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Illawarra Metallurgical Coal

SOUTH32 ILLAWARRA METALLURGICAL COAL:

Dendrobium – Area 3A – Longwall 19

End of Panel Subsidence Monitoring Review Report for Dendrobium Longwall 19

DOCUMENT REGISTER

Revision	Description	Author	Checker	Date
01	Draft issue	JB	BM	4 Jun 23
A	Final issue	JB	BM	20 Jul 23

Report produced for: Compliance with conditions attached to the SMP Approval set by Industry and Investment NSW (now DPE).

Associated reports:

WKA77 (January 2001) – Dendrobium Mine Project – Report on the prediction of mining subsidence parameters and the assessment of impacts on surface infrastructure – Longwalls 1 to 18 (in support of the EIS).

MSEC311 (October 2007) – The prediction of subsidence parameters and the assessment of mine subsidence impacts on natural features and surface infrastructure resulting from the extraction of proposed Longwalls 6 to 10 in Area 3A and future longwalls in Areas 3B and 3C at Dendrobium Mine (in support of the SMP Application and the Modification to the Development Consent).

MSEC1082 (March 2020) – Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the Proposed Longwall 19 in Area 3A at Dendrobium Mine.

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

Introduction to Longwall Mining and Subsidence (Revision A)

General Discussion of Mine Subsidence Ground Movements (Revision A)

Mine Subsidence Damage to Building Structures (Revision A)

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Drawings

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

1.1. Introduction

Illawarra Metallurgical Coal (IMC) has completed the mining of Longwall 19 (LW19) at Dendrobium Mine located in the Southern Coalfield of New South Wales. The longwalls in Area 3A at Dendrobium Mine are shown in Drawing No. MSEC1345-01, in Appendix A.

LW19 is the fourth longwall in the series in Area 3A and it is located on the southern side of the existing Longwalls 6 to 8 (LW6 to LW8). The mining of LW19 commenced on 20 June 2022 and the longwall was completed on 29 March 2023.

Mine Subsidence Engineering Consultants (MSEC) was previously commissioned by IMC to prepare subsidence predictions and impact assessments for LW19. Report No. MSEC1082 (Rev. C) was issued in March 2020 in support of the SMP Application for this longwall.

In accordance with Condition 9 End of Panel Reporting of the Development Consent (Schedule 3) for the Area 3A longwalls, this report provides:

- comparisons between the measured and predicted subsidence effects at the monitoring lines and points in Dendrobium Area 3A due to the mining of LW19; and
- comparisons between the observed and predicted effects and impacts on the natural and built features within the SMP Area due to the mining of LW19.

Further details on the observed and assessed impacts for natural features due to the mining of LW19 are provided in the reports by other consultants. The discussions provided in this report should be read in conjunction with those and all other relevant reports.

Chapter 2 of this report describes the locations of the ground monitoring lines and points which were surveyed during the mining of LW19. This section provides comparisons between the measured and predicted effects due to the mining of this longwall.

Chapter 3 of this report describes the natural and built features near LW19. This section provides comparisons between the observed and assessed impacts for these features due to the mining of this longwall.

Chapter 4 of this report provides a summary of the comparisons between the measured and predicted ground movements and the observed and assessed surface impacts due to the mining of LW19.

Appendix A includes all drawings associated with this report.

1.2. Mining geometry

The layout of the longwalls in Area 3A at Dendrobium Mine is shown in Drawing No. MSEC1345-01, in Appendix A. A summary of the as-extracted dimensions for LW6 to LW8 and LW19 is provided in Table 1.1.

Table 1.1 Mining geometry of the as-extracted longwalls

Location	Longwall	Overall void length including installation heading (m)	Overall void width including first workings (m)	Overall tailgate chain pillar width (m)
Area 3A	LW6	2575	249	-
	LW7	2225	249	40
	LW8	2220	305	40
	LW19	1660	305	45

The mined lengths of the longwalls excluding the installation headings are approximately 9 m shorter than the overall void lengths provided in Table 1.1. The length of longwall mining for LW19, therefore, is approximately 1651 m. The longwall face widths excluding the first workings are approximately 294 m.

LW19 was mined within the Wongawilli Seam from the east towards the west, i.e. towards Wongawilli Creek. The natural surface and the seam levels along the centreline of LW19 are illustrated in Fig. 1.1.

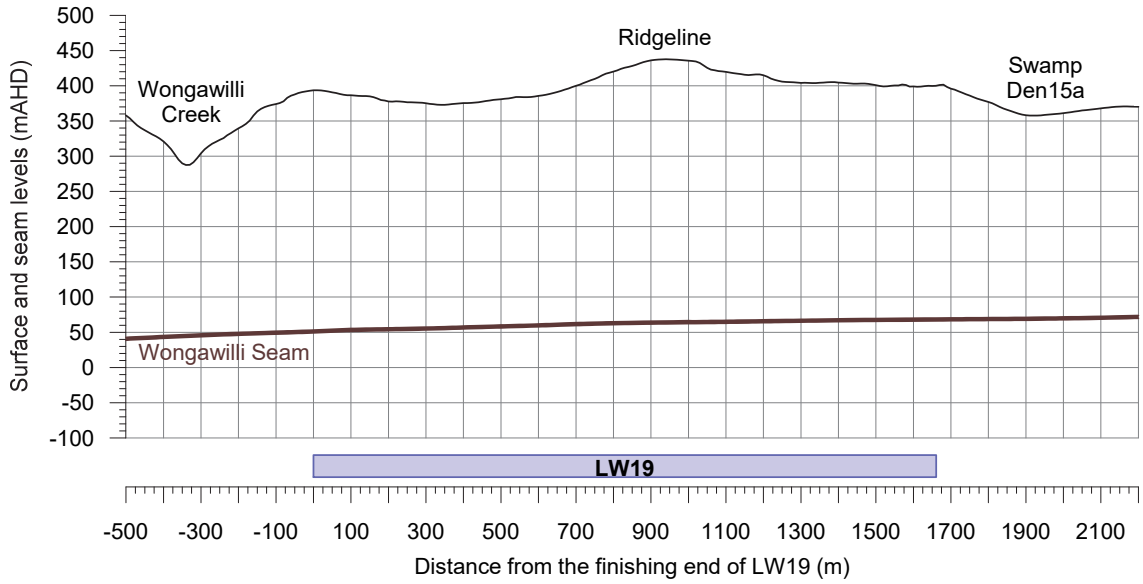

Fig. 1.1 Surface and seam levels along the centreline of LW19

The depths of cover to the Wongawilli Seam directly above LW19 vary between 280 m and 370 m. The minimum depth of cover occurs along Drainage Line WC14 near the finishing (i.e. western) end of LW19. The maximum depth of cover occurs along the ridgeline towards the middle of the longwall. The average depth of cover directly above LW19 is 335 m.

The seam floor generally dips from the south-east to the north-west. The average gradient of the seam within the extents of the mining area is approximately 2 %, or 1 in 50.

The mining height varies along the length of LW19, depending on the local roof conditions, with a maximum mining height of 3.9 m. The predictions provided in this report have been based on the maximum proposed mining height of 3.9 m, as adopted in Report No. MSEC1082, which supported the SMP Application.

2.1. Introduction

The mine subsidence effects due to the mining of Dendrobium LW19 were monitored along several monitoring lines and monitoring points including the following:

- Wongawilli Creek closure lines;
- Sandy Creek Waterfall closure lines;
- Area 3A 3D monitoring points;
- 330 kV transmission line monitoring points;
- Tributary cross lines;
- Swamp cross lines; and
- Airborne laser scans of the area.

The locations of these survey lines and survey points are shown in Drawing No. MSEC1345-01, in Appendix A. Comparisons between the measured and predicted subsidence effects at these monitoring lines and points are provided in the following sections. The predicted subsidence effects have been obtained using subsidence model presented in Report No. MSEC1082 which supported the SMP Application for LW19.

2.2. Wongawilli Creek closure lines

Closure movements across Wongawilli Creek have been measured by IMC using 2D survey techniques at the Wong X A-Line to Wong X E-Line. These monitoring lines have been measured after the mining of each of LW6 to LW8 in Area 3A, LW9 to LW18 in Area 3B and then LW19 in Area 3A.

The locations of the Wongawilli Creek closure lines are shown in Drawing No. MSEC1345-01 (note that the Wong X E-Line is located 1.3 km south of LW19 and it is outside the extents of the drawing). The survey dates for these monitoring lines are provided in Table 2.1.

Table 2.1 Survey dates for the Wongawilli Creek closure lines for LW19

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Completion of LW19	13 February 2013 (base survey) 4 March 2016 (end of LW11) 28 April 2017 (end of LW12) 14 June 2018 (end of LW13) 28 March 2019 (end of LW14) 28 March 2020 (end of LW15) 10 December 2020 (end of LW16) 11 December 2021 (end of LW17) 23 June 2022 (end of LW18) 5 May 2023 (end of LW19)	Completion of LW19A

The monitoring lines each comprise two survey marks, with the marks located on either side of Wongawilli Creek and, therefore, they measure closure between the valley sides. Survey marks could not be installed near the base of the valley due to the difficult terrain and safety concerns with access. The upsidence in the base of the valley, therefore, could not be measured.

The development of total closure for the Wongawilli Creek closure lines due to the mining in both Area 3A and 3B is illustrated in Fig. 2.1. The base survey for the Wong X D-Line was carried out after the completion of LW12 and, therefore, this line measured the additional movements due to LW13 to LW19 only. The base survey for the Wong X E-Line was carried out after the completion of LW14 and, therefore, this line measured the additional movements due to LW15 to LW19 only.

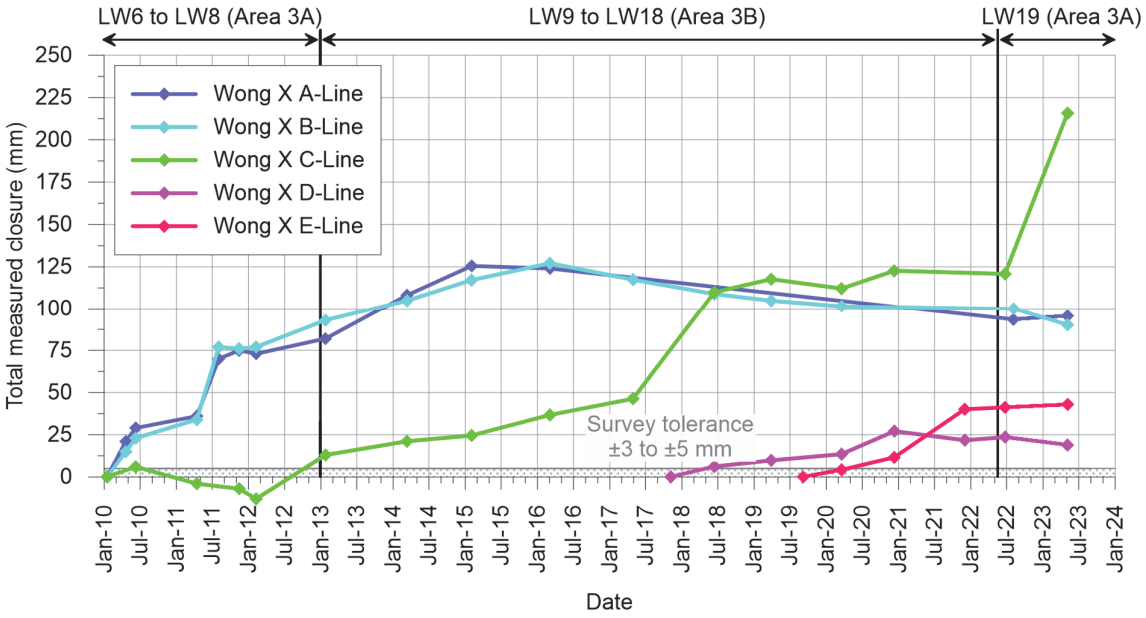

Fig. 2.1 Development of total closure for the Wongawilli Creek closure lines

The predictions of vertical subsidence, upsidence and closure for Wongawilli Creek due to the mining in Areas 3A and 3B are provided in Report No. MSEC1082. The measured and predicted total closures along Wongawilli Creek after the completion of LW19 are illustrated in Fig. 2.2.

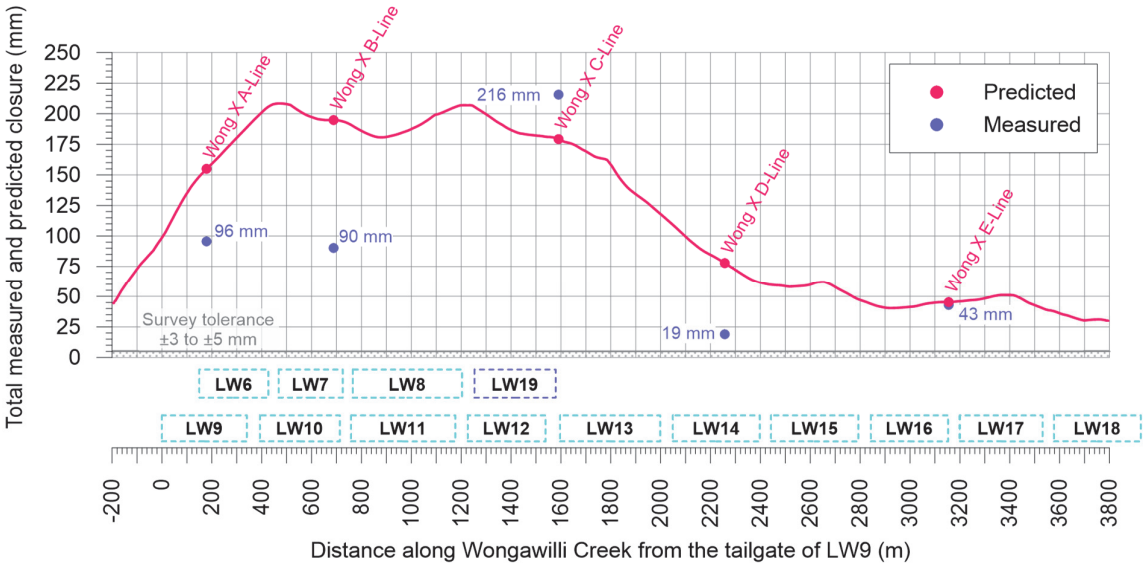

Fig. 2.2 Measured and predicted total closure along Wongawilli Creek after LW19

A summary of the maximum measured and maximum predicted total closure movements for each of the Wongawilli Creek closure lines due to the mining in Areas 3A and 3B is provided in Table 2.2. The predicted total closures are based on the as-extracted finishing ends.

Table 2.2 Measured and predicted total closure at the Wongawilli Creek closure lines due to the mining of LW6 to LW19

Location	Longwalls	Measured total closure (mm)	Predicted total closure (mm)
Wong X A-Line	LW6 to LW19	96	160
Wong X B-Line	LW6 to LW19	90	200
Wong X C-Line	LW6 to LW19	216	180 at Wong X C-Line *(210 mm downstream)*
Wong X D-Line	LW13 to LW19	19	80
Wong X E-Line	LW15 to LW19	43	50

The accuracies of the measured closure movements are in the order of ±5 mm.

The measured total closures at the Wong X A-Line and B-Line were 124 mm and 101 mm, respectively, after the completion of LW18 and they reduced to 96 mm and 90 mm, respectively, after the completion of LW19. The final measured closures are less than the predicted values at these two monitoring lines.

The measured total closure at the Wong X C-Line of 216 mm is greater than the predicted total closure of 180 mm in that location. The exceedance of 36 mm at this monitoring line represents +20 % of the measured value and, therefore, it is within the order of the accuracy of the prediction method of ±25 %.

The measured total closure at the Wong X C-Line is similar to but slightly greater than the maximum predicted closure slightly downstream of this location of 210 mm. The exceedance of 6 mm compared to the maximum predicted value represents less than 3 % of the measured value and it is in the order of survey tolerance.

It is therefore considered that the movements measured using the Wongawilli Creek closure lines are reasonably consistent with the predictions (i.e. in the order of accuracy of the prediction method of ±25 %) provided in Report No. MSEC1082 which supported the SMP Application for LW19.

2.3. Sandy Creek Waterfall closure lines

Closure across Sandy Creek Waterfall (SCW) has been measured by IMC using the High Resolution Survey (HRS) monitoring lines consisting of the H2-Line, H3-Line, G2-Line, A-Line and B-Line. The locations of these monitoring lines are shown in Drawing No. MSEC1345-01.The HRS SCW monitoring lines each comprise two survey marks with one mark on each valley side.

The survey dates for the SCW HRS closure lines are provided in Table 2.3. The original base surveys were carried out on 24 October 2010 before the commencement of LW6 and subsequent surveys were carried out during the mining of LW6 to LW8. The monitoring lines were re-established for LW19 with the base survey carried out on 2 September 2021.

Table 2.3 Survey dates for the HRS SCW closure lines for LW19

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Base survey before the commencement of LW19, weekly surveys for the first 600 m of mining and then final survey at the completion of LW19	2 September 2021 (base survey) and seven additional surveys through to 20 July 2022 (before start of LW19), then approximate weekly surveys to 20 September 2022 (600 m retreat), then 18 October 2022, 10 November 2022, 12 January 2023 and then 12 April 2023 (end of LW19)	Monthly surveys until the Technical Committee agree to the cessation of monitoring

The monitoring results were included in the subsidence review reports (MSEC1277, Rev. R01 to R19) which were issued during and after the mining of LW19. The SCW Technical Committee reviewed the monitoring data and made recommendations on the management of the waterfall.

The development of the measured incremental movements for the HRS SCW closure lines is illustrated in Fig. 2.3. This figure illustrates the additional movements since the base survey carried out on 2 September 2021 before the commencement of LW19.

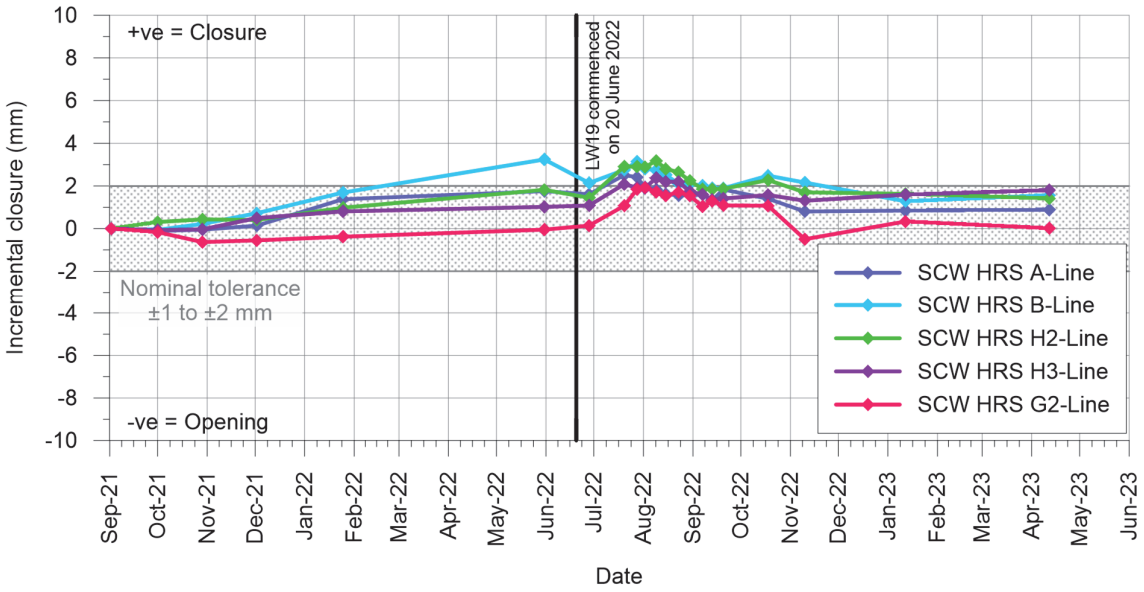

Fig. 2.3 Measured incremental closures for the HRS SCW closure lines due to LW19 only

A summary of the maximum measured and predicted incremental movements for each of the HRS SCW closure lines is provided in Table 2.4. The measured values are based on the latest survey carried out on 12 April 2023.

Table 2.4 Maximum measured and maximum predicted incremental movements for the HRS SCW closure lines due to the mining of LW19

Location	Measured incremental closure (mm)	Predicted incremental closure (mm)
A-Line	+ 0.9	±2
B-Line	+1.6	
H2-Line	+1.4	
H3-Line	+1.8	
G2-Line	~0.0	

The accuracies of the measured closure movements are in the order of ±1 mm to ±2 mm.

In the latest survey, the measured incremental movements for the HRS SCW closure lines are less than ±2 mm which is within the nominal accuracy when considering survey tolerance and environmental effects. That is, the mining-related movements are not measurable outside the nominal accuracy.

The HRS SCW closure lines measured up to approximately 3 mm closure during the mining of LW19 before reducing below the nominal accuracy at the completion of mining. These movements are likely to include survey tolerance and environmental effects.

The development of the measured total movements for the HRS SCW closure lines is illustrated in Fig. 2.4. This figure illustrates the accumulated movements during the mining of LW6 to LW8 and LW19.

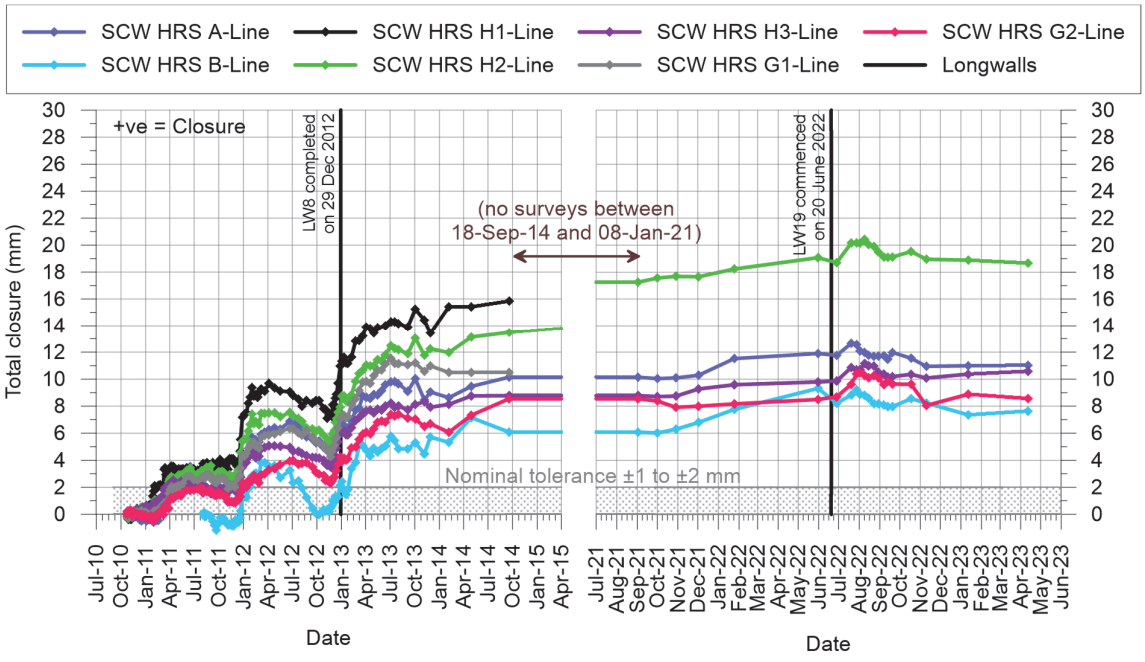

Fig. 2.4 Measured total closures for the HRS SCW closure lines due to LW6 to LW8 and LW19

The maximum measured total closure due to the mining of LW6 to LW8 and LW19 is 19 mm at the HRS SCW H2-Line. The majority of this movement occurred during the mining of the previous LW6 to LW8.

The maximum measured incremental closure across SCW of less than 2 mm is within the order of the nominal tolerance and, therefore, the mining-related movements are not measurable. The measured movements are also similar to the maximum predicted movement of less than 2 mm.

It is considered that the ground movements measured using these monitoring lines are consistent with the predictions provided in Report No. MSEC1082 which supported the SMP Application for LW19.

2.4. Dendrobium Area 3B three-dimensional monitoring points

Far-field horizontal movements near LW19 have been measured by IMC using the Dendrobium Area 3A 3D monitoring points (DA3A 3D) monitoring points. The locations of these monitoring points are shown in Drawing No. MSEC1345-01.

The survey dates for the DA3A 3D monitoring points are provided in Table 2.5.

Table 2.5 Survey dates for the DA3A 3D monitoring points for LW19

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Completion of LW19	15 January 2010 (base survey) 14 April 2011 (end of LW6) 31 January 2012 (end of LW7) 25 January 2013 (end of LW8) 20 June 2022 30 August 2022 05 May 2023 (end of LW19)	Completion of LW19A

The measured incremental horizontal movement vectors for DA3A 3D monitoring points due to the mining of LW19 are shown in Drawing No. MSEC1345-04. The accuracies of the measured absolute positions (i.e. eastings and northings) are in the order of ±20 mm.

The greatest incremental horizontal movements occur directly above LW19. The maximum measured incremental value due to the mining of LW19 is 301 mm at Mark DA3a-34 located near the top of a ridgeline directly above that longwall. The vector of incremental horizontal movement at DA3a-34 is orientated towards the west south-west generally in a downslope direction and slightly oblique to the mining direction.

The vectors located above the previously mined longwalls are orientated towards the south and towards the active LW19. The incremental horizontal movements outside of LW19 are greatest above the existing LW8 with a maximum value of 272 mm at Mark DA3a-3B and 235 mm at Mark DA3a-12B. Only low level incremental horizontal movements have been measured outside the extents of the mining area.

The comparison between the maximum measured incremental horizontal movements at the DA3A 3D monitoring points with those previously measured in Dendrobium Area 1 (DA1 3D) and Dendrobium Area 2 (DA2 3D) and Dendrobium Area 3B (DA3B 3D) is provided in Fig. 2.5. The mean and the 95 % confidence level for the 3D monitoring data at Dendrobium Mine are also shown in this figure.

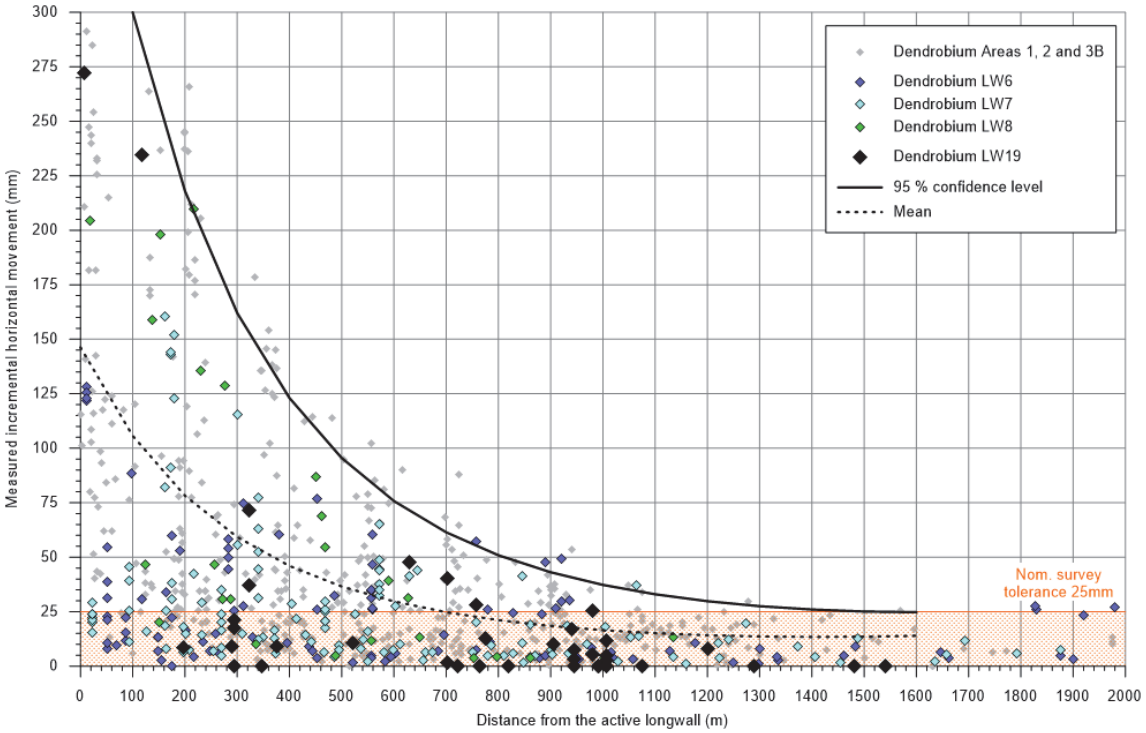

Fig. 2.5 Measured incremental horizontal movements in Area 3A at Dendrobium Mine

The measured incremental horizontal movements due to the mining of LW19 (i.e. black diamonds) are within the range of those measured at similar distances from previously mined longwalls at Dendrobium Mine (i.e. grey, blue, cyan and green diamonds).

2.5. 330 kV transmission line monitoring

The mine subsidence effects for the 330 kV transmission line have been measured by IMC using 2D monitoring points located on and around Towers TWR17-14 to TWR17-19. The locations of the transmission towers are shown in Drawing No. MSEC1345-01. The survey dates for the 330 kV transmission line for LW19 are provided in Table 2.6.

Table 2.6 Survey dates for the 330 kV transmission line for LW19

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Before the influence of LW19, then monthly surveys when the longwall is 100 m before to 400 m beyond the transmission line and then at the completion of LW19	8 August 2022 (base survey) 23 August 2022 13 September 2022 1 November 2022, then approximate weekly surveys to 26 April 2023 (end of LW19)	Monitoring as per the 330 kV transmission line management plan for LW19A

The monitoring results were included in the subsidence review reports (MSEC1300, Rev. R01 to R26) which were issued during and after the mining of LW19. The monitoring data was reviewed by IMC, MSEC and TransGrid and no additional management measures were required during mining.

The measured incremental vertical subsidence movements for Towers TWR17-14, TWR17-15, TWR17-16 and TWR17-17 are illustrated in Fig. 2.6. This figure presents the additional movements due to the mining of LW19 only since the base survey.

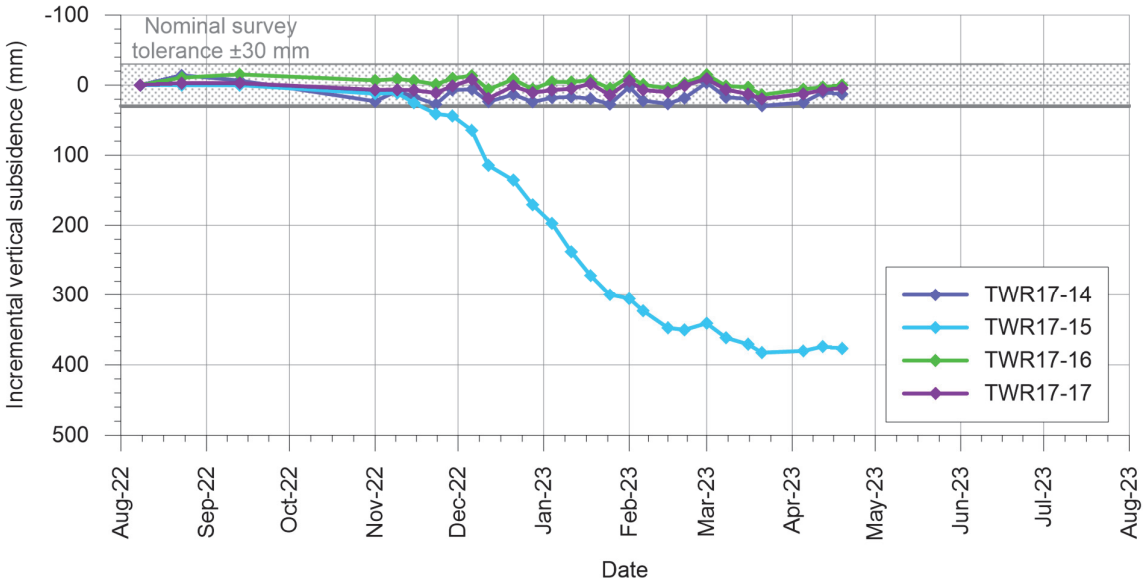

Fig. 2.6 Measured incremental vertical subsidence for TWR17 14, TWR17 15, TWR17 16 and TWR17 17 due to the mining of LW19 only

The vertical subsidence developed progressively at Tower TWR17-15 as LW19 mined adjacent to and beyond it. Only low-level vertical subsidence was measured at the remaining towers which were in the order of survey tolerance for absolute height of ±30 mm.

A summary of the maximum measured and predicted incremental subsidence effects and the Level 1 triggers for the 330 kV transmission line is provided in Table 2.7. This table provides the additional movements due to the mining of LW19 only.

Table 2.7 Maximum measured and predicted incremental subsidence effects and Level 1 triggers for the 330 kV transmission line due to the mining of LW19

Monitoring	Final measured value	Predicted final value	Level 1 trigger level
Maximum incremental vertical subsidence due to LW19 only (mm)	377	1150	1150
Maximum incremental change in relative levels of the tower legs at TWR17-14 due to LW19 (mm)	1.5	-	±4
Maximum incremental tilt due to LW19 only (mm/m)	1.2	3.5	-
Maximum incremental change in distance between the tower legs due to LW19 (mm)	+2.2 -0.2	-	±4
Maximum incremental change in distances between the bases of adjacent towers (mm)	+157 -200	+200 -200	-

The accuracies of the measured absolute levels of the survey marks are in the order of ±30 mm. The accuracies of the measured relative levels and changes in distances are in the order of ±5 mm.

The maximum measured incremental vertical subsidence of 377 mm at Tower TWR17-15 is less than one-third the maximum predicted value. The reason is that the subsidence model was calibrated to conservatively provide additional subsidence above the tailgate chain pillar and adjacent longwalls, therefore, providing increased predictions in these locations.

The measured incremental changes in relative level, tilt, changes in distance between tower legs and changes in distance between the bases of adjacent towers were similar to or less than the predicted values and were less than the Level 1 triggers.

It is therefore considered that the ground movements measured using the 330 kV transmission line monitoring points are consistent with the predictions provided in Report No. MSEC1082 which supported the SMP Application for LW19.

2.6. Tributary cross line

The mine subsidence effects for a tributary to Wongawilli Creek have been measured by IMC using 2D survey techniques at the WC14 cross line. The location of this monitoring line is shown in Drawing No. MSEC1345-01. The survey dates for the WC14 cross line for LW19 are provided in Table 2.8.

Table 2.8 Survey dates for the WC14 cross line for LW19

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Completion of LW19	21 October 2015 (base survey) 5 May 2023 (end of LW19)	Completion of LW19A

A summary of the maximum measured and predicted subsidence and closure at the WC14 cross line after the completion of LW19 are provided in Table 2.9. The predicted subsidence value has been derived from the predicted subsidence contours illustrated in Report No. MSEC1082. The predicted closure is based on a combination of the conventional horizontal movements and valley-related movements, taking the equivalent height of the valley within half-depth of cover from the valley base.

Table 2.9 Maximum measured and predicted incremental vertical subsidence and closure at the WC14 cross line due to the mining of LW19

Type	Maximum incremental vertical subsidence (mm)	Maximum incremental closure (mm)
Measured	105	55
Predicted	150	250

The accuracies of the measured absolute levels of the survey marks are in the order of ±30 mm. The accuracies of the measured closures are in the order of ±5 mm.

The maximum measured incremental vertical subsidence and closure at the WC14 cross line are less than the maximum predicted values.

It is therefore considered that the ground movements measured using the WC14 cross line are consistent with the predictions provided in Report No. MSEC1082 which supported the SMP Application for LW19.

2.7. Swamp cross lines

The mine subsidence effects at the swamps and their associated drainage lines have been measured by IMC using 2D survey techniques at the Swamp 15A, Swamp 15B and Swamp 148 cross lines. Other swamp monitoring lines are located outside the zone of influence for this longwall.

The locations of the swamp cross lines are shown in Drawing No. MSEC1345-01. The survey dates for the swamp cross lines are provided in Table 2.10.

Table 2.10 Survey dates for the swamp cross lines during LW19

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Completion of LW19	22 July 2022 (base survey) 02 August 2022 30 August 2022 18 October 2022 23 November 2022 (Swamp 148 only) 5 May 2023 (end of LW19)	Completion of LW19A

The development of the measured accumulated closure at the Swamp 15A, Swamp 15B and Swamp 148 cross lines is illustrated in Fig. 2.7. The cross lines were established after the completion of LW8 and, therefore, the measured movements represent the additional movements due to LW19 only. These three monitoring lines have short lengths and they are located near the valley base and, therefore, they may not measure the maximum closure within the valley.

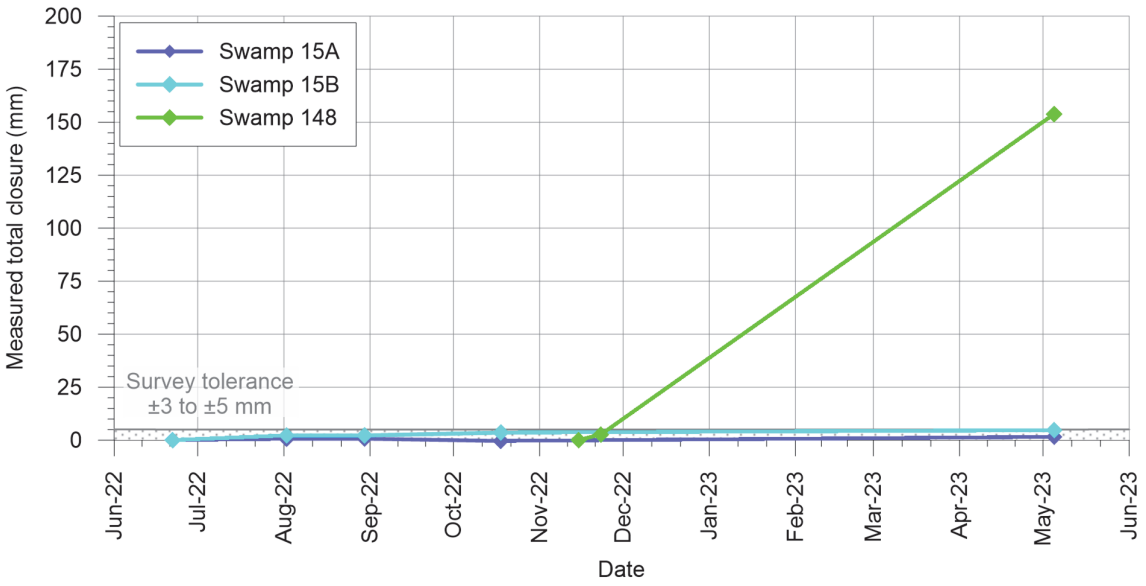

Fig. 2.7 Measured accumulated closure for the swamp cross lines

Summaries of the maximum measured and predicted incremental vertical subsidence and closure for the Swamp 15A, Swamp 15B and Swamp 148 cross lines are provided in Table 2.11, Table 2.12 and Table 2.13, respectively. The values represent the additional movements due to LW19 only.

Table 2.11 Maximum measured and predicted incremental vertical subsidence and closure at the Swamp 15A cross line due to the mining of LW19 only

Type	Maximum incremental vertical subsidence (mm)	Maximum incremental closure (mm)
Measured	5	2
Predicted	< 20	50

Table 2.12 Maximum measured and predicted incremental vertical subsidence and closure at the Swamp 15B cross line due to the mining of LW19 only

Type	Maximum incremental vertical subsidence (mm)	Maximum incremental closure (mm)
Measured	30	5
Predicted	275	50

Table 2.13 Maximum measured and predicted incremental vertical subsidence and closure at the Swamp 148 cross line due to the mining of LW19 only

Type	Maximum incremental vertical subsidence (mm)	Maximum incremental closure (mm)
Measured	86	154
Predicted	300	150

The accuracies of the measured absolute levels of the survey marks are in the order of ±30 mm. The accuracies of the measured closures are in the order of ±5 mm.

The maximum measured incremental closure at the Swamp 148 cross line of 154 mm is similar to but slightly greater than the maximum predicted value of 150 mm. The exceedance of 4 mm represents less than 3 % of the measured value and it is in the order of survey tolerance.

The maximum measured incremental vertical subsidence and closure at the Swamp 15A and Swamp 15B cross lines and the measured incremental vertical subsidence at the Swamp 148 cross line are less than the maximum predicted values.

It is therefore considered that the ground movements measured using the swamp cross lines are consistent with the predictions provided in Report No. MSEC1082 which supported the SMP Application for LW19.

2.8. ALS / LiDAR surveys

Changes in surface level due to the mining in Area 3A have been measured using Airborne Laser Scan (ALS) / Light Detection and Ranging (LiDAR) surveys.

The initial surface level contours have been determined from the survey carried out in January 2010 before the commencement of LW6. The post-mining surface level contours have been determined from the subsequent surveys carried out in April 2011 after the completion of LW6, March 2012 after the completion of LW7, January 2013 after the completion LW8 and April 2023 after the completion of LW19.

The measured incremental changes in surface level due to the mining of LW19 only are shown in Fig. 2.8. These contours have been determined by taking the differences between the surface levels measured before and after the mining of this longwall. The data located outside the predicted limit of vertical subsidence (i.e. incremental 20 mm subsidence contour) have been removed for clarity.

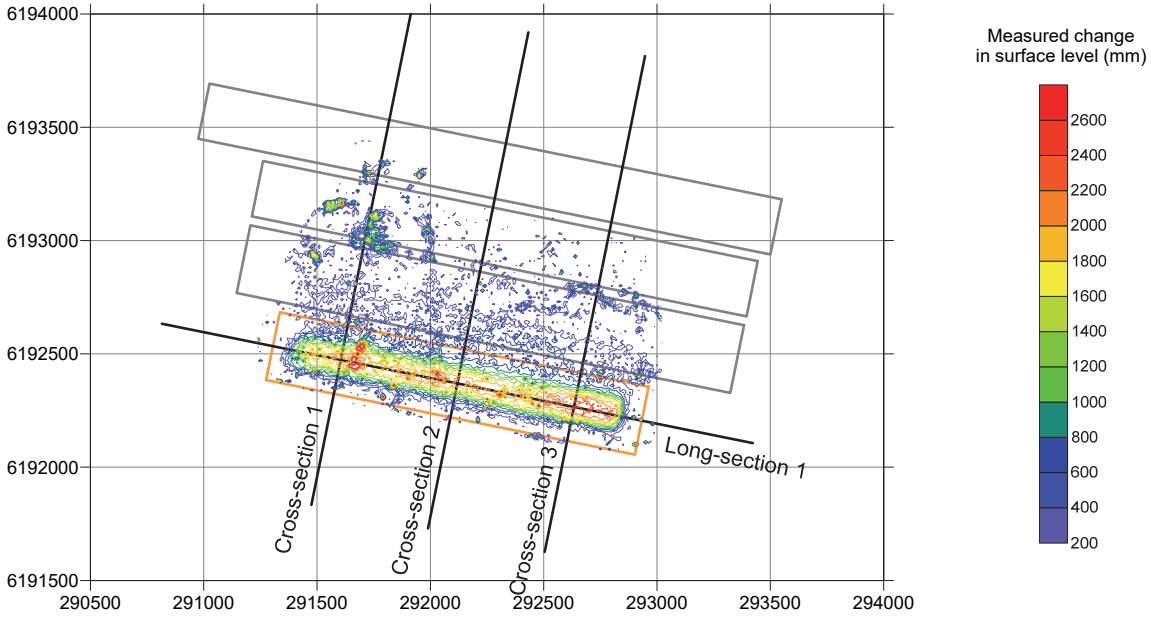

Fig. 2.8 Measured incremental changes in surface level due to the mining LW19

The measured total changes in surface level due to the mining of LW6 to LW8 and LW19 are shown in Fig. 2.9. These contours have been determined by taking the differences between the surface levels measured after the completion of LW19 from those measured before the commencement of LW6. The data located outside the predicted limit of vertical subsidence (i.e. total 20 mm subsidence contour) have been removed for clarity.

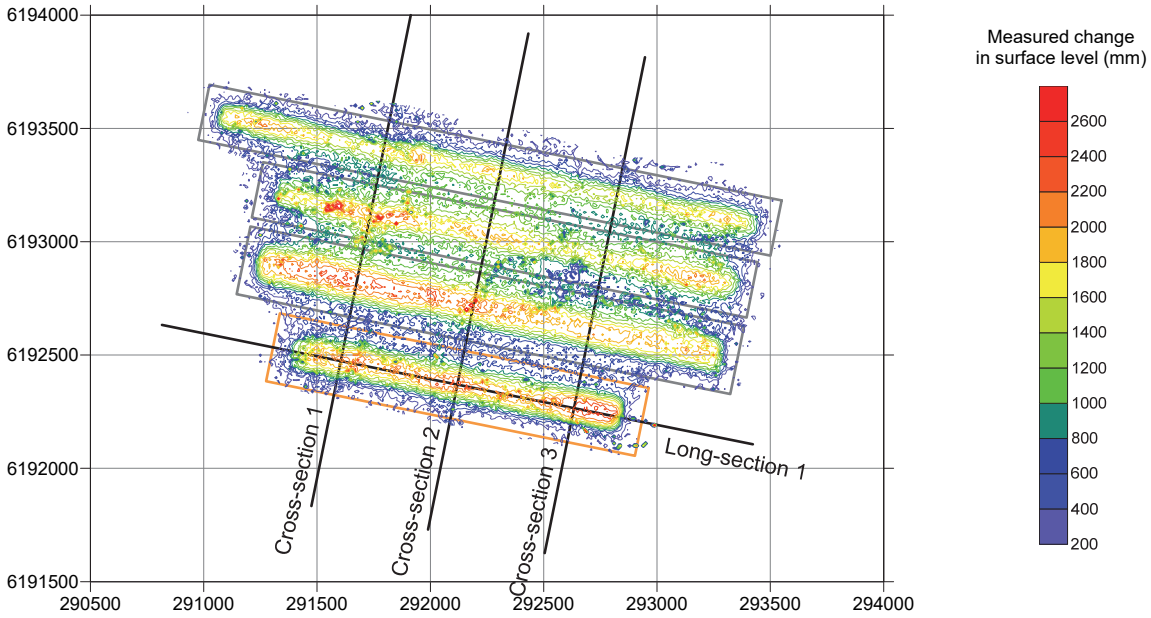

Fig. 2.9 Measured total changes in surface level due to the mining of LW6 to LW8 and LW19

The LiDAR surveys have an accuracy for absolute level in the order of ±100 mm. The accuracy of the measured changes in surface level (i.e. the difference between two surveys), therefore, is in the order of ±200 mm.

The contours of the measured changes in surface level, developed from the LiDAR surveys, show the changes in the heights of points at fixed positions in space (i.e. eastings and northings). This differs from traditional subsidence contours that include both the vertical and horizontal components of the movements of points fixed to the surface. Horizontal movements are usually included in the subsidence profiles, as traditional ground monitoring data is based on the movements of survey marks that are fixed to the ground.

The contours can contain artefacts (i.e. locally increased or decreased movements), particularly in the locations of steeply incised terrain, such as at the cliffs and steep slopes. These artefacts can be seen in Fig. 2.8 and Fig. 2.9 as the localised areas of dark purple to red contours above the longwalls and the lower level subsidence outside the extents of the longwalls.

The change in surface level at a fixed position in space (i.e. easting and northing), therefore, can be large in the locations of cliffs and steep slopes and does not provide a true indication of the actual vertical subsidence at a point on the ground. However, where the ground is reasonably flat, the contours of the measured changes in surface level should provide a good indication of the actual vertical subsidence.

Comparisons of the measured changes in surface level and the predicted vertical subsidence along three cross-sections and one long-section are provided in Fig. 2.10 to Fig. 2.13. The locations of these sections are indicated in Fig. 2.8 and Fig. 2.9. The predicted profiles of vertical subsidence have been derived from the predicted subsidence contours illustrated in Report No. MSEC1082.

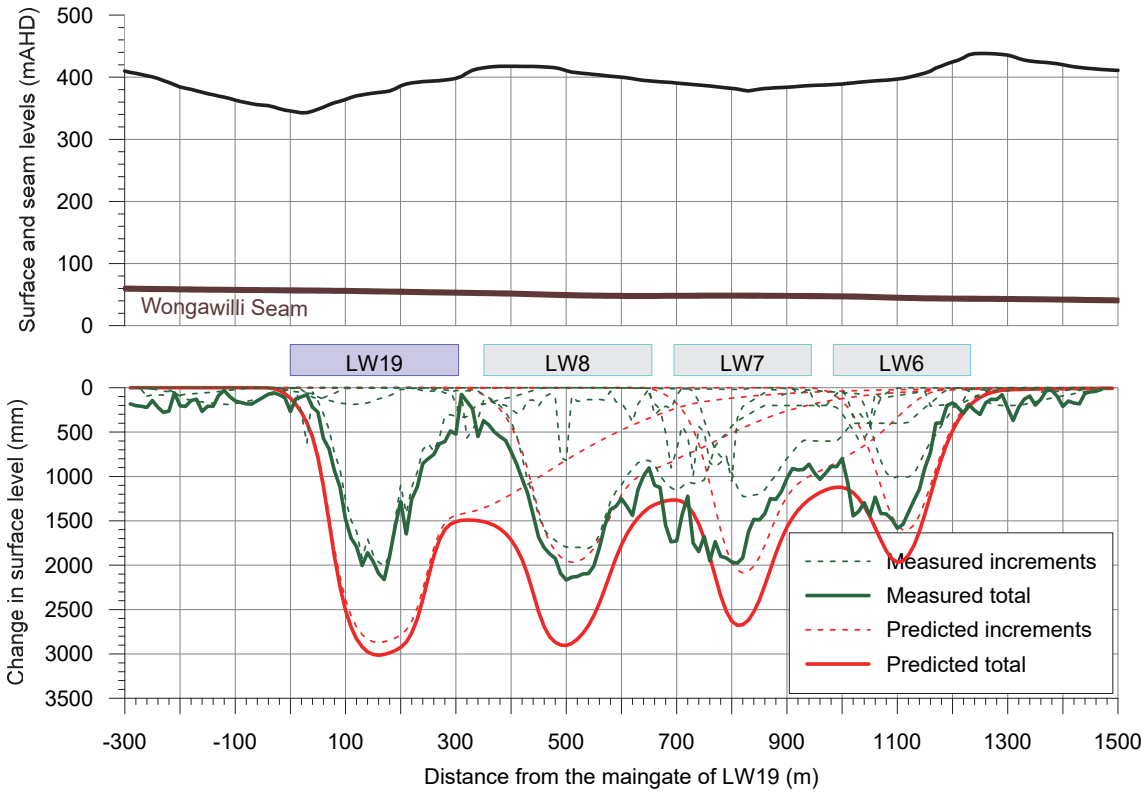

Fig. 2.10 Measured changes in surface level and predicted vertical subsidence along Cross-section 1

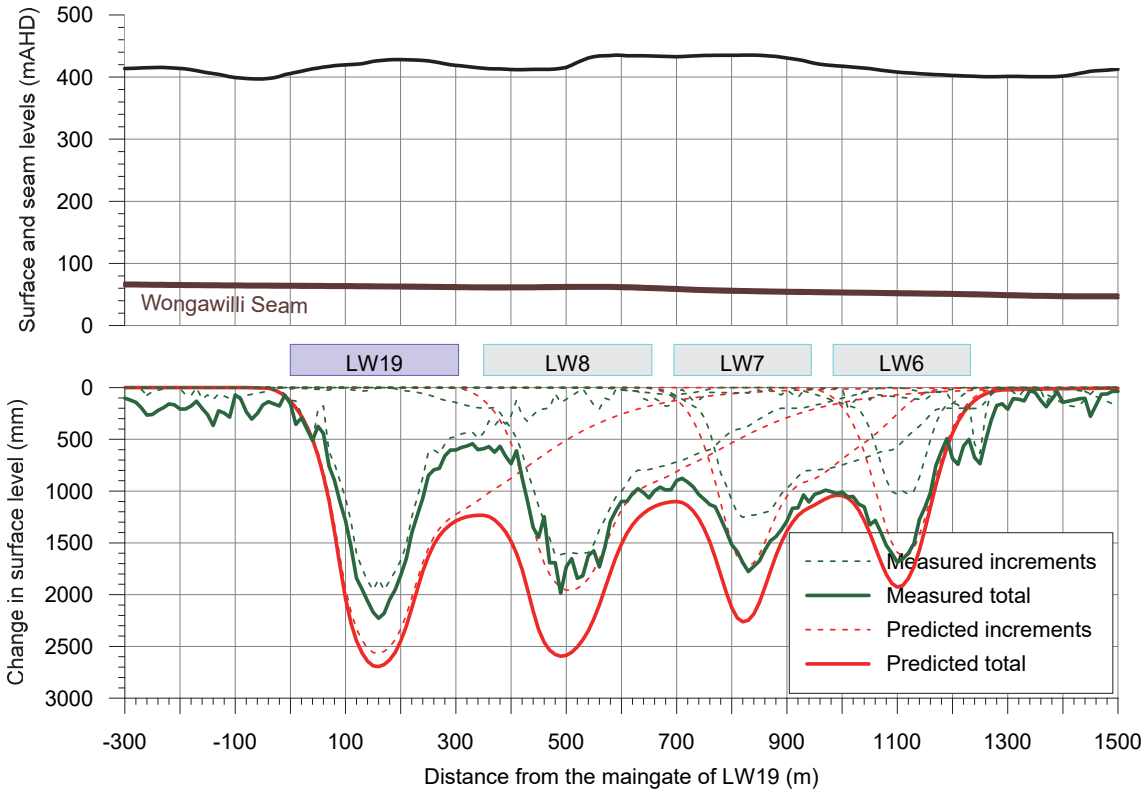

Fig. 2.11 Measured changes in surface level and predicted vertical subsidence along Cross-section 2

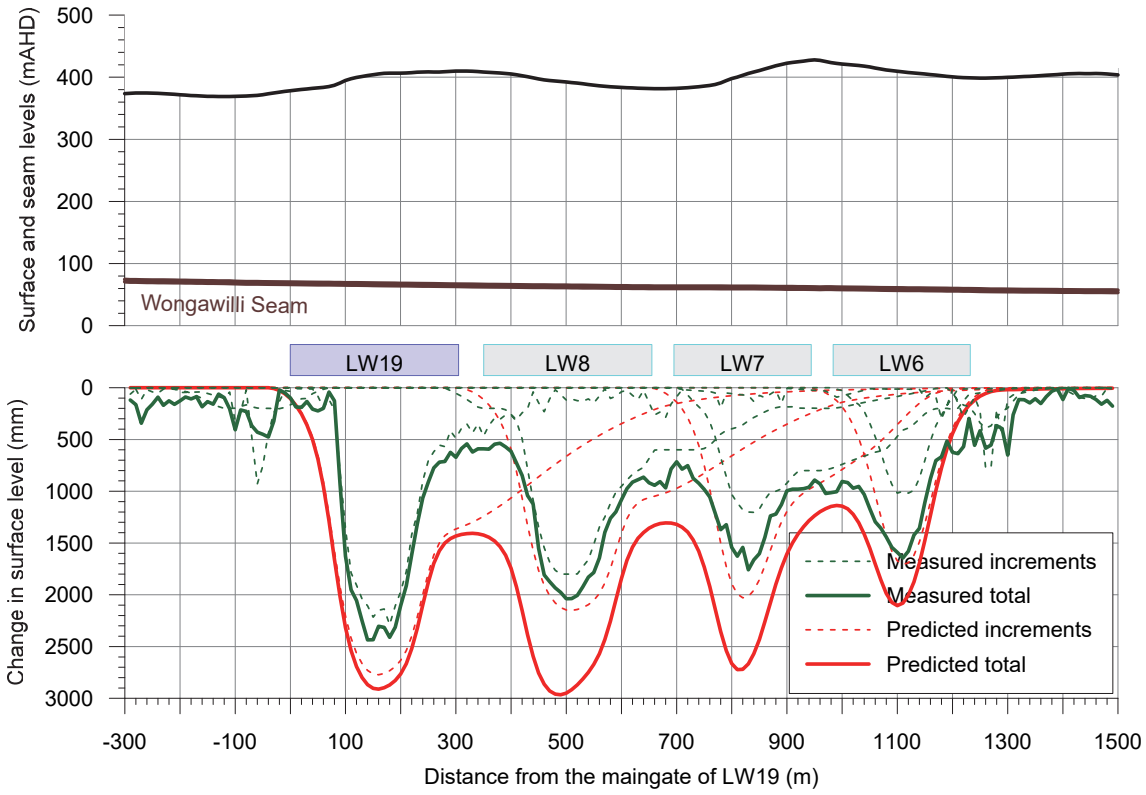

Fig. 2.12 Measured changes in surface level and predicted vertical subsidence along Cross-section 3

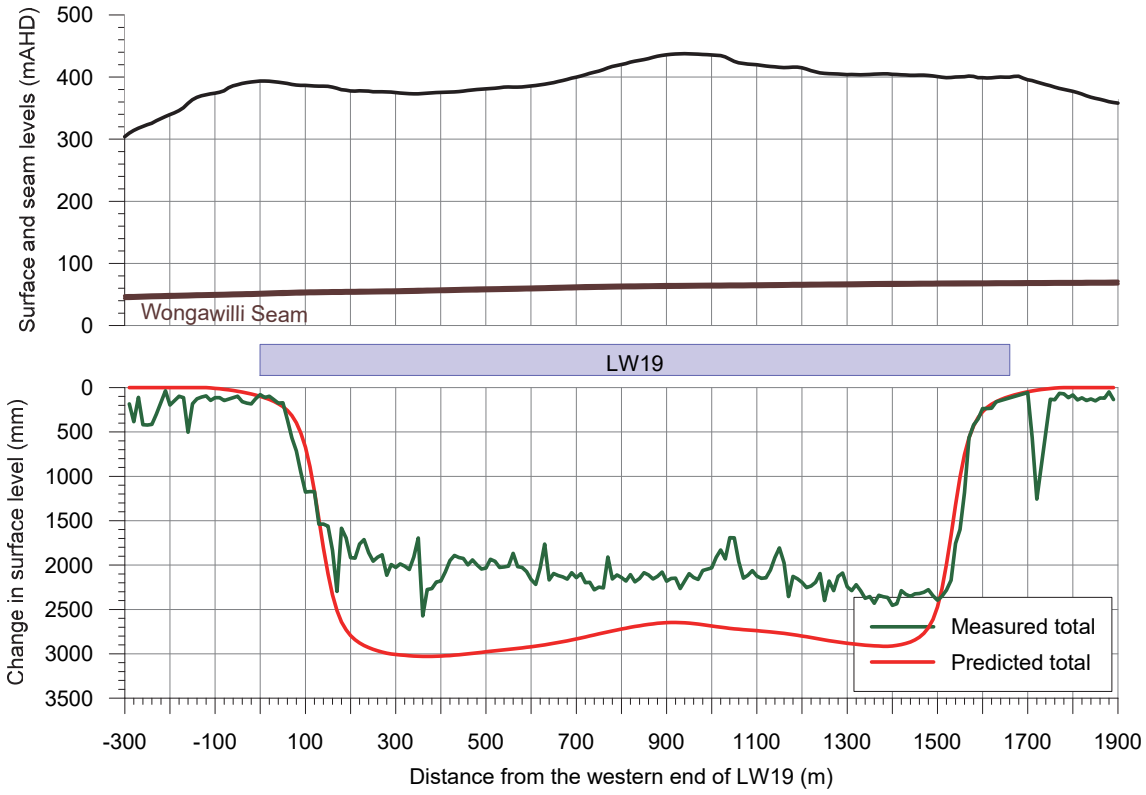

Fig. 2.13 Measured changes in surface level and predicted vertical subsidence along Long-section 1

The profiles of the measured changes in surface level reasonably match the predicted profiles of vertical subsidence along the cross-sections and long-section. The maximum measured changes in surface level above each of the longwalls are less than the maximum predicted values. Also, the measured changes in surface level above each of the chain pillars are similar to or less than the predicted values in these locations.

The measured changes in surface level are greater than the predicted vertical subsidence outside the mining area for each of the cross-sections and long-section. However, this is due to the measurement tolerance and the effects of the horizontal movements and sloping terrain on the LiDAR surveys. The differences between the measured and predicted movements above solid coal are generally in the order of accuracy of the LiDAR surveys of ±200 mm. There are localised areas where these differences exceed the measurement tolerance; however, these are artefacts of the LiDAR surveys and are not real movements.

It can be inferred from the slopes of the profiles, that the measured changes in grade are similar to the predicted tilts along the cross-sections and long-section. It is not possible to derive the curvature nor the horizontal movements from the LiDAR surveys.

It is considered that the ground movements measured using the LiDAR surveys are consistent with the predictions provided in Report No. MSEC1082 which supported the SMP Application for LW19.

3.1. Surface deformations

Surface deformations due to the mining of LW19 have been identified by the IMC Environmental Field Team and are described in the accompanying IMC landscape report. The locations of the surface deformations identified during and after the mining of LW19 are illustrated in Fig. 3.1.

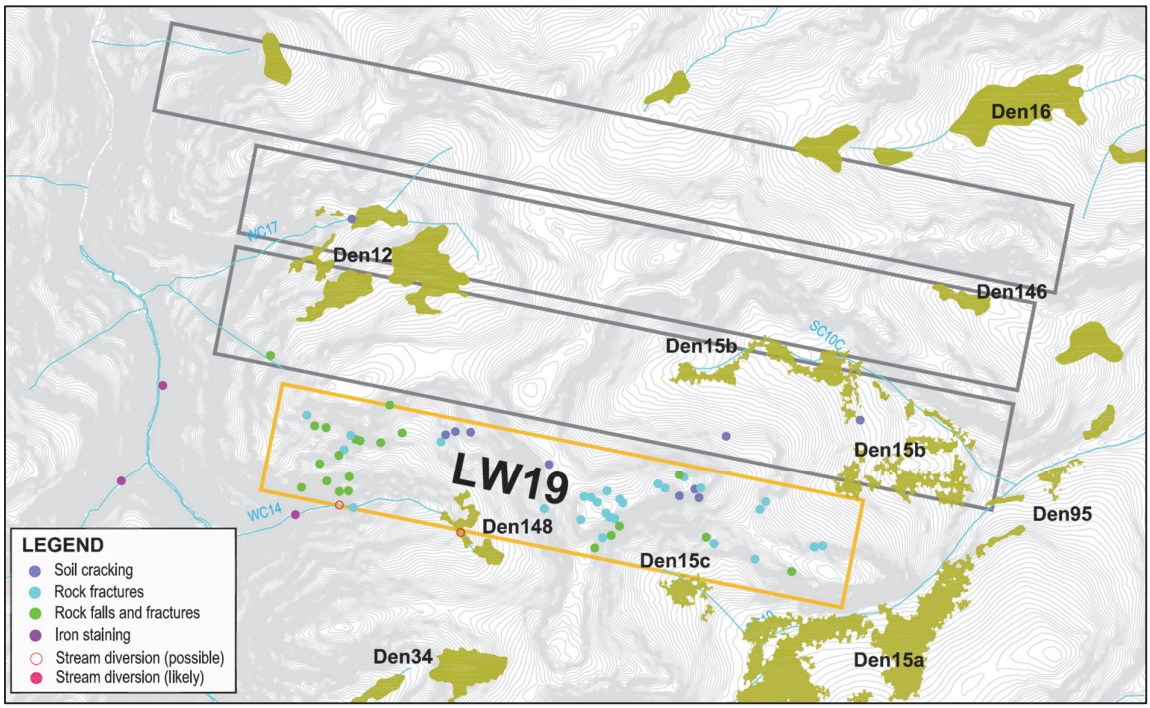

Fig. 3.1 Surface deformations due to the mining of LW19

Soil cracking (i.e. blue circles) was identified in seven locations above LW19 and three locations above the previous LW7 and LW8. Rock fracturing (i.e. cyan circles) was identified in 26 locations and rockfalls (i.e. green circles) in 21 locations at the rock outcrops and minor cliffs on the sides of the ridgelines located above the mining area.

The soil crack and rock fracture widths were typically less than 50 mm in 24 locations (i.e. 59 % of cases), ranged between 50 mm and 100 mm in eight locations (i.e. 20 % of cases) and were greater than 100 mm in nine locations (i.e. 21 % of cases). The maximum crack width was 180 mm (LW19_020); however, one crack (LW19_006) had eroded and the overall deformation width was approximately 0.7 m.

Rockfalls (i.e. green circles) were identified in 20 locations above LW19 and one location above the previous LW8 at the rock outcrops and minor cliffs on the sides of the ridgelines. The largest rockfall occurred on the northern valley side of WC14 (LW19_056) and it had an estimated volume of approximately 110 m^3 (10 m wide x 2.8 m high and an average width of 4 m). The remaining rockfalls had estimated volumes of up to 1 m^3 in 10 locations and up to 10 m^3 in six locations.

Fracturing occurred in two locations along stream WC14 where it crosses the maingate of LW19 (LW19_043 and LW19_051) with lengths up to 10 m and widths up to 100 mm. Possible surface water flow diversions occur in these two locations. Previously observed fracturing along WC14 after LW8 (LW8_003) has been reactivated by LW19 with length up to 3 m and widths up to 40 mm.

No fracturing was observed along Wongawilli Creek due to the mining of LW19. However, gas release was observed in Pool 50 (LW19_029) during the mining of the longwall. Iron staining was also identified along stream WC14 (LW19_003), a hillslope on the valley of Wongawilli Creek (LW19_044) and along WC15 (LW19_045).

Further details of these surface deformations are provided in the accompanying IMC landscape report.

3.2. Natural features

The natural features near LW19 are shown in Drawing No. MSEC1345-02, in Appendix A, and include:

- Wongawilli Creek;
- Sandy Creek
- tributaries;
- cliffs;
- rock outcrops;
- steep slopes;
- swamps; and
- Aboriginal heritage sites.

The MSEC assessed impacts for the natural features due to the mining of LW19 are provided in Report No. MSEC1082 which supported the SMP Application for that longwall. More detailed assessments for the natural features are also provided in other consultants' reports that supported the SMP Application.

Comparisons between the MSEC assessments and the reported impacts for the natural features listed above due to the mining of LW19 are provided in Table 3.1. The reported impacts are based on those recorded by IMC Environmental Field Team, that are described in the accompanying landscape report.

Table 3.1 Assessed and reported impacts for the natural features due to LW19

Natural feature	MSEC assessed impacts	Reported impacts
Wongawilli Creek	Very localised additional **ponding** or **flooding** developing in the locations of existing pools, steps or cascades due to vertical subsidence or tilt.	No reported impacts due to the mining-induced vertical subsidence or tilt.
	Minor **fracturing** of the bedrock within 400 m of the longwalls due to strain.	No new fracturing or iron staining identified along the creek due to the mining of LW19. A gas release zone was observed in Pool 50 in January 2023 before the completion of LW19 and was observed again in April 2023 after the completion of mining. The gas release could indicate that fracture has occurred in the bedrock beneath the stream
	Low-likelihood that **surface water flow diversions** would occur due to fracturing of the bedrock.	No new surface water flow diversions (i.e. Type 3 impacts) identified along the creek due to the mining of LW19. One Type 3 impact was previously observed between LW6 and LW9, where fracturing was first observed during the mining of LW9.
Drainage lines (tributaries)	Localised additional **ponding**, **flooding** or **scouring** along sections of the drainage lines located directly above the longwall.	No reported impacts.
	Buckling and **fracturing** of the bedrock along the drainage lines above or within 400 m of the longwalls.	Multiple rock fractures and some associated uplift in two locations along WC14 (LW19_043 and LW19_051) with lengths up to 10 m and widths up to 100 mm. Previously observed fracturing along WC14 after LW8 (LW8_003) has been reactivated by LW19 with length up to 3 m and widths up to 40 mm.
	Surface water flow diversions into the dilated strata beneath the drainage lines which are directly mined beneath.	Possible surface water flow diversions in two locations along WC14 (LW19_043 and LW19_051) where the creek crosses above the maingate of LW19. Rock fracturing in the stream bed runs across main flow path and no surface water flow present at time of inspections.

Natural feature	MSEC assessed impacts	Reported impacts
Drainage lines (tributaries) (continued)	**Water quality** – refer to the accompanying water quality report. **Terrestrial ecology** – refer to the accompanying terrestrial ecology report. **Aquatic ecology** – refer to the accompanying aquatic ecology report.	
Cliffs	Fracturing resulting in isolated **rockfalls** for the cliffs that are located within and just outside the mining area. Large-scale cliff instabilities are not expected.	No reported impacts to the cliffs within the valley of Wongawilli Creek (DA3-CF16 to DA3-CF18) which are located outside the mining area.
Rock outcrops	Fracturing of bedrock which could result in **rockfalls** along the exposed rockfaces. Fracture widths up to approximately 300 mm previously observed at the Mine.	Fracturing causing localised rock falls identified in 21 locations at the rock outcrops and minor cliffs on the sides of the ridgelines above LW8 and LW19. Refer to the IMC landscape report for further details.
Steep slopes	**Soil slippage** resulting in tension cracks and compression ridges. Soil cracks between approximately 100 mm and 400 mm previously observed at the Mine.	Soil cracking and rock fracturing observed in 36 locations above LW8 and LW19. Crack widths typically up to 180 mm; however, in one case the crack had eroded with an overall width of approximately 0.7 m. Refer to the IMC landscape report for further details.
Swamps	**Fracturing** of the underlying strata which could result in the **diversion of surface water**.	Soil moisture lower than baseline in Swamp 148 (S148_01) and groundwater recession rate greater than baseline at Swamp 35b (35b_01). Refer to the IMC landscape report for further details.
Aboriginal heritage sites	Impacts on overhang sites including fracturing of sandstone, rock falls, or water seepage through joints which may affect artwork.	Rock fracturing and small rockfalls near cultural heritage sites Sandy Creek 21 (LW19_037) and DM15 (LW19_38). Refer to the accompanying cultural heritage report.

It is considered that the observed impacts on the natural features due to the mining of LW19 are consistent with the MSEC assessments provided in Report No. MSEC1082 which supported the SMP Application for that longwall. Further assessments of natural features have been provided by other specialist consultants on the project, which are described in the relevant reports accompanying the *End of Panel* report.

3.3. Built features

The built features near LW19 are shown in Drawing No. MSEC1345-03, in Appendix A, and include:

- Fire trails and four-wheel drive tracks;
- Sandy Creek Waterfall;
- Cordeaux Dam; and
- Survey control marks.

The MSEC assessed impacts for the built features due to the mining of LW19 are provided in Report No. MSEC1082 which supported the SMP Application for that longwall.

Comparisons between the MSEC assessments and the reported impacts for the built features due to the mining of LW19 are provided in Table 3.2. The reported impacts are based on those recorded by IMC Environmental Field Team, that are described in the accompanying landscape report.

Table 3.2 Assessed and reported impacts for the built features due to LW19

Built feature	MSEC assessed impacts	Reported impacts
Fire trails and four-wheel drive tracks	Cracking of unsealed road surfaces.	Soil cracking observed in one location (LW19_026) along Fire Road 6F due to the mining of LW19. Cracking also observed in bushland near the trails and tracks, with widths typically ranging between 10 mm and 180 mm. Refer to the IMC landscape report for further details.
Sandy Creek Waterfall	Adverse impacts not anticipated.	No reported impacts to the waterfall due to the mining of LW19.
Cordeaux Dam	Adverse impacts not anticipated.	No reported impacts on the dam walls. Refer to associated groundwater report for further details on impacts to the stored water.
Survey control marks	Vertical and horizontal movements which could require re-establishment.	No reported damage to the survey control marks. The marks to be re-established after completion of mining, as required.

It is considered that the observed impacts on the built features due to the mining of LW19 are similar to or less than the MSEC assessments provided in Report No. MSEC1082 which supported the SMP Application for that longwall.

4.0 SUMMARY

The mine subsidence effects due to the mining of LW19 were measured using the Wongawilli Creek closure lines, Sandy Creek Waterfall closure lines, Area 3A 3D monitoring points, 330 kV transmission line monitoring points, Tributary cross lines, Swamp cross lines and Airborne laser scans of the area.

The measured ground movements after the mining of LW19 are generally similar to or less than the predicted values based on the subsidence model outlined in Report No. MSEC1082 which supported the SMP Application for LW19. The measured closure at the Wong X C-Line of 216 mm is greater than the maximum predicted value of 210 mm that occurs slightly downstream. However, the exceedance of 6 mm is similar to the order of survey tolerance. The measured closure at the Swamp 148 cross line of 154 mm is also greater than the maximum predicted value of 150 mm. Again, the exceedance is similar to the order of survey tolerance.

Elsewhere, the maximum measured subsidence effects are less than the maximum predicted values. It is considered, therefore, that the ground movements measured due to the mining of LW19 are consistent with the predictions provided in Report No. MSEC1082 which supported the SMP Application for LW19.

Soil cracking and rock fracturing were observed directly above the existing LW8 and active LW19. The crack and fracture widths were typically up to 180 mm; however, in one case the crack had eroded and the overall deformation width was approximately 0.7 m. It was assessed that soil and fracture widths between approximately 100 mm and 400 mm could occur directly above the extracted longwalls and that more isolated surface impacts could occur outside of the longwalls.

There were no new surface water diversions (i.e. Type 3 impact) observed along Wongawilli Creek due to the mining of LW19. However, gas release was observed in Pool 50 during the mining of this longwall.

Two possible surface water diversions were identified along stream WC14 where the creek crosses above the maingate of LW19. Rock fracturing in the stream bed runs across main flow path and no surface water flow present at time of inspections. It was assessed that surface water flow diversions could occur where the streams are directly mined beneath.

It is considered, therefore, that the observed surface impacts on the natural and built features, due to the mining of LW19, are consistent with the MSEC assessments provided in Report No. MSEC1082 which supported the SMP Application for LW19. Further assessments for the natural features have been provided by the specialist consultants on the project and the findings in this report should be read in conjunction with the findings provided in the accompanying specialist reports.

APPENDIX A. DRAWINGS

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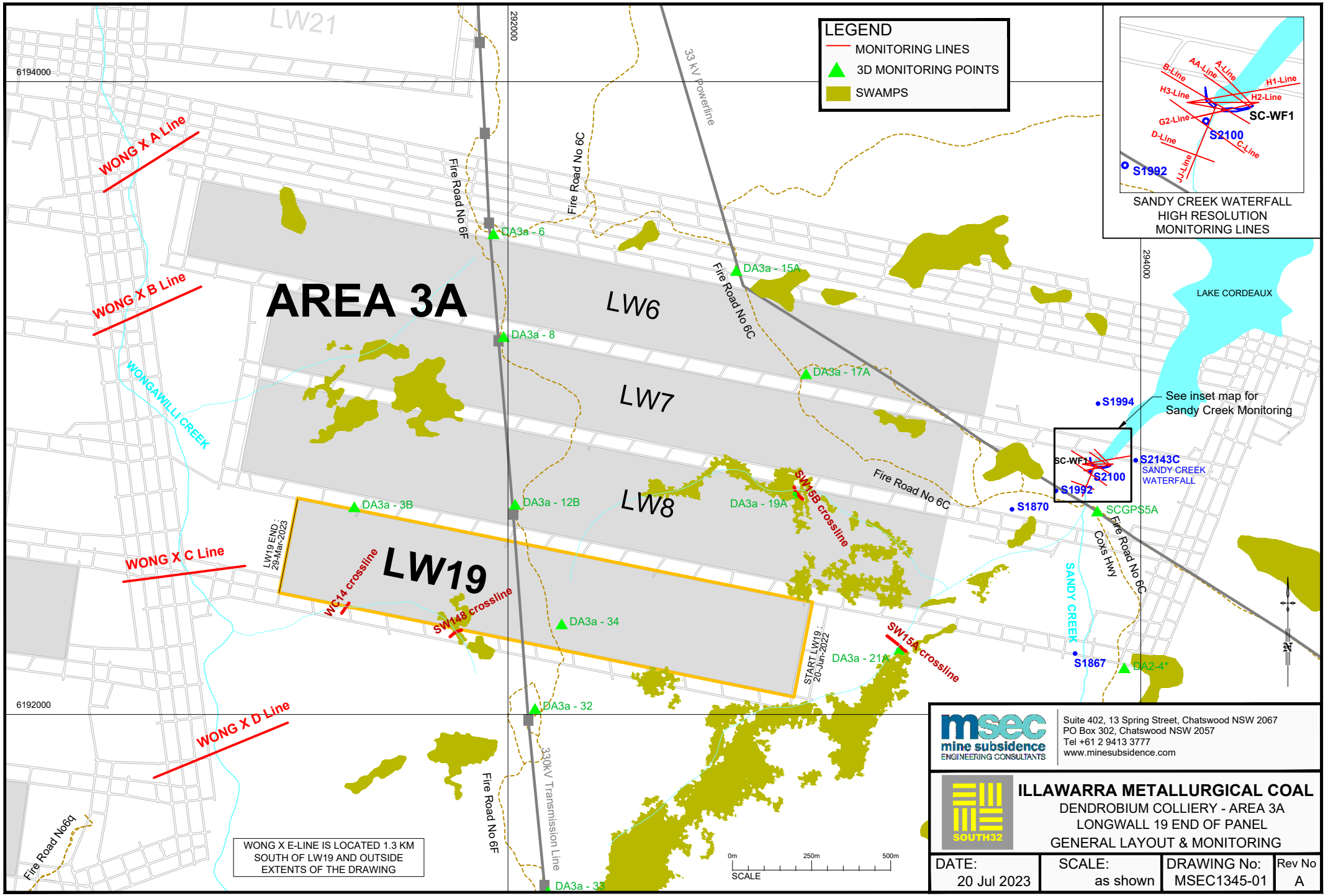

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SOUTH32

ILLAWARRA METALLURGICAL COAL

DENDROBIUM COLLIERY - AREA 3A
LONGWALL 19 END OF PANEL
GENERAL LAYOUT & MONITORING

DATE:	SCALE:	DRAWING No:	Rev No
20 Jul 2023	as shown	MSEC1345-01	A

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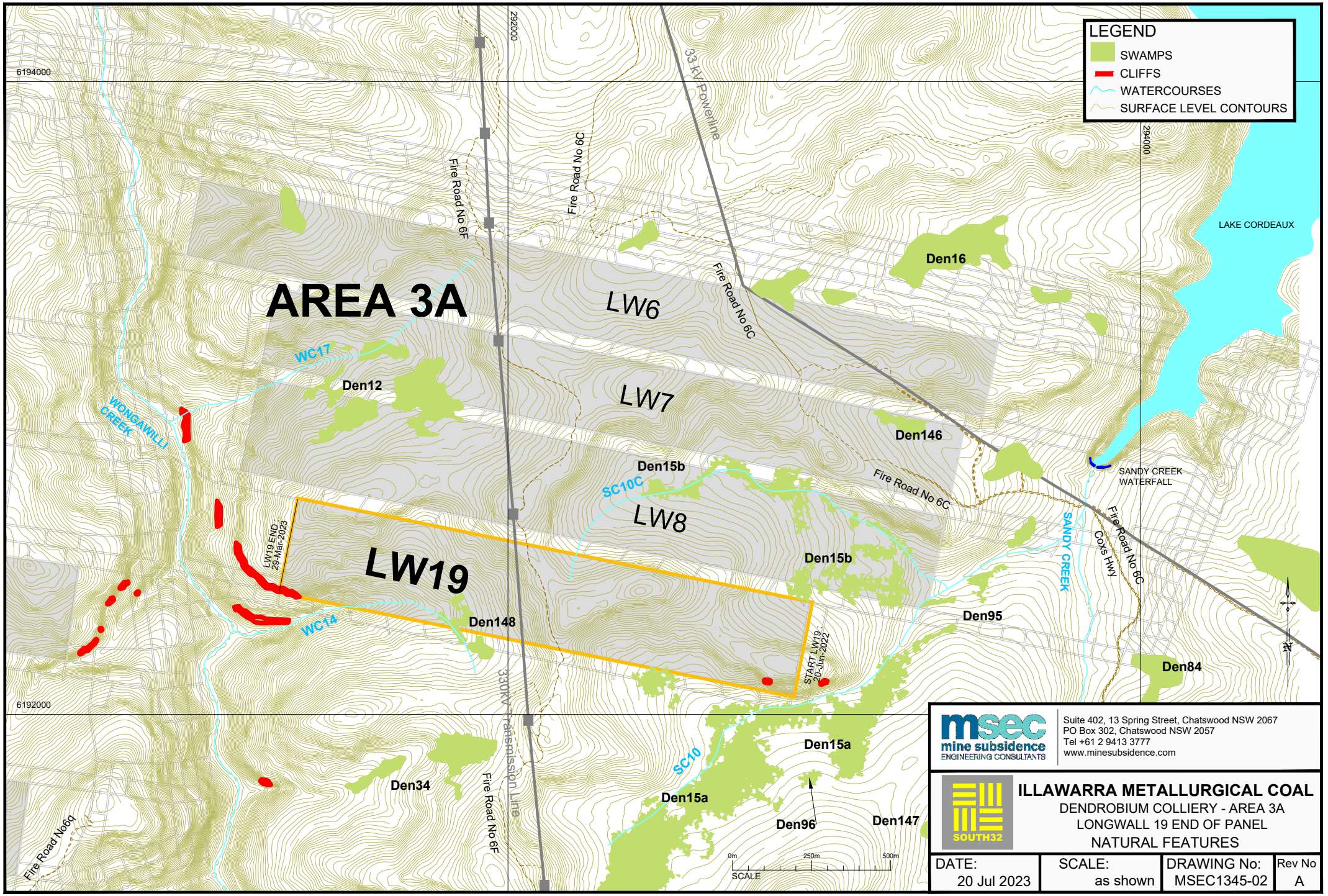

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ILLAWARRA METALLURGICAL COAL

DENDROBIUM COLLIERY - AREA 3A

LONGWALL 19 END OF PANEL

NATURAL FEATURES

DATE:	SCALE:	DRAWING No:	Rev No
20 Jul 2023	as shown	MSEC1345-02	A

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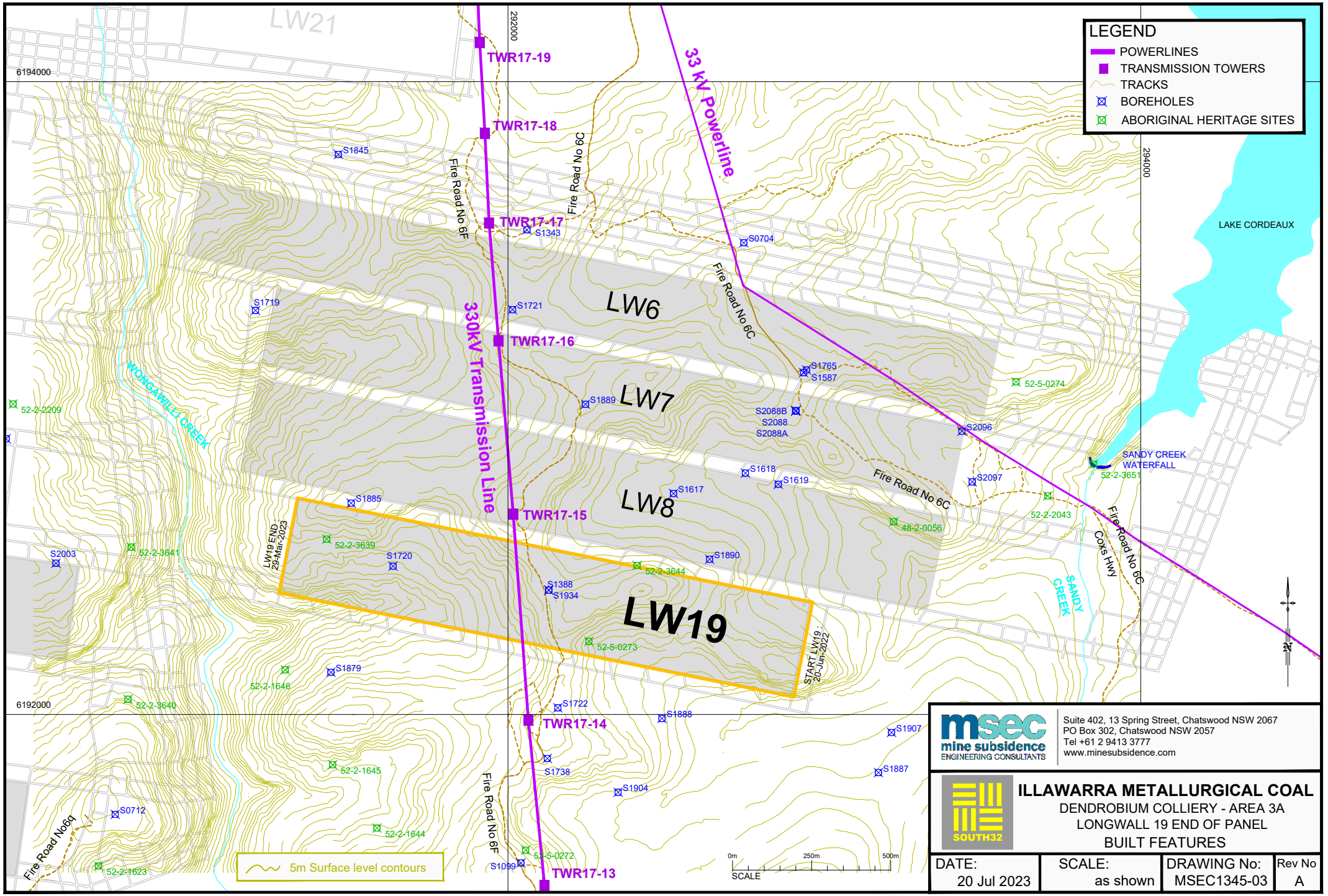

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DENDROBIUM COLLIERY - AREA 3A
LONGWALL 19 END OF PANEL
BUILT FEATURES

DATE:	SCALE:	DRAWING No:	Rev No
20 Jul 2023	as shown	MSEC1345-03	A

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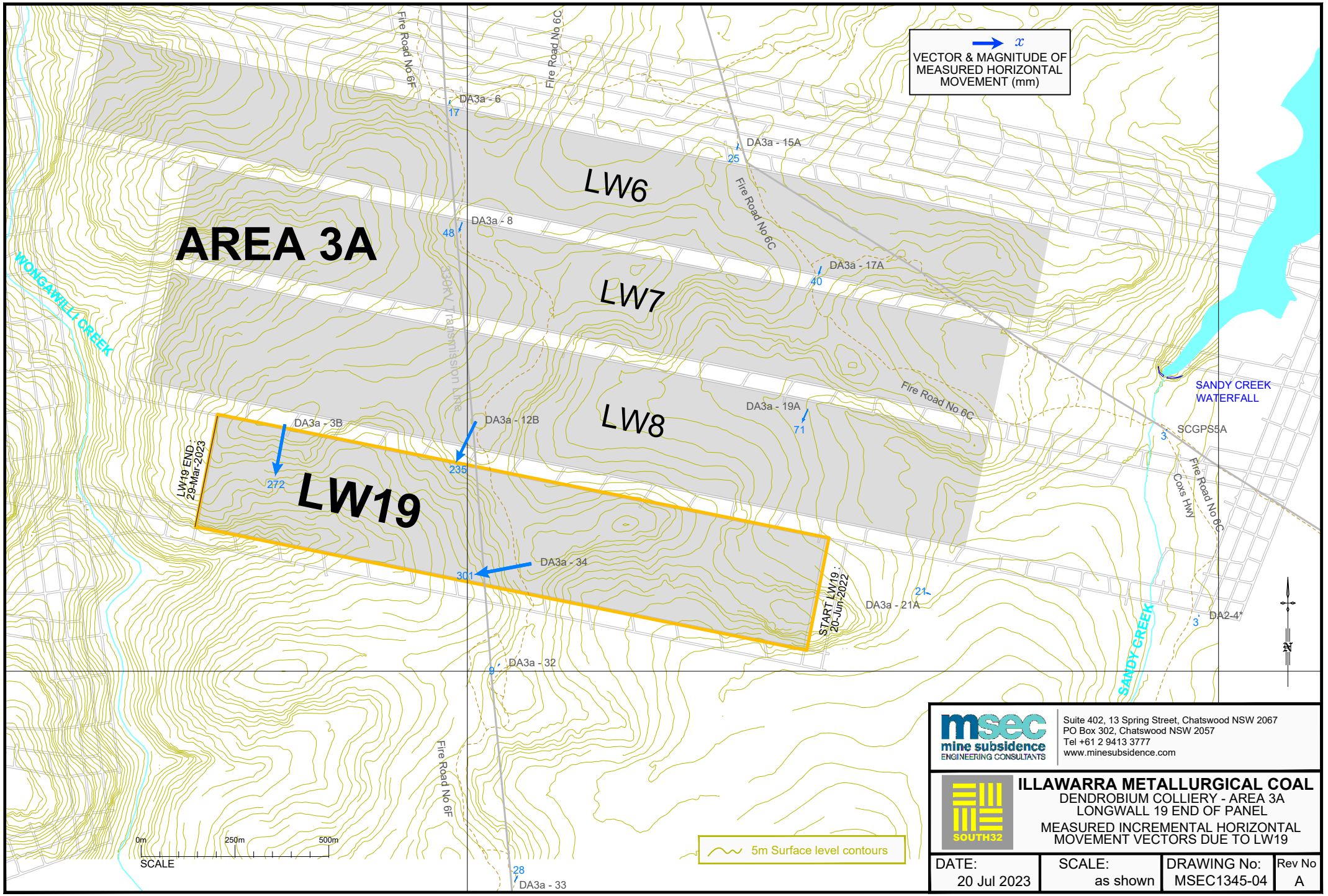

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ILLAWARRA METALLURGICAL COAL

DENDROBIUM COLLIERY - AREA 3A
LONGWALL 19 END OF PANEL
MEASURED INCREMENTAL HORIZONTAL MOVEMENT VECTORS DUE TO LW19

DATE:	SCALE:	DRAWING No:	Rev No
20 Jul 2023	as shown	MSEC1345-04	A