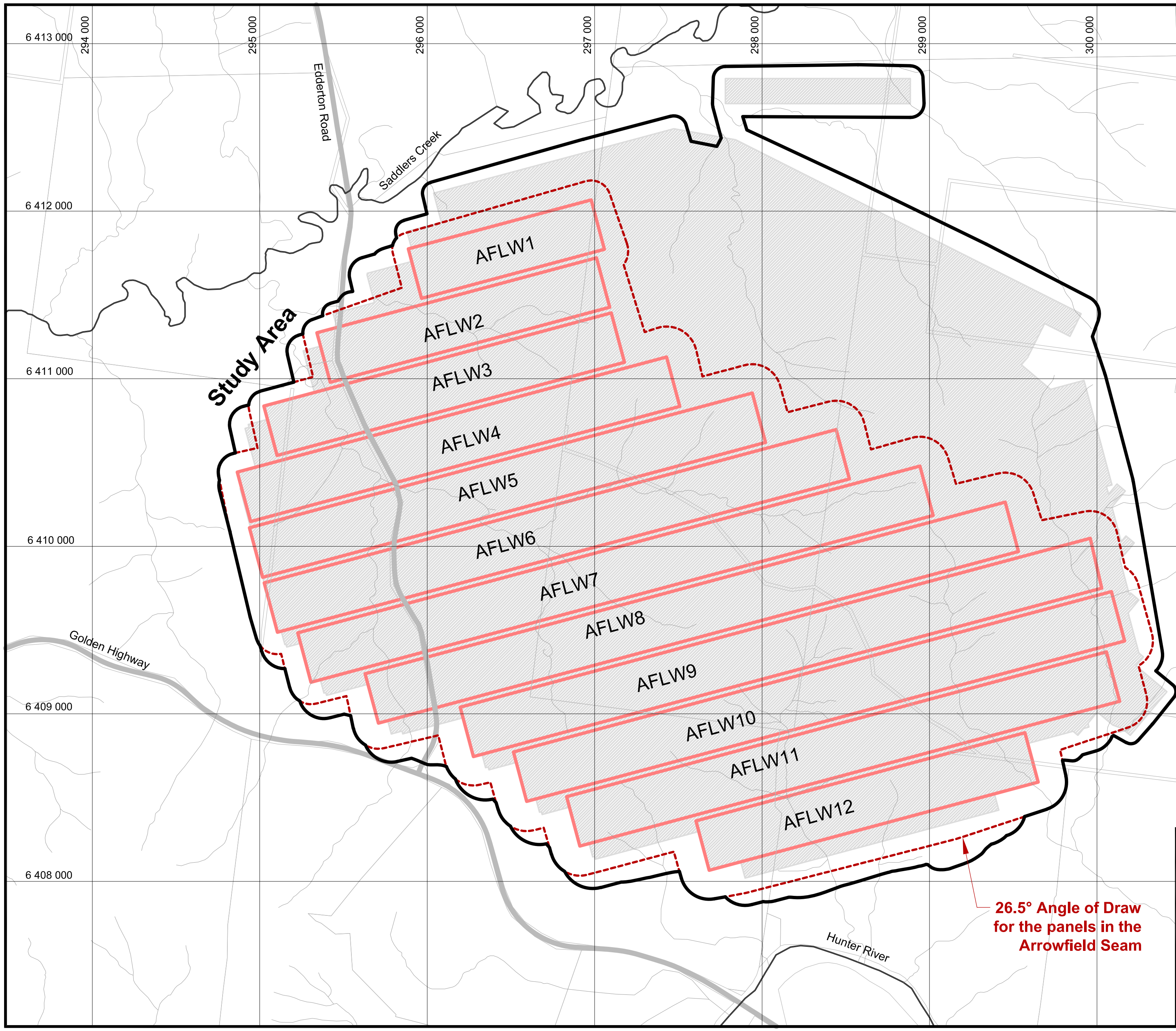
MAXWELL PROJECT
LAYOUT OF LONGWALLS IN WOODLANDS HILL SEAM

DATE:	SCALE:	DRAWING No:	Rev No
23 Jun 2022	as shown	MSEC1186-03	A

I:\Projects\Maxwell Project\MSEC1186 - Modified Longwall Layout\AcadData\MSEC1186-04 Longwalls in Arrowfield Seam.dwg



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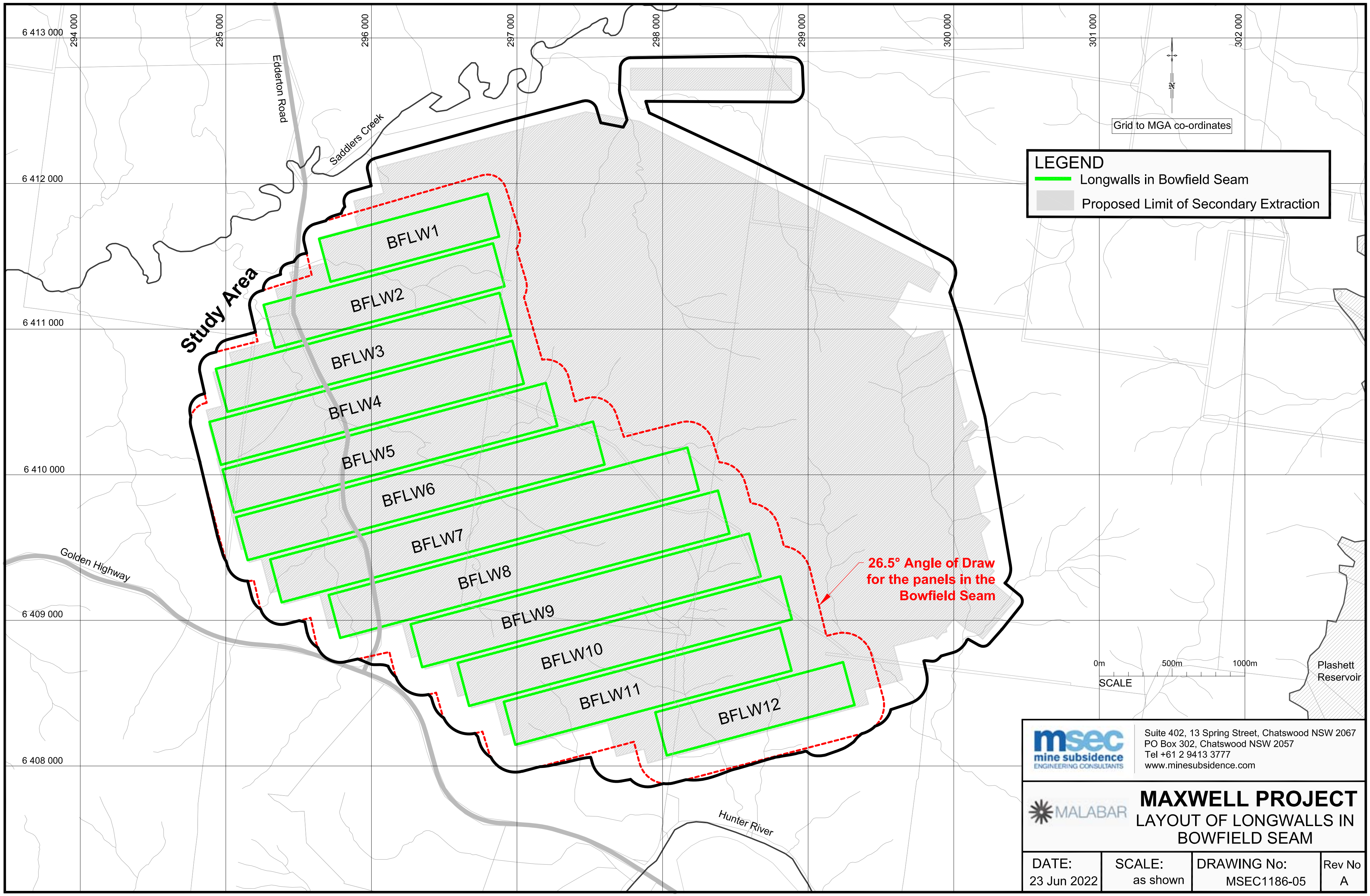
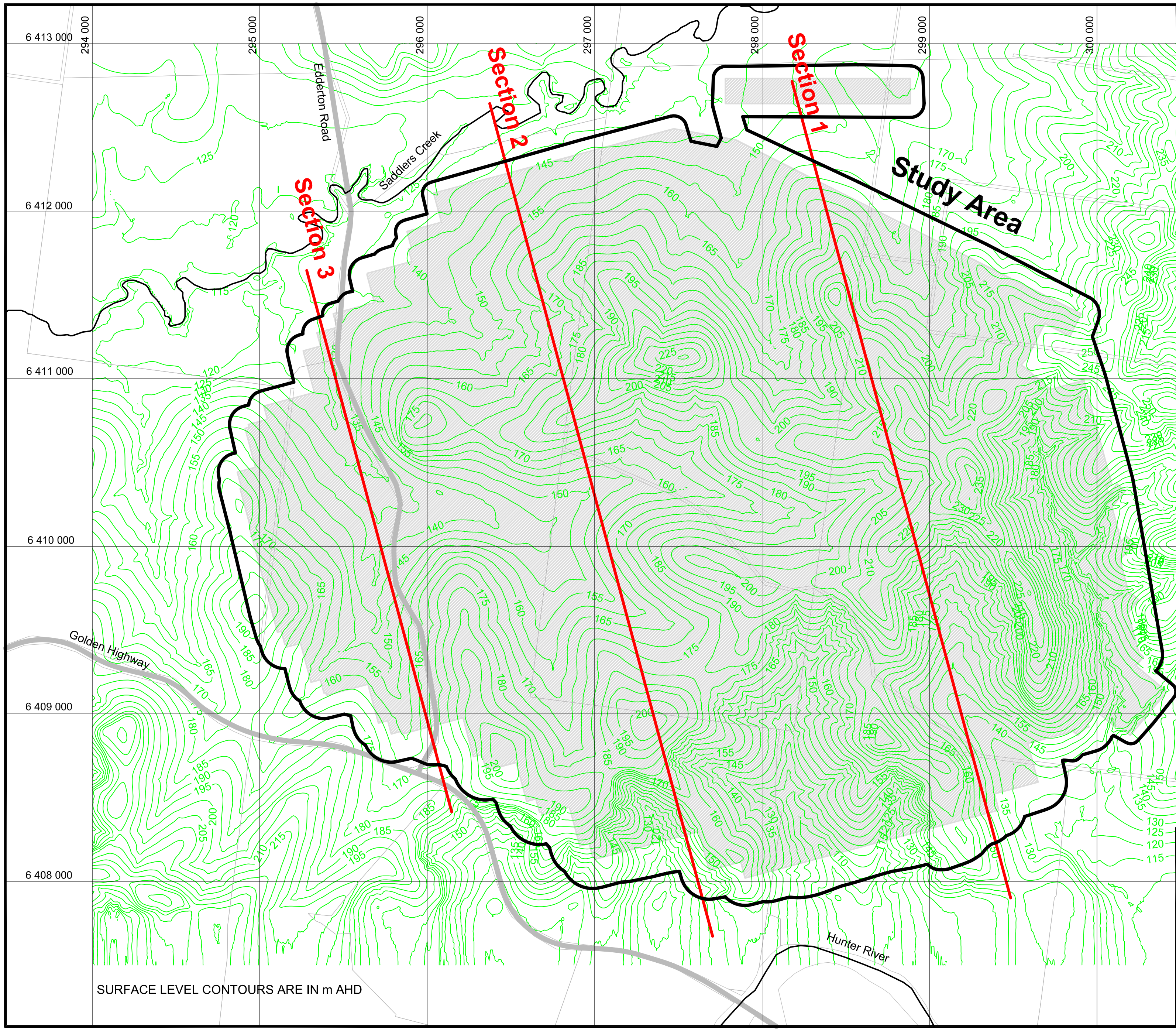
MAXWELL PROJECT
LAYOUT OF LONGWALLS IN ARROWFIELD SEAM

DATE:	SCALE:	DRAWING No:	Rev No
23 Jun 2022	as shown	MSEC1186-04	A

I:\Projects\Maxwell Project\MSEC1186 - Modified Longwall Layout\AcadData\MSEC1186-05 Longwalls in Bowfield Seam.dwg



I:\Projects\Maxwell Project\MSEC1186 - Modified Longwall Layout\AcadData\MSEC1186-06 Surface Level Contours.dwg



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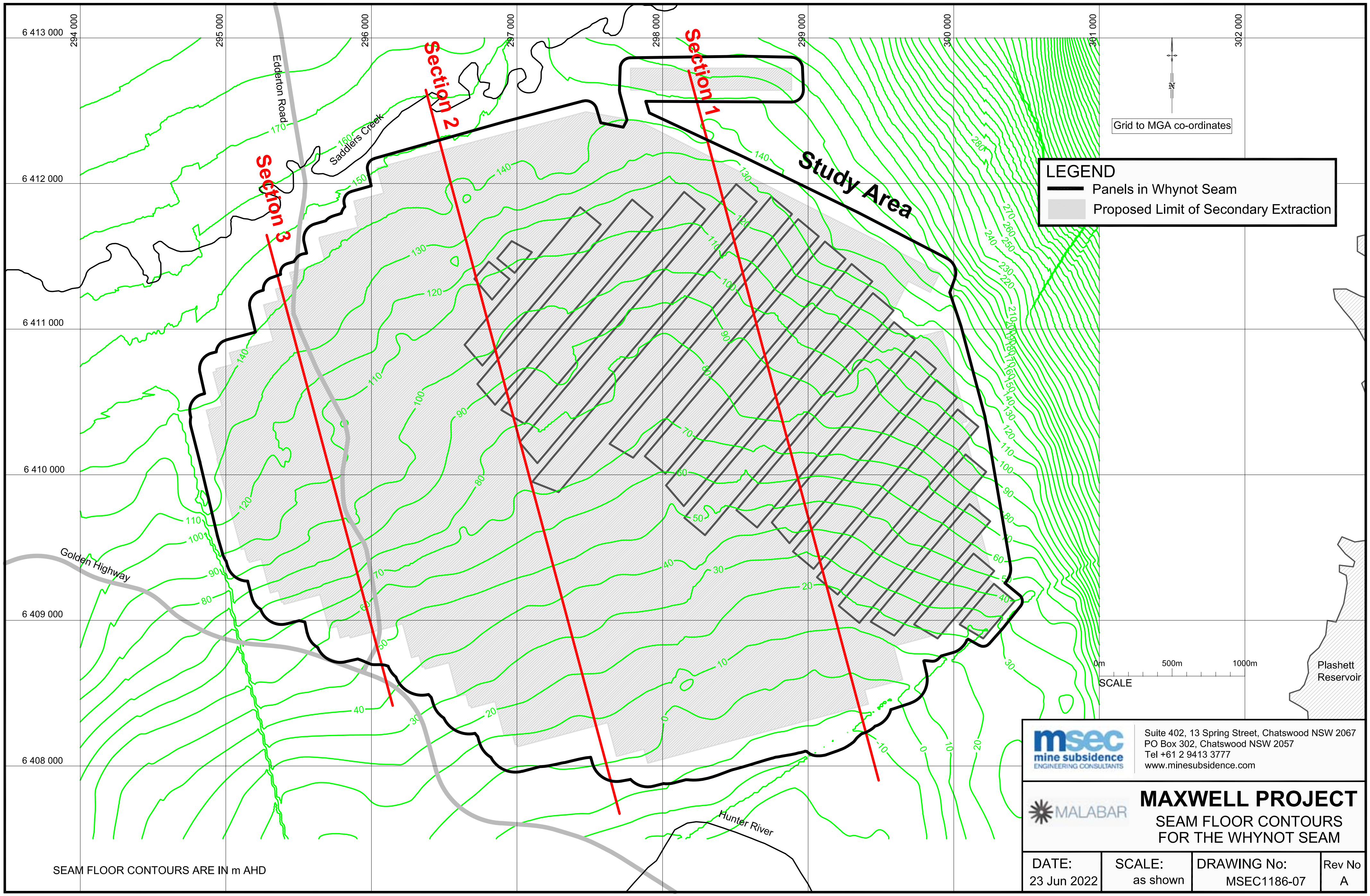
MAXWELL PROJECT

SURFACE LEVEL CONTOURS

DATE:	SCALE:	DRAWING No:	Rev No
23 Jun 2022	as shown	MSEC1186-06	A

I:\Projects\Maxwell Project\MSEC1186 - Modified Longwall Layout\AcadData\MSEC1186-07 Seam Floor for the Whynot Seam.dwg



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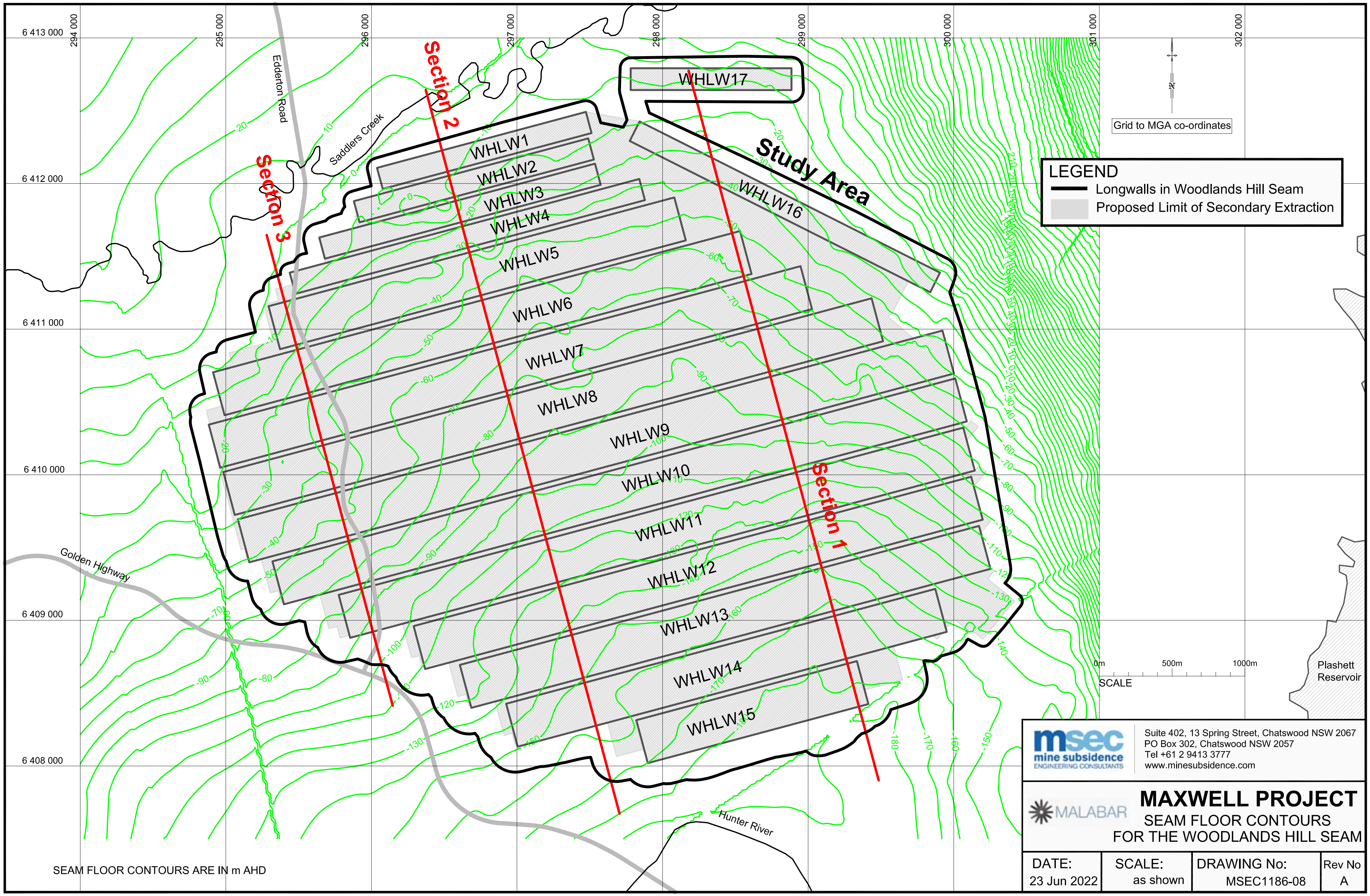
MAXWELL PROJECT

SEAM FLOOR CONTOURS FOR THE WHYNOT SEAM

DATE:	SCALE:	DRAWING No:	Rev No
23 Jun 2022	as shown	MSEC1186-07	A

I:\Projects\Maxwell Project\MSEC1186 - Modified Longwall Layout\AcadData\MSEC1186-08 Seam Floor for the Woodlands Hill Seam.dwg



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SEAM FLOOR CONTOURS FOR THE WOODLANDS HILL SEAM

DATE:	SCALE:	DRAWING No:	Rev No
23 Jun 2022	as shown	MSEC1186-08	A

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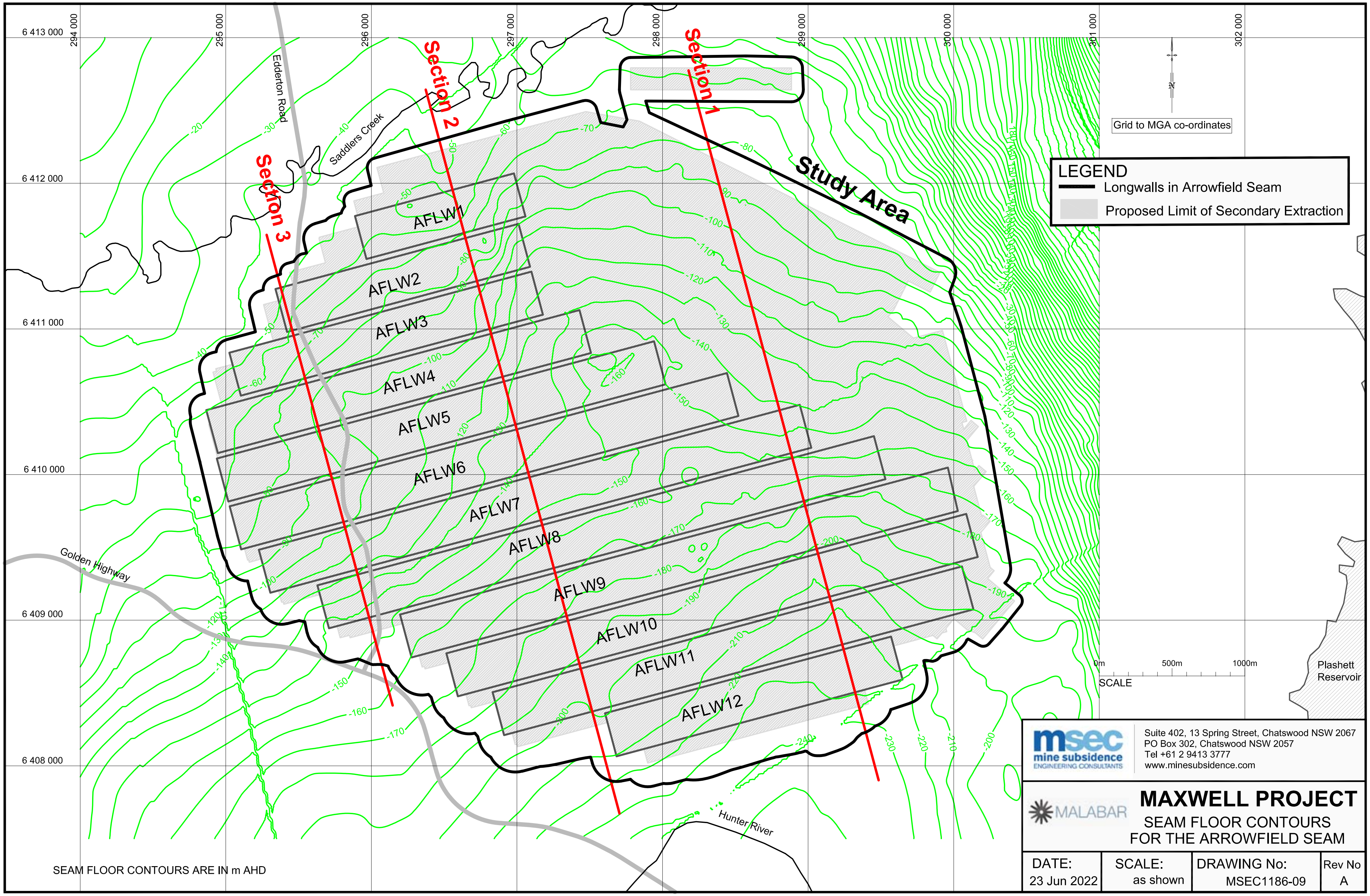

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SEAM FLOOR CONTOURS FOR THE ARROWFIELD SEAM

DATE:	SCALE:	DRAWING No:	Rev No
23 Jun 2022	as shown	MSEC1186-09	A

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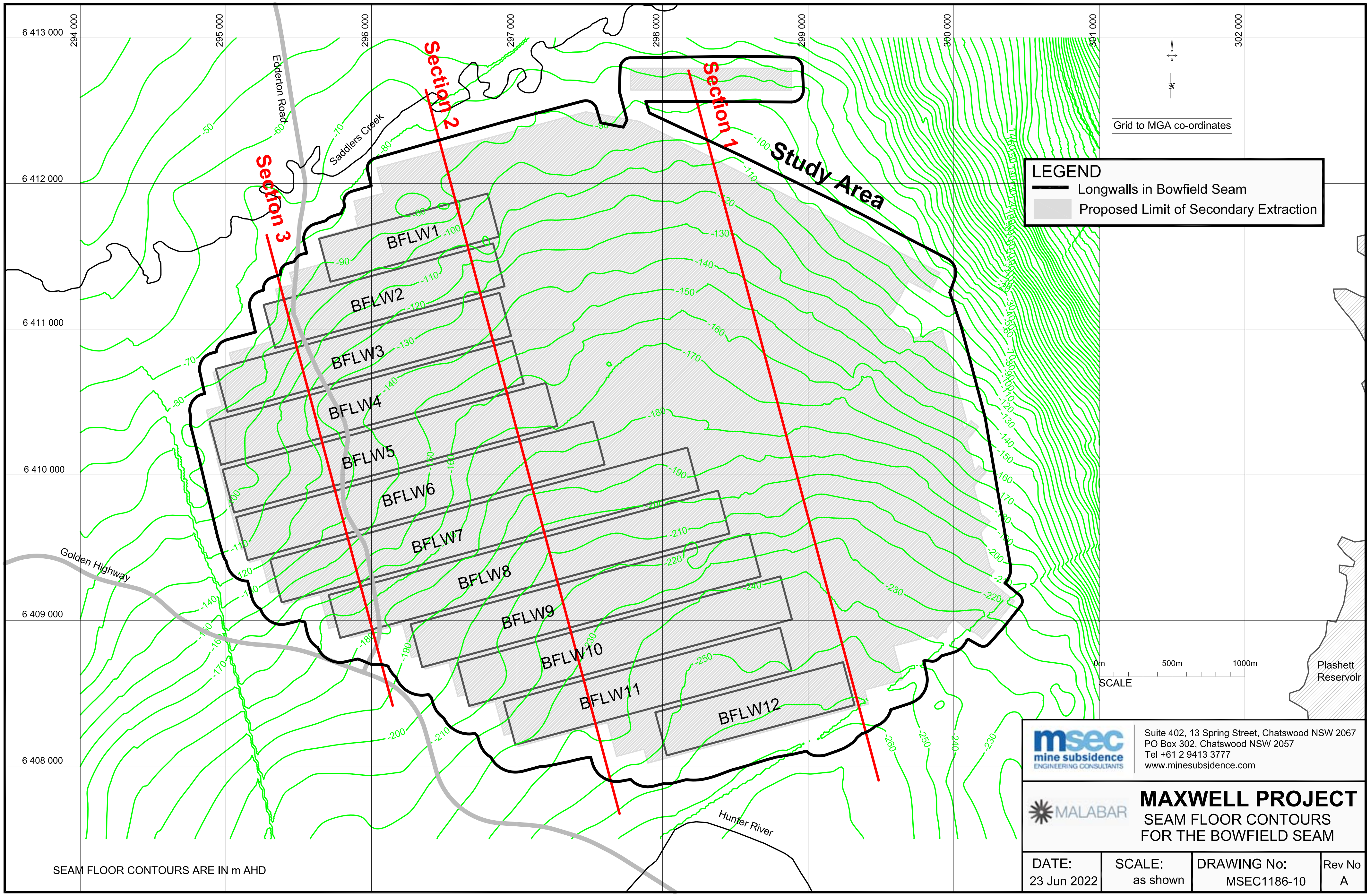

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SEAM FLOOR CONTOURS FOR THE BOWFIELD SEAM

DATE:	SCALE:	DRAWING No:	Rev No
23 Jun 2022	as shown	MSEC1186-10	A

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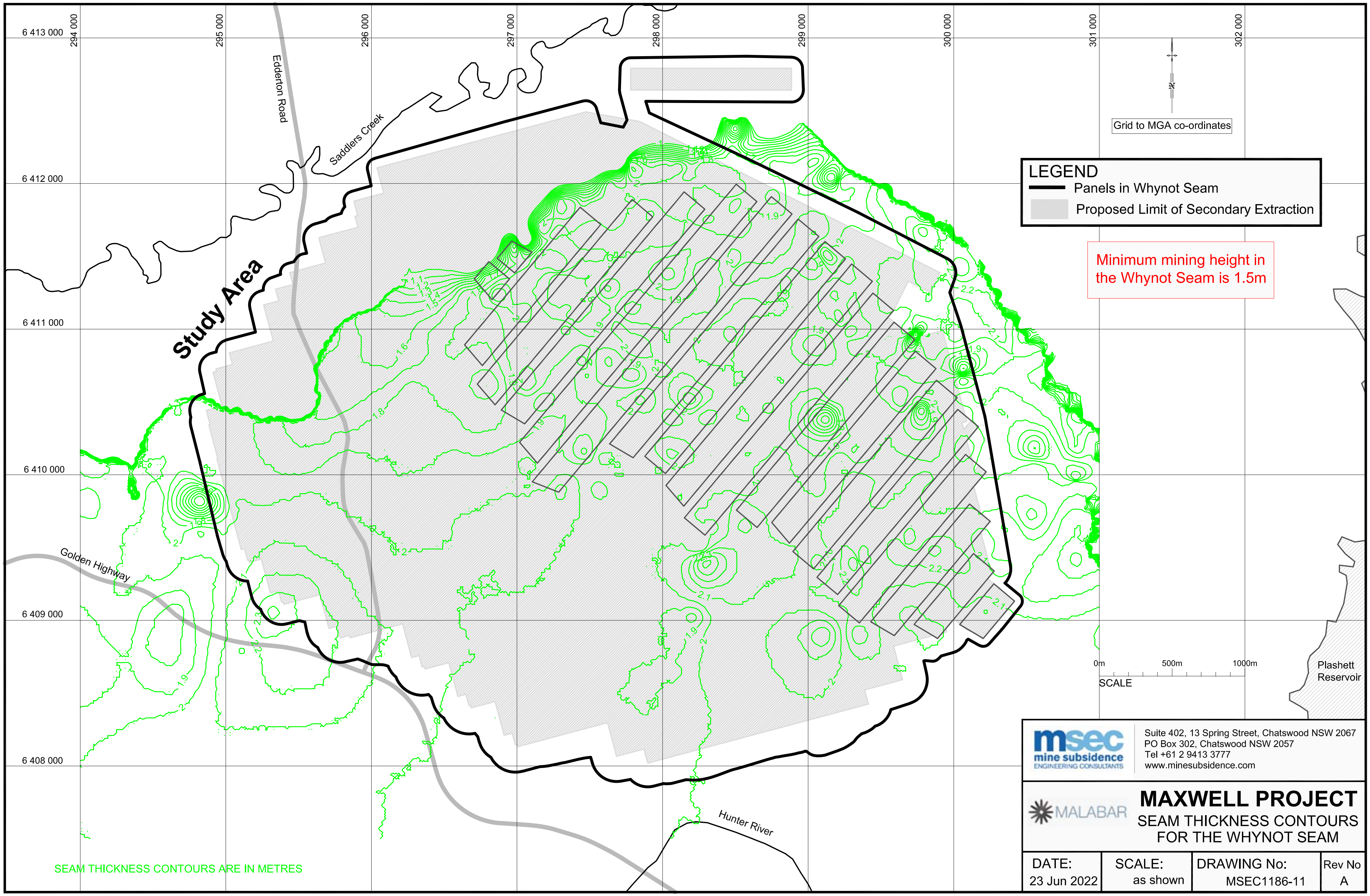

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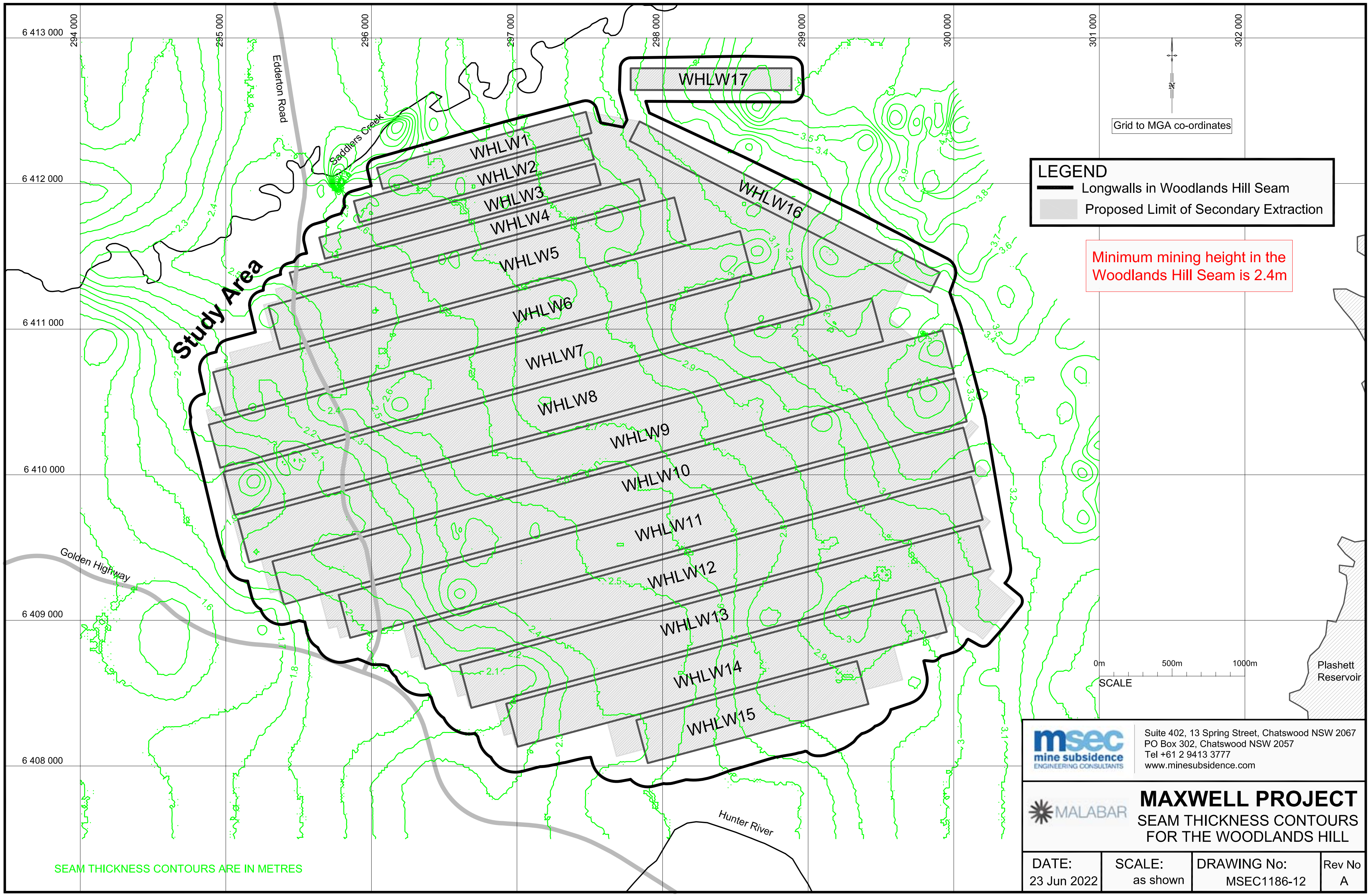

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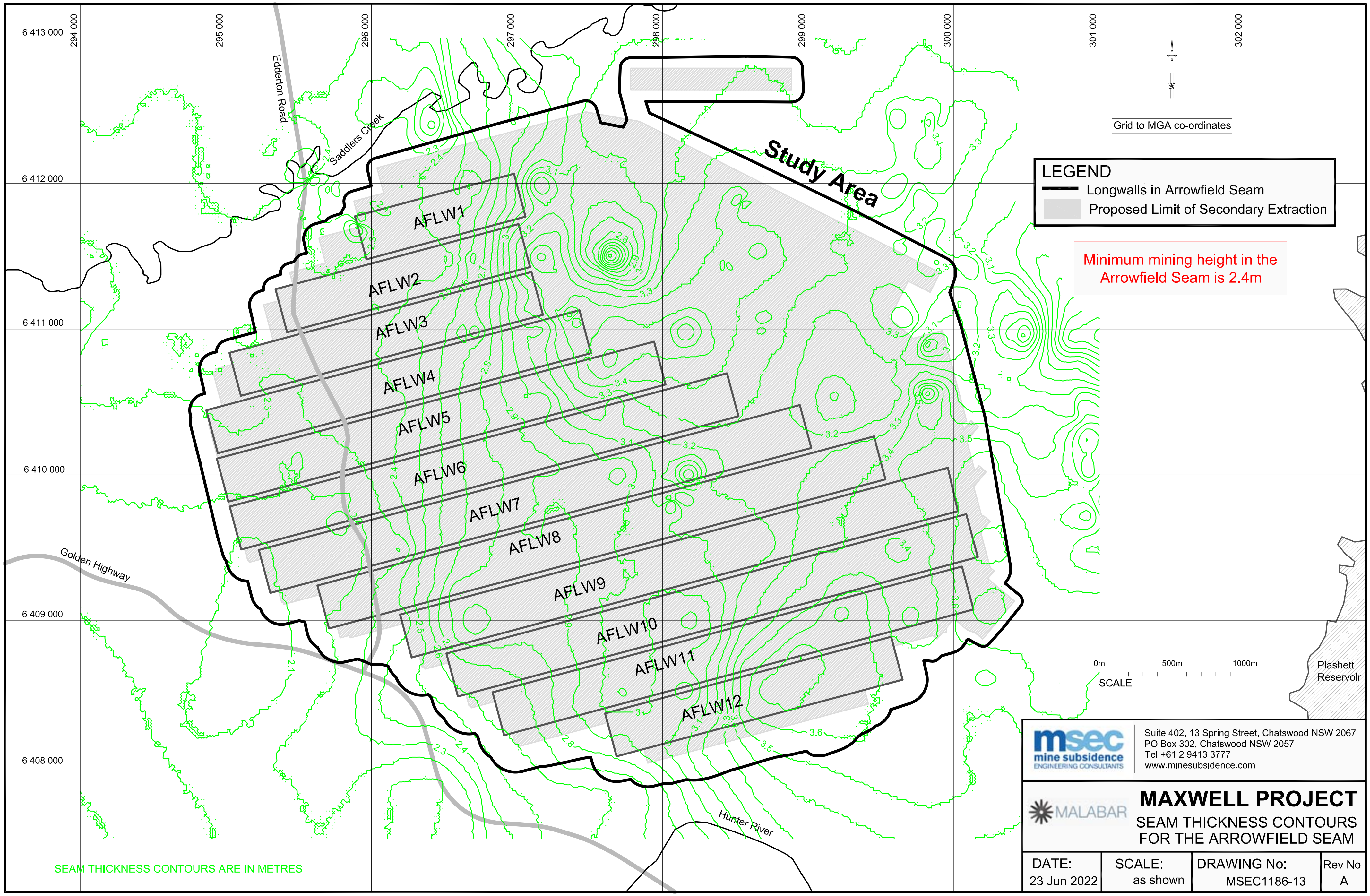

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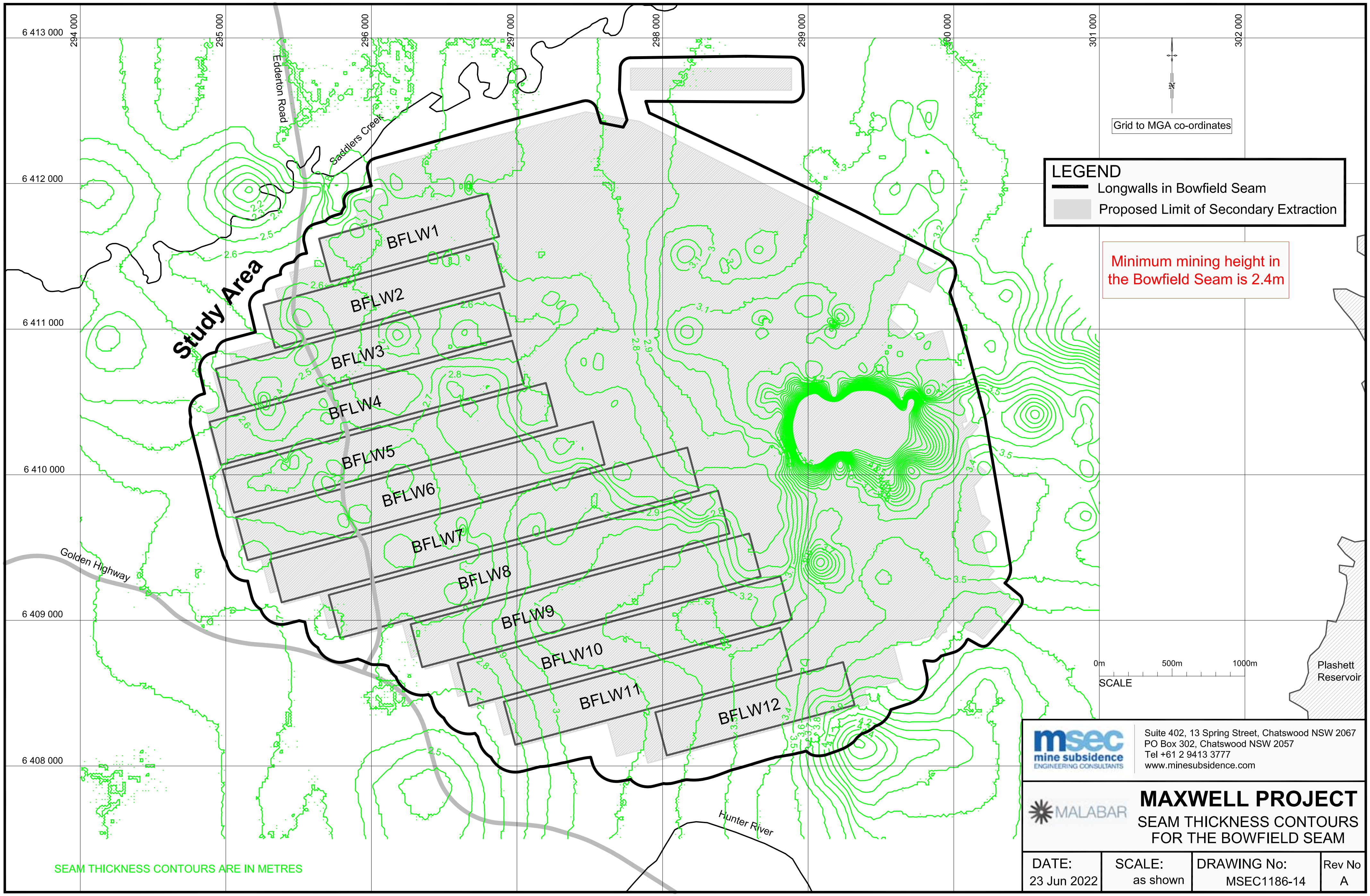

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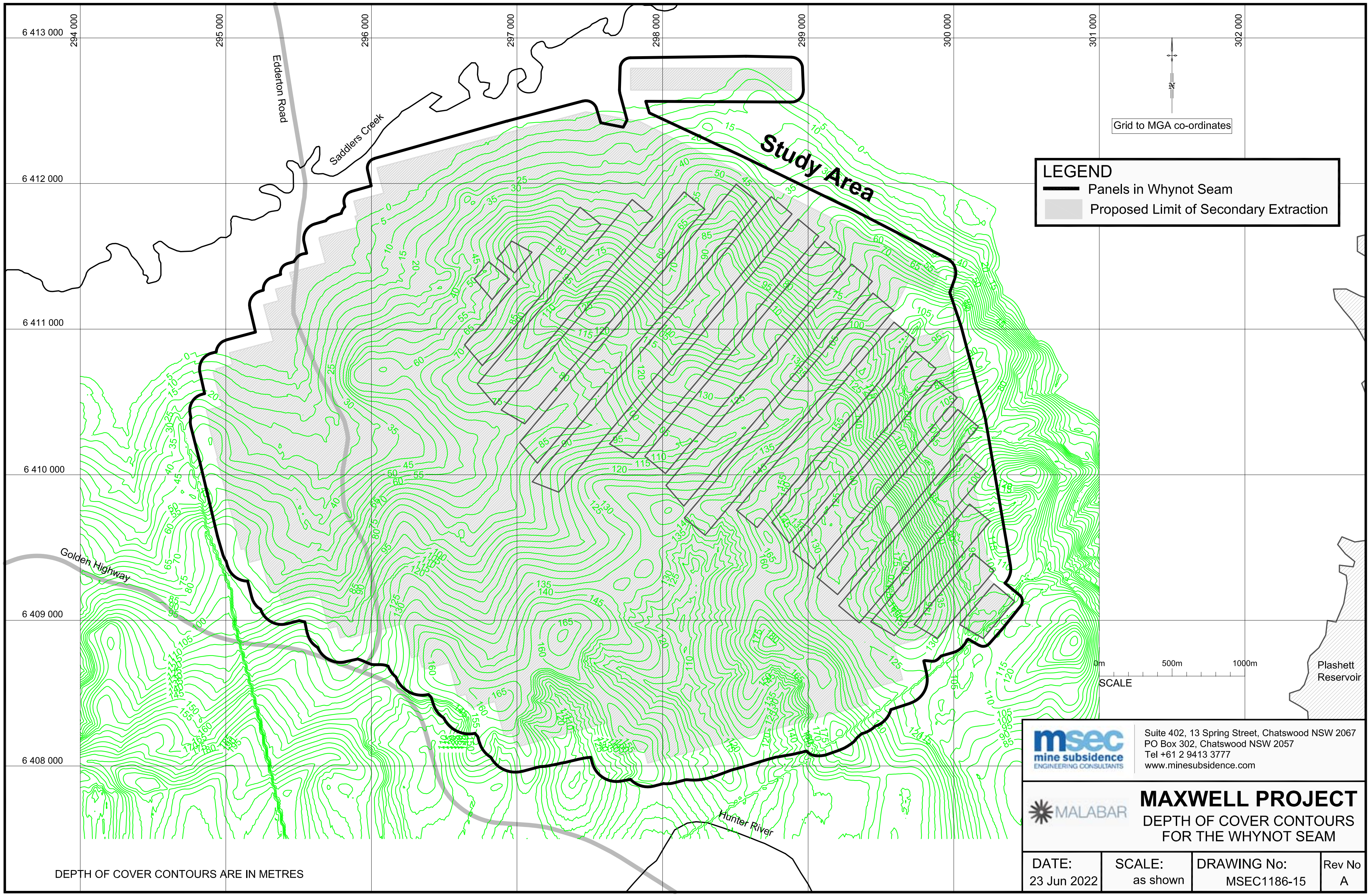

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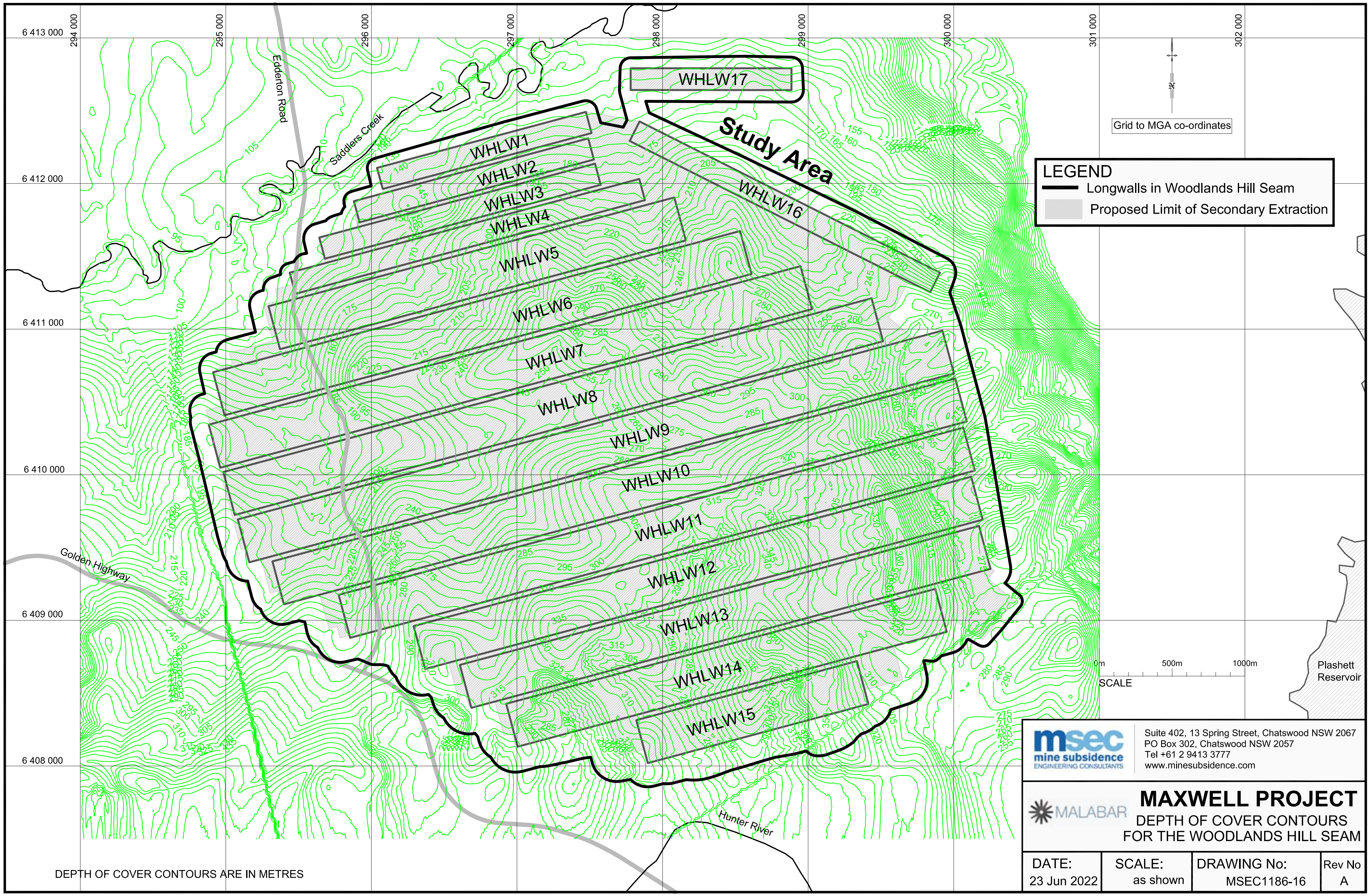
MAXWELL PROJECT

DEPTH OF COVER CONTOURS FOR THE WHYNOT SEAM

DATE:	SCALE:	DRAWING No:	Rev No
23 Jun 2022	as shown	MSEC1186-15	A

I:\Projects\Maxwell Project\MSEC1186 - Modified Longwall Layout\AcadData\MSEC1186-16 DoC for the Woodlands Hill Seam.dwg



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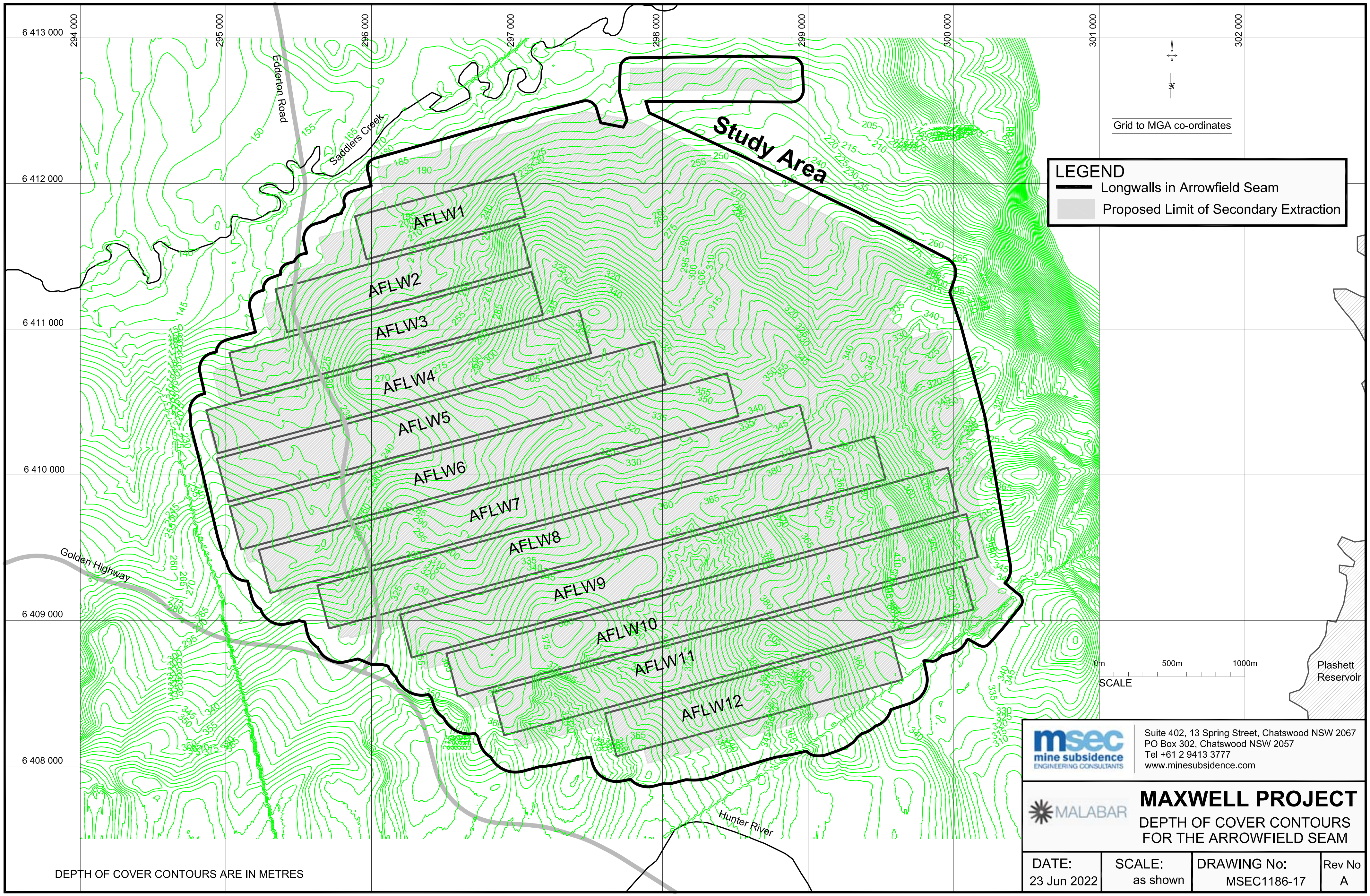
DEPTH OF COVER CONTOURS FOR THE WOODLANDS HILL SEAM

DATE:	SCALE:	DRAWING No:	Rev No
23 Jun 2022	as shown	MSEC1186-16	A

I:\Projects\Maxwell Project\MSEC1186 - Modified Longwall Layout\AcadData\MSEC1186-17 DoC for the Arrowfield Seam.dwg



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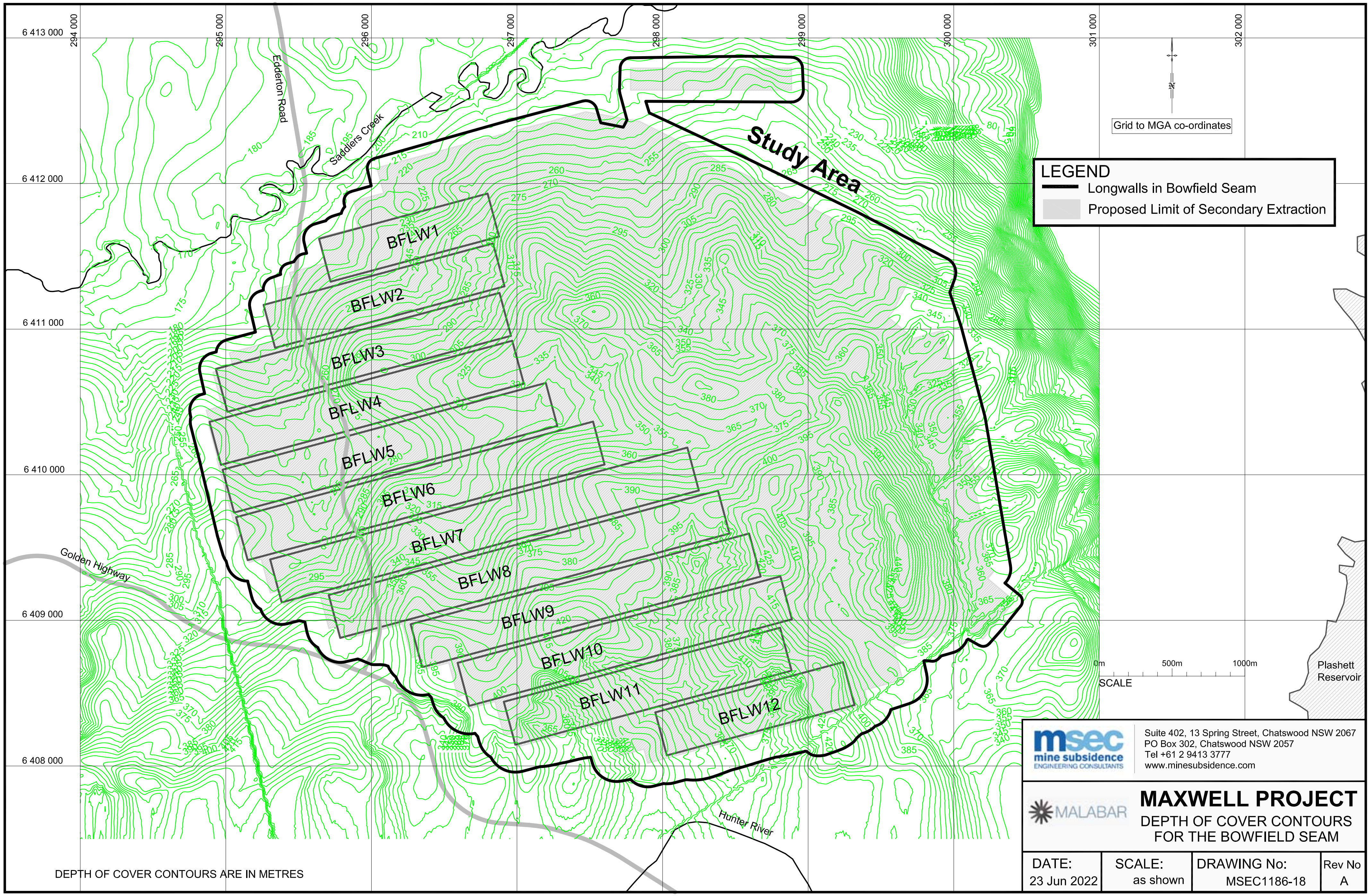
DEPTH OF COVER CONTOURS FOR THE ARROWFIELD SEAM

DATE:	SCALE:	DRAWING No:	Rev No
23 Jun 2022	as shown	MSEC1186-17	A

I:\Projects\Maxwell Project\MSEC1186 - Modified Longwall Layout\AcadData\MSEC1186-18 DoC for the Bowfield Seam.dwg



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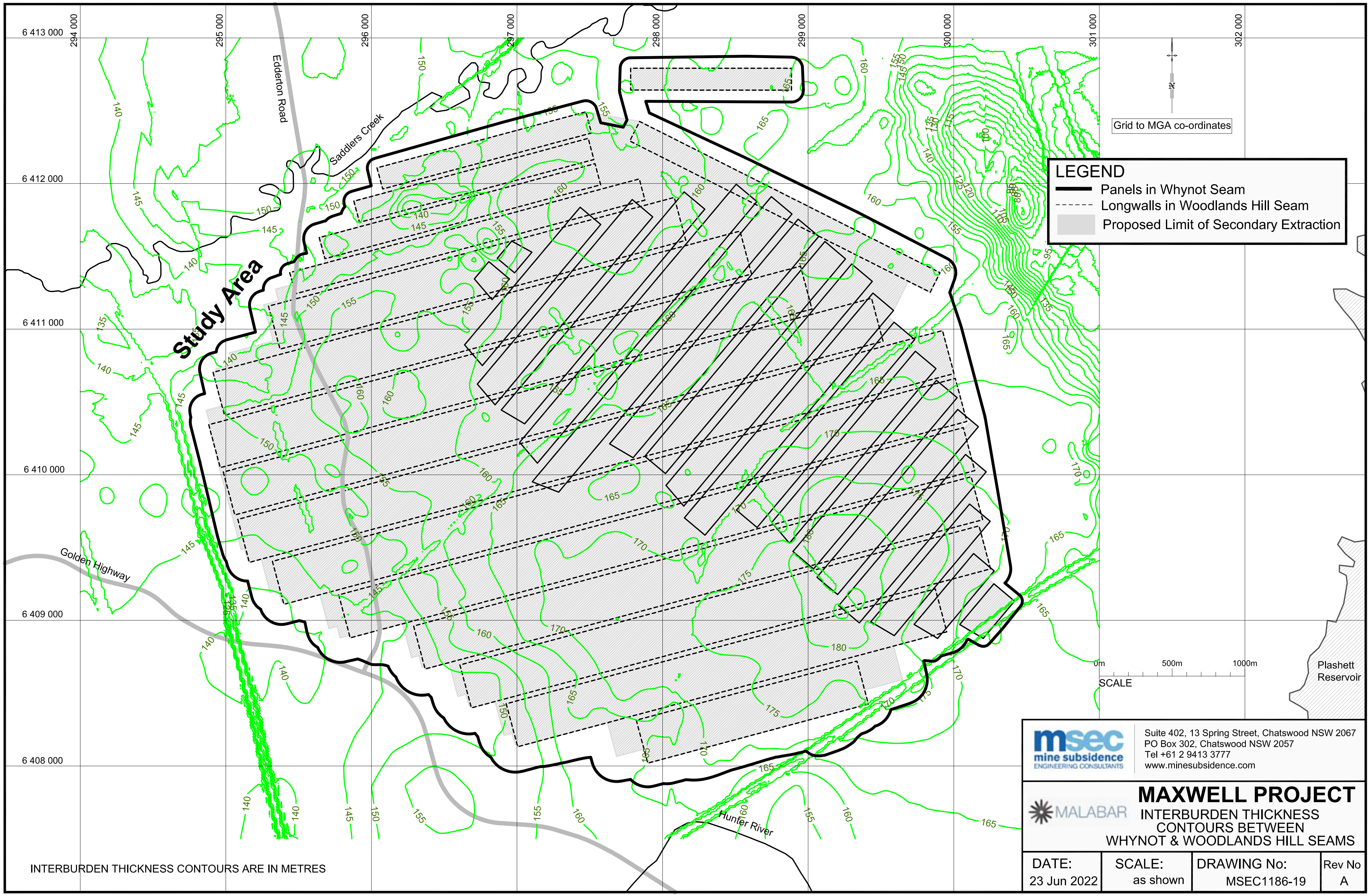
DEPTH OF COVER CONTOURS FOR THE BOWFIELD SEAM

DATE:	SCALE:	DRAWING No:	Rev No
23 Jun 2022	as shown	MSEC1186-18	A

I:\Projects\Maxwell Project\MSEC1186 - Modified Longwall Layout\AcadData\MSEC1186-19 Interburden Thickness for the WN & WH.dwg



INTERBURDEN THICKNESS CONTOURS ARE IN METRES

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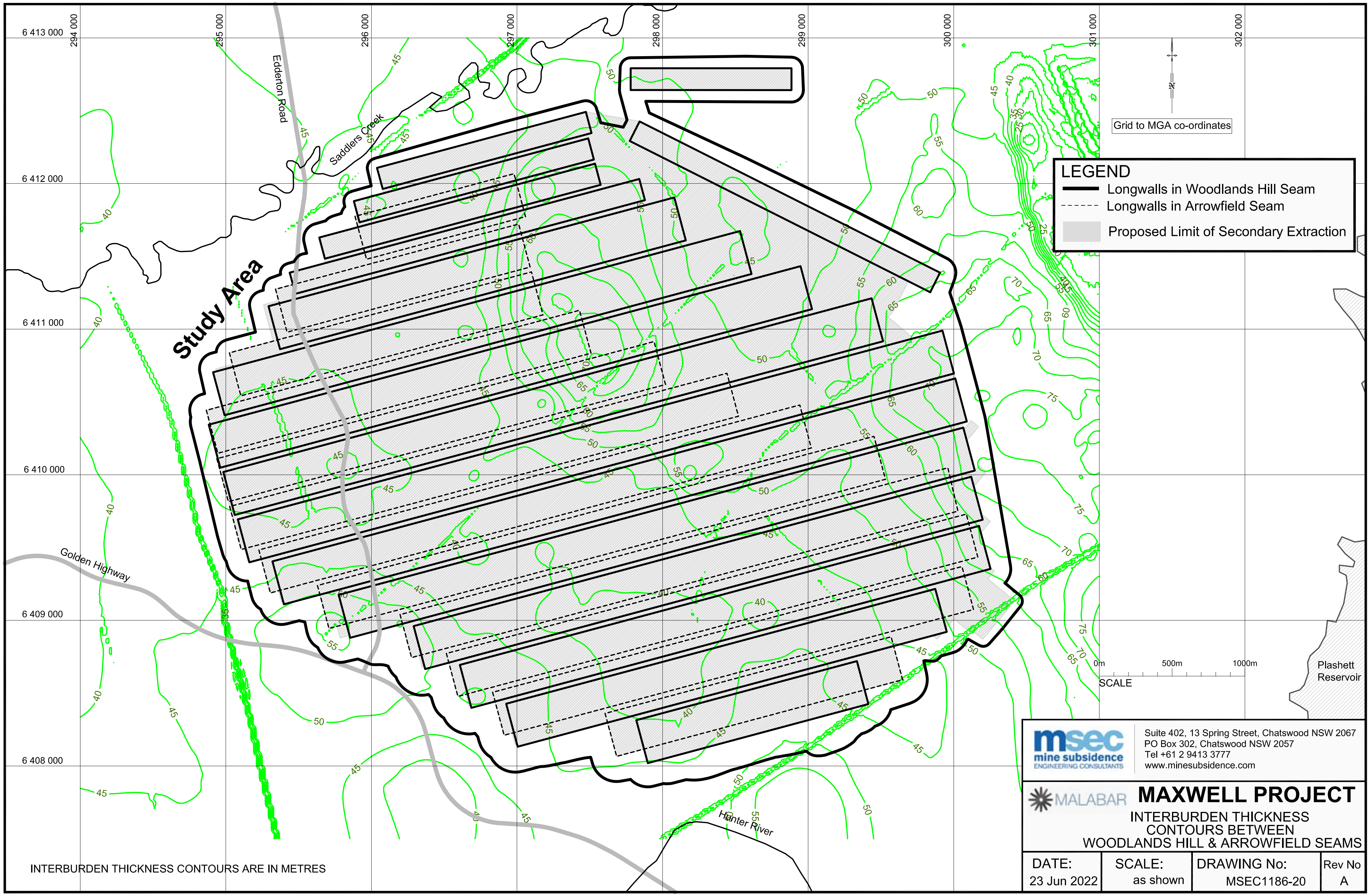
MAXWELL PROJECT

INTERBURDEN THICKNESS CONTOURS BETWEEN WHYNOT & WOODLANDS HILL SEAMS

DATE:	SCALE:	DRAWING No:	Rev No
23 Jun 2022	as shown	MSEC1186-19	A

I:\Projects\Maxwell Project\MSEC1186 - Modified Longwall Layout\AcadData\MSEC1186-20 Interburden Thickness for the WH & AF.dwg



INTERBURDEN THICKNESS CONTOURS ARE IN METRES

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MAXWELL PROJECT

INTERBURDEN THICKNESS CONTOURS BETWEEN WOODLANDS HILL & ARROWFIELD SEAMS

DATE:	SCALE:	DRAWING No:	Rev No
23 Jun 2022	as shown	MSEC1186-20	A

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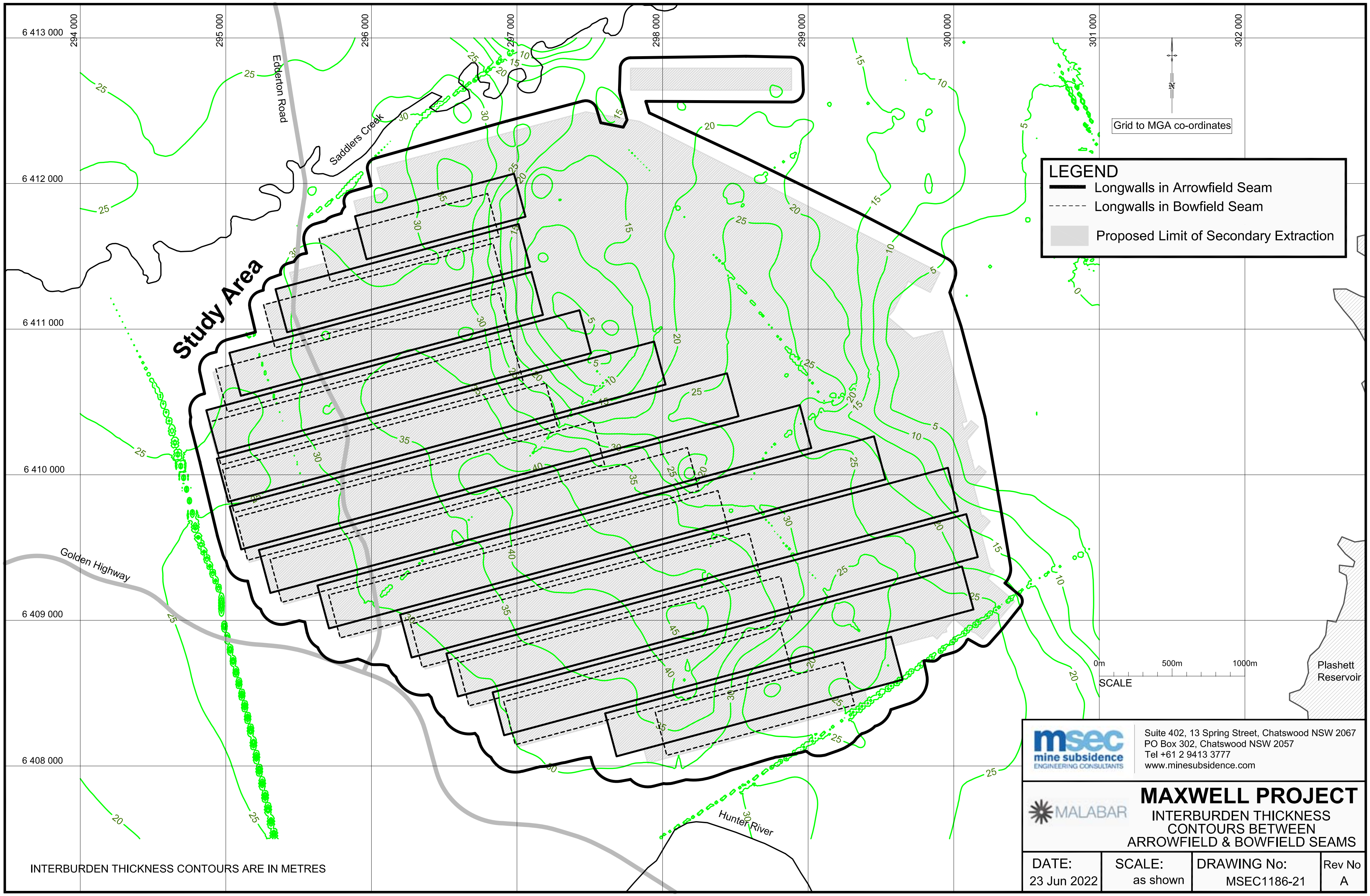

INTERBURDEN THICKNESS CONTOURS ARE IN METRES

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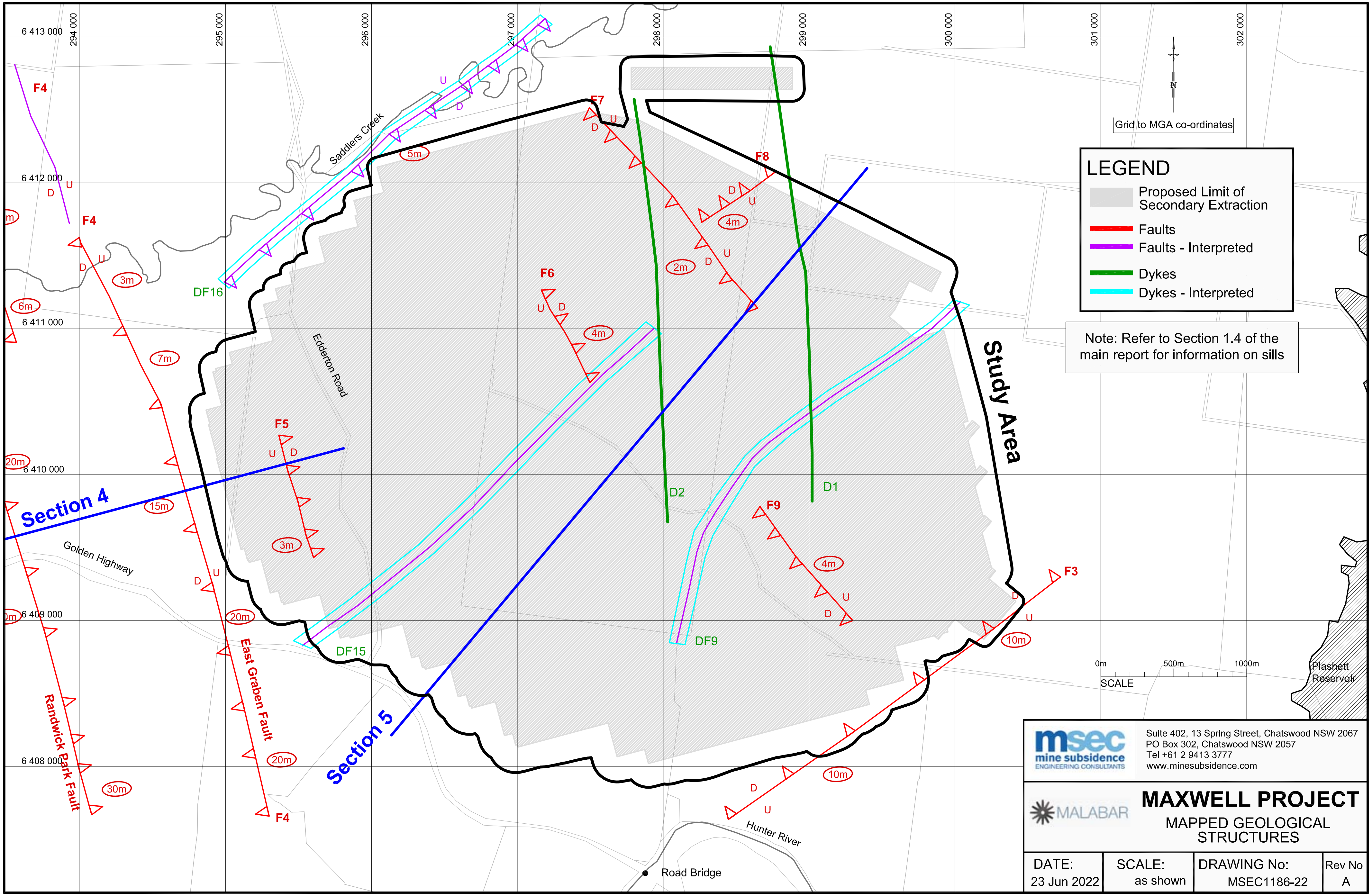
INTERBURDEN THICKNESS CONTOURS BETWEEN ARROWFIELD & BOWFIELD SEAMS

DATE:	SCALE:	DRAWING No:	Rev No
23 Jun 2022	as shown	MSEC1186-21	A

I:\Projects\Maxwell Project\MSEC1186 - Modified Longwall Layout\AcadData\MSEC1186-22 Mapped Geology.dwg



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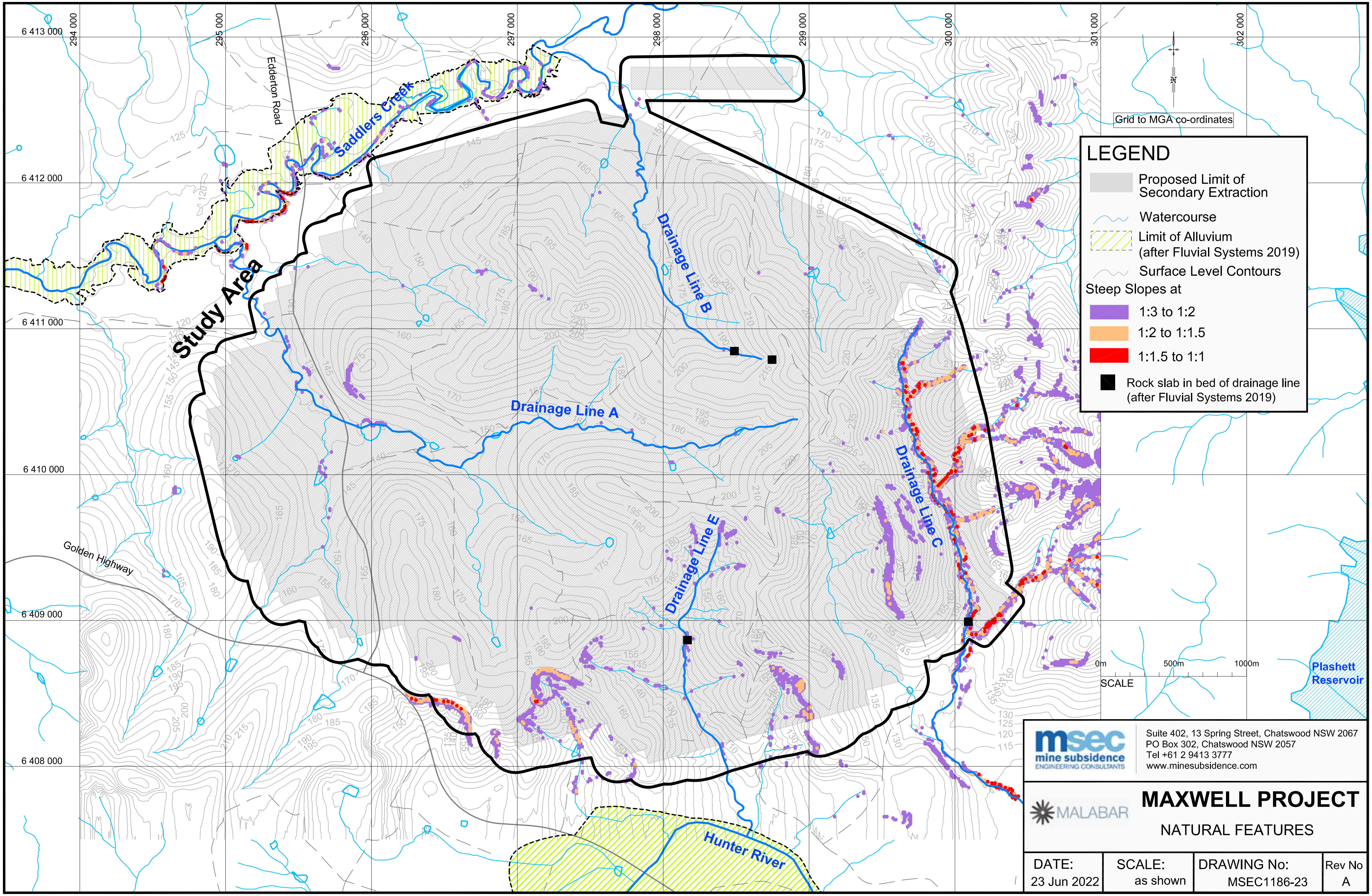

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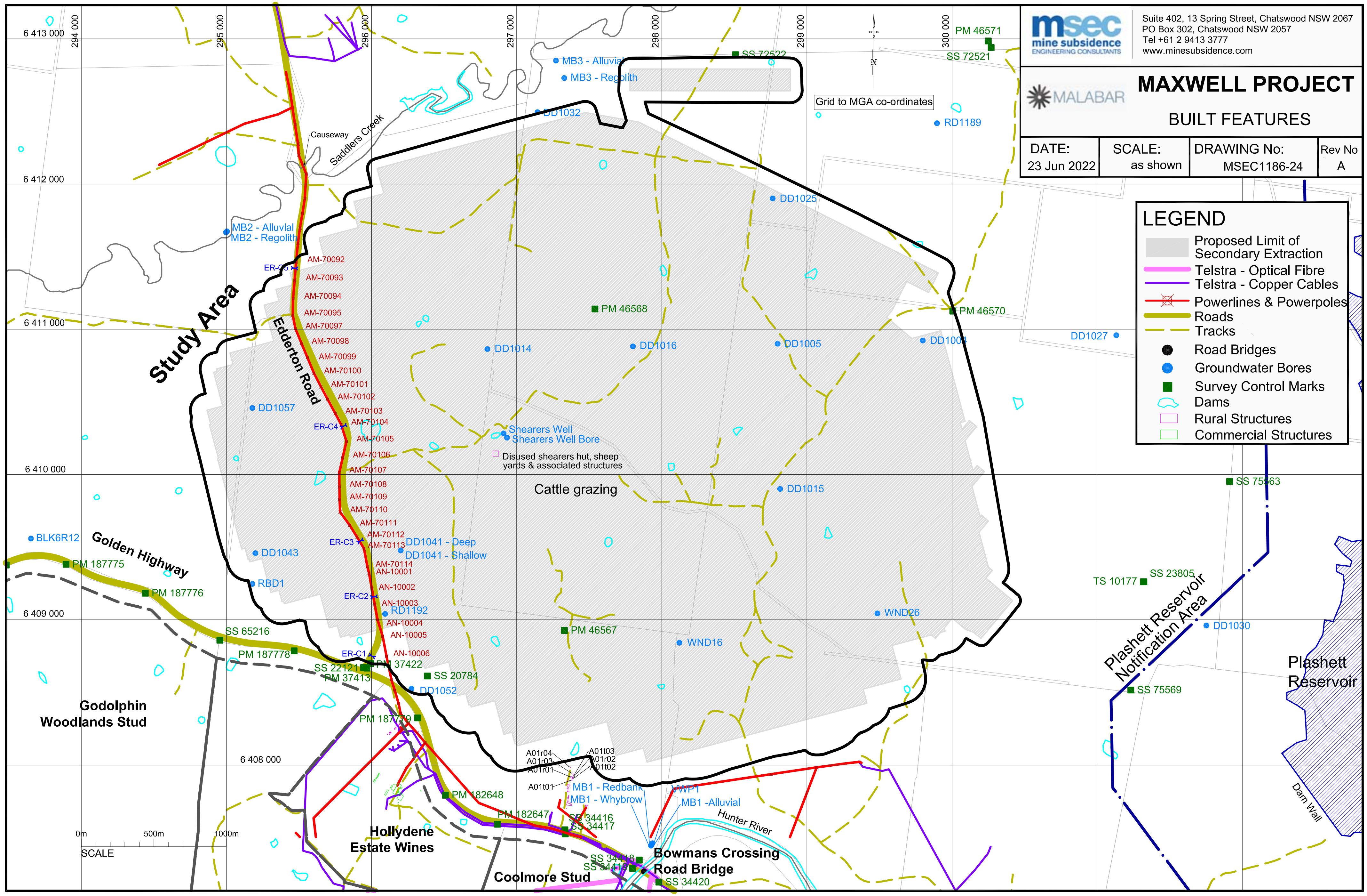

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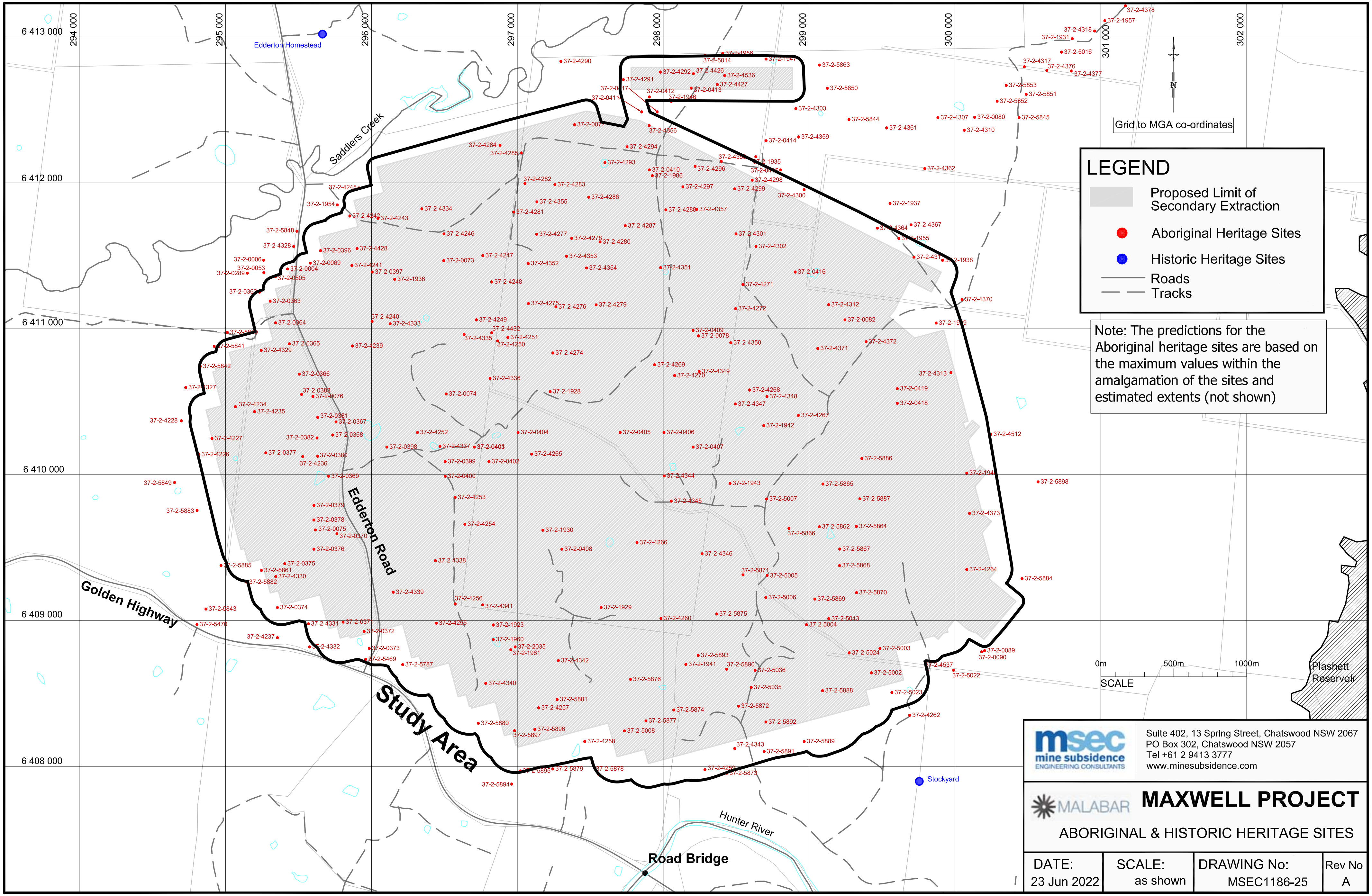
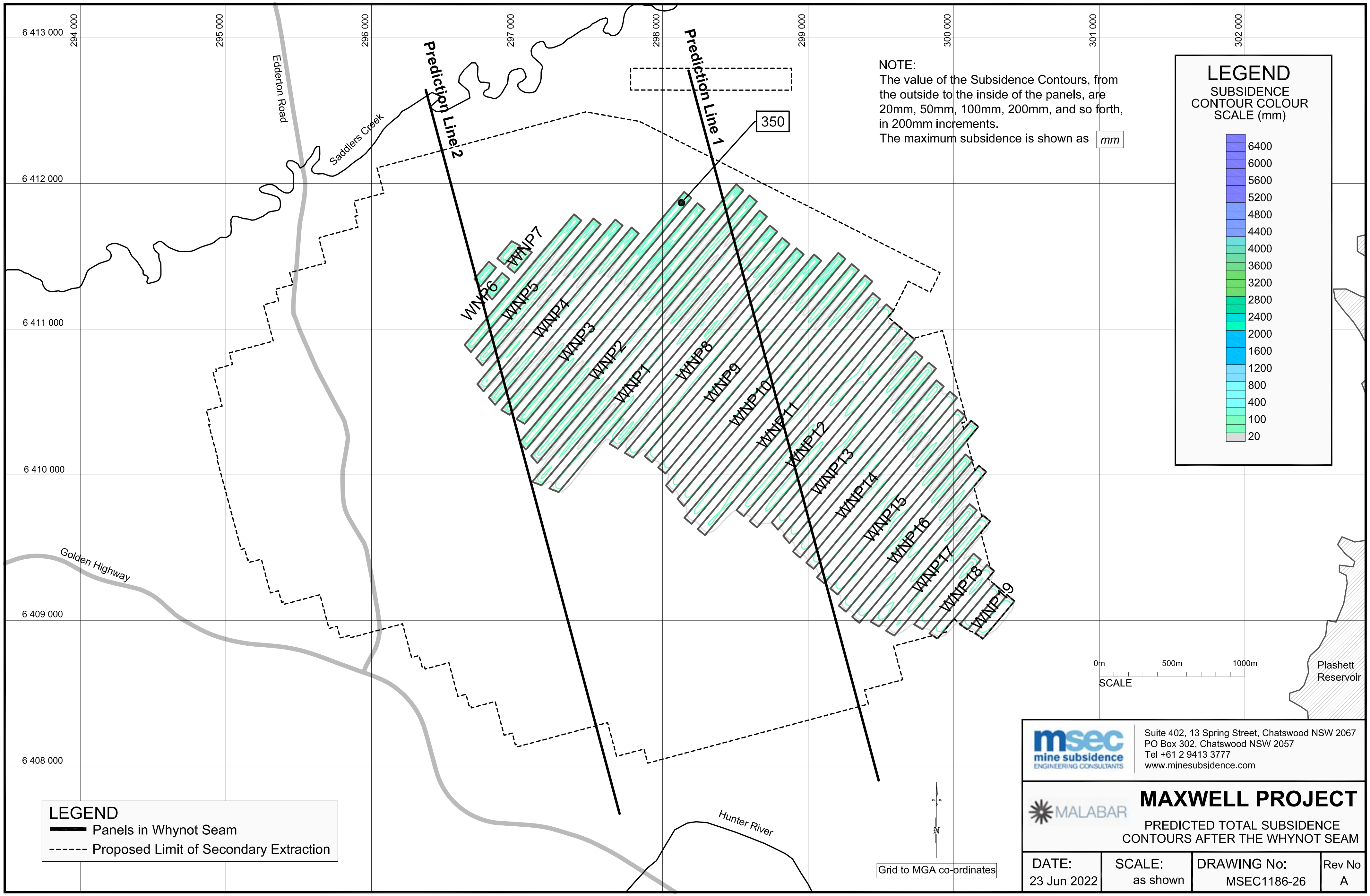


I:\Projects\Maxwell Project\MSEC1186 - Modified Longwall Layout\AcadData\MSEC1186-26 Pred Total Subs after Whynot Seam.dwg



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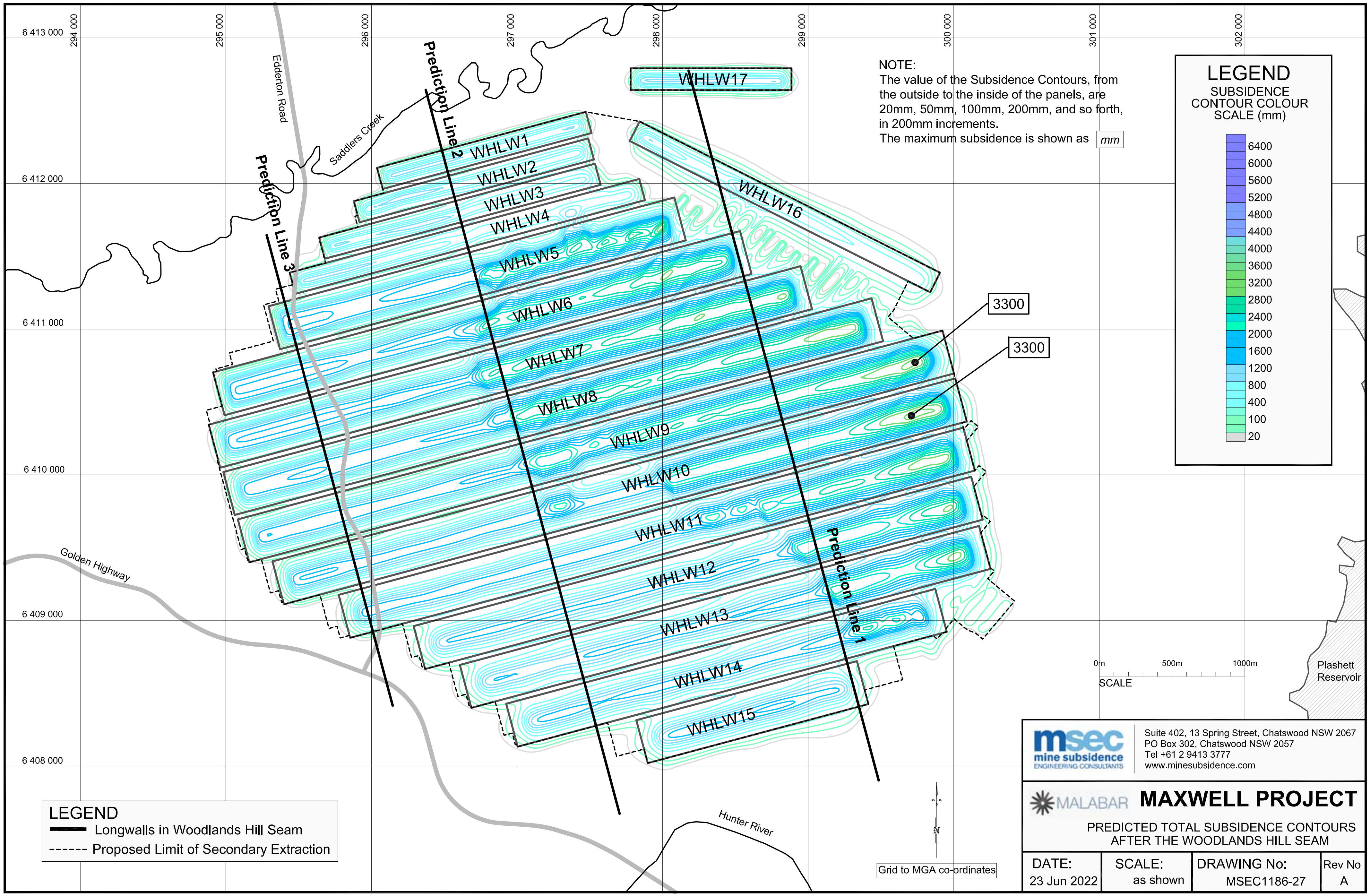

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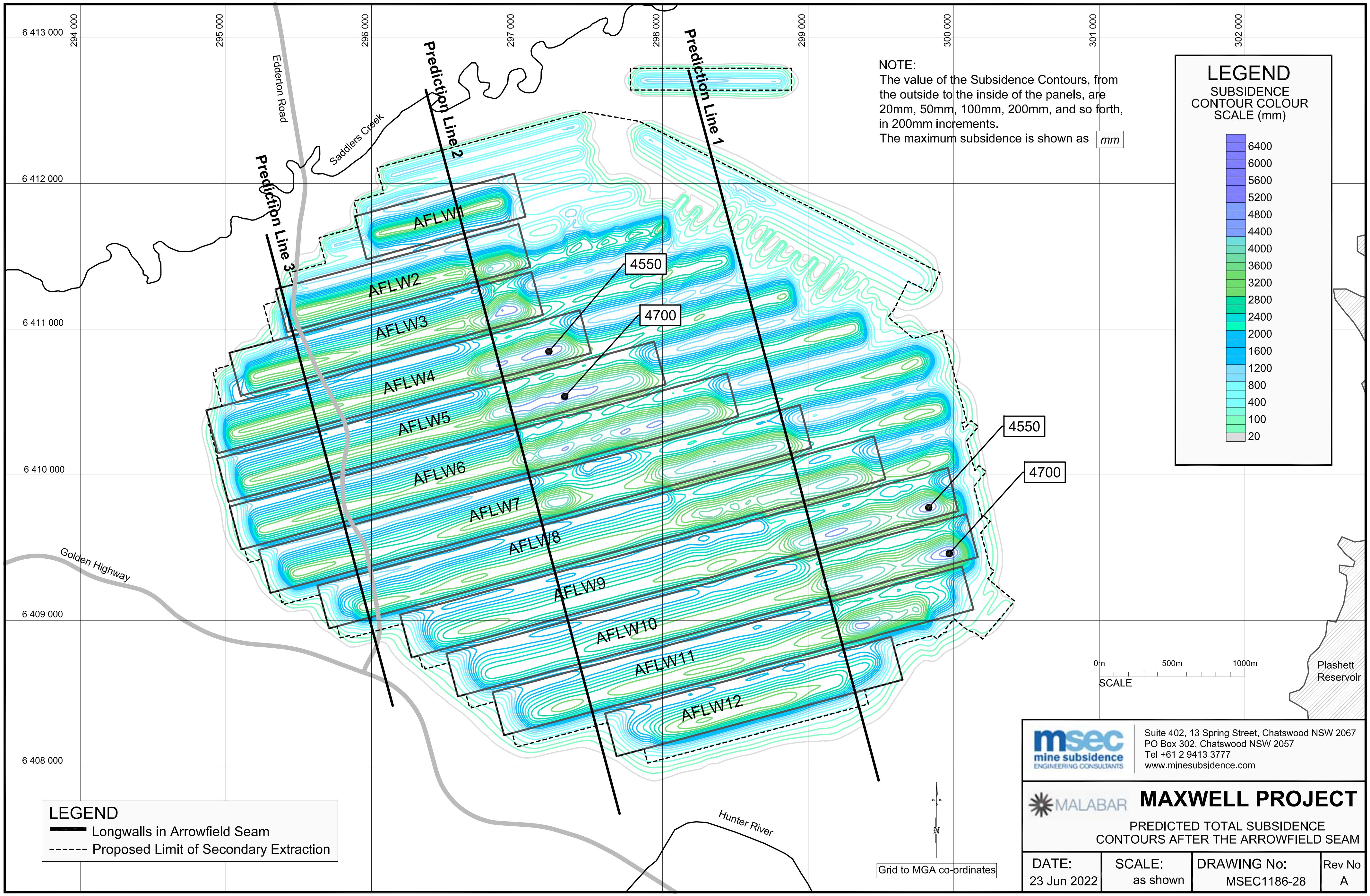

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