mine subsidence ENGINEERING CONSULTANTS

GM³

a mining and metals company

GM³:

Dendrobium – Area 3A – Longwall 19A

End of Panel Subsidence Monitoring Review Report for Dendrobium Longwall 19A

© MSEC SEPTEMBER 2024 | REPORT NUMBER: MSEC1436 | REVISION A

DOCUMENT REGISTER

Revision	Description	Author	Checker	Date
01	Draft issue	JB	KK	28 Aug 24
A	Final issue	JB	KK	5 Sep 24

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).

MSEC1234 (September 2022) – Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the Proposed Longwall 19A in Area 3A at Dendrobium Mine.

MSEC1384 (October 2023) – Dendrobium Mine – Area 3A – Modified commencing end of LW19A Updated predicted subsidence effects for Swamp 15a. Letter report supporting the modified commencing end of LW19A

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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1.1. Introduction

Golden Energy and Resources Pty Limited and M Resources Pty Limited (GM[3]), formally Illawarra Metallurgical Coal, has completed the mining of Longwall 19A (LW19A) 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. MSEC1436-01 in Appendix A.

LW19A is the fifth and last longwall in the series in Area 3A and it is located on the southern side of the existing Longwalls 6 to 8 and 19 (LW6 to LW8 and LW19). The mining of LW19A commenced on 2 November 2023 and the longwall was completed on 28 June 2024.

Mine Subsidence Engineering Consultants (MSEC) was previously commissioned by GM[3] to prepare subsidence predictions and impact assessments for LW19A. Report No. MSEC1234 (Rev. B) was issued on 27 September 2022 in support of the Subsidence Management Plan (SMP) Application for this longwall.

The commencing (i.e. eastern) end of LW19A was then shorted by approximately 145 m. MSEC prepared letter report MSEC1384, dated 10 October 2023, in support of the Modification Application.

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 LW19A; 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 LW19A.

Further details on the observed and assessed impacts for natural features due to the mining of LW19A 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 LW19A. 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 LW19A. 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 LW19A.

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. MSEC1436-01 in Appendix A. A summary of the as-extracted dimensions for LW6 to LW8, LW19 and LW19A is provided in Table 1.1.

Table 1.1 Mining geometry of the as-extracted longwalls in Area 3A

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
	LW19A	900	281	40

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 LW19A is therefore approximately 891 m. The longwall face width for LW19A excluding the first workings is approximately 270 m.

LW19A 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 LW19A are illustrated in Fig. 1.1.

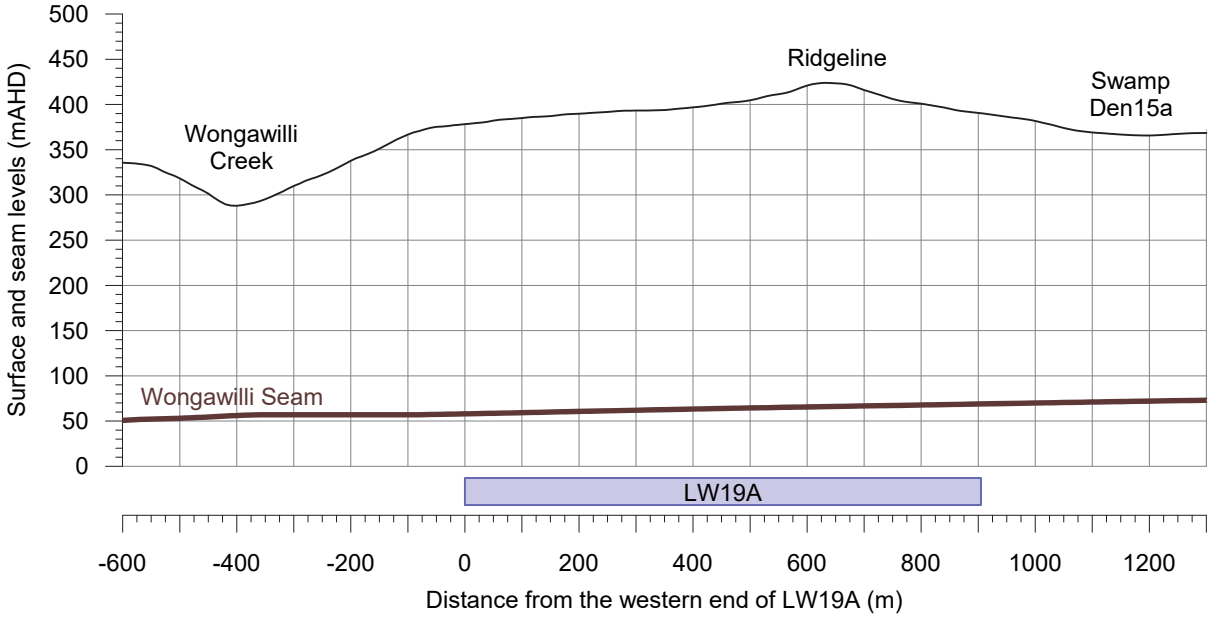

Fig. 1.1 Surface and seam levels along the centreline of LW19A

The depths of cover to the Wongawilli Seam directly above LW19A vary between 290 m and 360 m. The minimum depth of cover occurs along Drainage Line WC14 near the finishing (i.e. western) end of LW19A. The maximum depth of cover occurs along the ridgeline above the eastern part of the longwall. The average depth of cover directly above LW19A is 330 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 LW19A, 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 Nos. MSEC1234 and MSEC1384, which supported the SMP and Modification Applications, respectively.

2.1. Introduction

The mine subsidence effects due to the mining of Dendrobium LW19A 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. MSEC1436-01 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 the subsidence model presented in Report Nos. MSEC1234 and MSEC1384 which supported the SMP and Modification Applications, respectively, for LW19A.

2.2. Wongawilli Creek closure lines

The closure movements across Wongawilli Creek have been measured by GM[3] using 2D survey techniques at the Wong X A-Line to Wong X E-Line. The locations of the Wongawilli Creek closure lines are shown in Drawing No. MSEC1436-01. The Wong X E-Line is located more than 1 km south of LW19A and therefore it is outside the extents of the drawing.

The Wongawilli Creek closure lines have been measured after the mining of each of LW6 to LW8 in Area 3A, LW9 to LW18 in Area 3B and LW19 in Area 3A, LW21 in Area 3C and then LW19A in Area 3A. However, only the Wong X C-Line to Wong X E-Line were measured after the completion of LW19A. The Wong X A-Line was not measured due to its distance from LW19A. The Wong X B-Line was not able to be measured due to degradation of the survey prism.

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 LW19A

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Completion of LW19A	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) 9 September 2023 (end of LW21) 31 July 2024 (end of LW19A)	Completion of LW22

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 Areas 3A, 3B and 3C 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 LW19A 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 LW19A only.

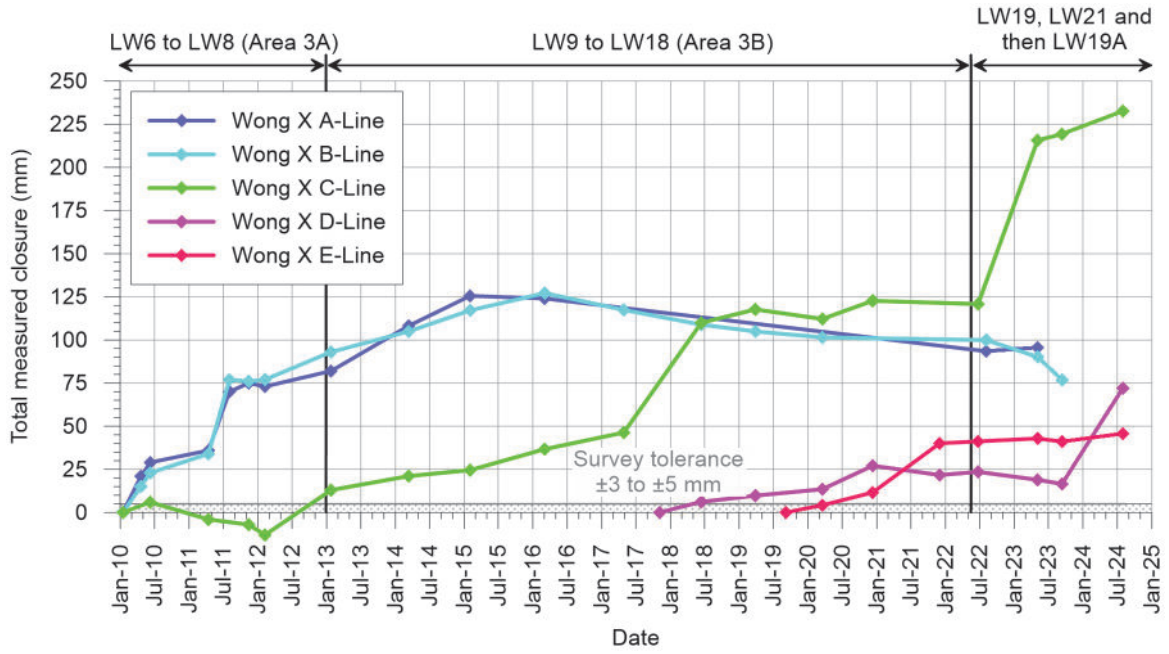

Fig. 2.1 Development of total closure for the Wongawilli Creek closure lines

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. MSEC1234. The measured and predicted total closures along Wongawilli Creek after the completion of LW19A are illustrated in Fig. 2.2.

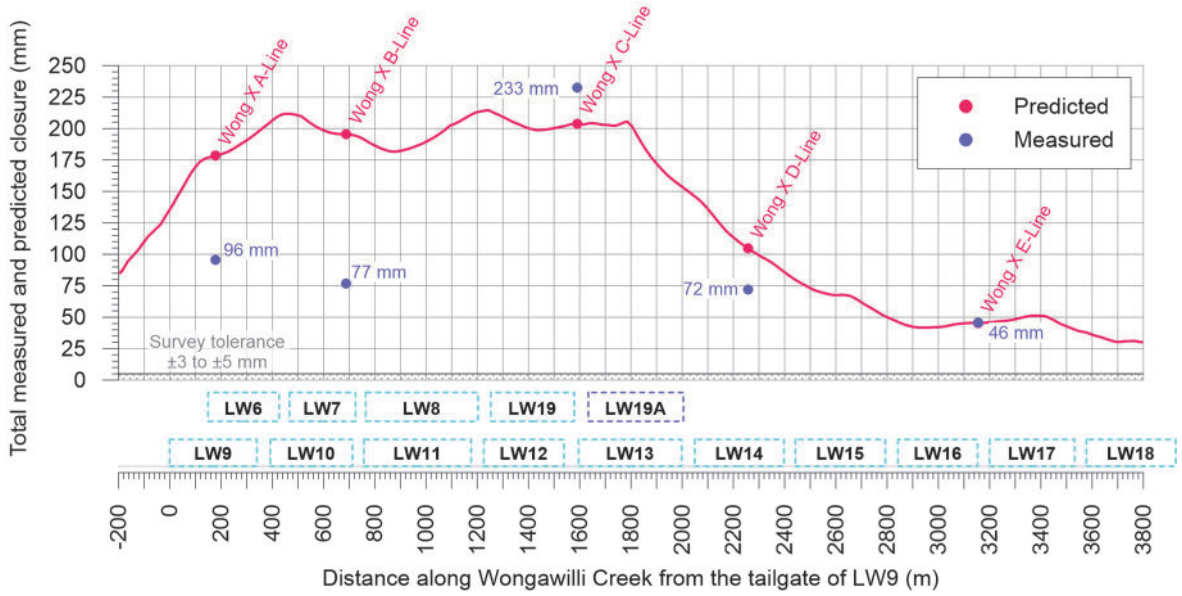

Fig. 2.2 Measured and predicted total closure along Wongawilli Creek after LW19A

A summary of the maximum measured and maximum predicted incremental closure movements for each of the Wongawilli Creek closure lines due to the mining of LW19A only is provided in Table 2.2. The Wong X A-Line and Wong X B-Line were not measured after the completion of LW19A.

Table 2.2 Measured and predicted incremental closure at the Wongawilli Creek monitoring lines due to the mining of LW19A only

Location	Longwalls	Measured incremental closure (mm)	Predicted incremental closure (mm)
Wong X C-Line	LW19A only	13	30
Wong X D-Line	LW19A only	55	30
Wong X E-Line	LW19A only	5	10

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

The measured incremental closure at the Wong X D-Line is greater than the predicted incremental value; however, the measured total closure at the monitoring line is less than the predicted total value (refer discussions below). The measured incremental closures at the Wong X C-Line and E-Line due to the mining of LW19A are less than the predicted incremental values.

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 2.3. The predicted total closures are based on the as-extracted finishing ends.

Table 2.3 Measured and predicted total closure at the Wongawilli Creek closure lines due to the mining of LW6 to 8 in Area 3, LW9 to LW18 in Area 3B and LW19 and LW19A in Area 3A

Location	Longwalls	Measured total closure (mm)	Predicted total closure (mm)
Wong X A-Line	LW6 to LW19	96	180
Wong X B-Line	LW6 to LW19	77	200
Wong X C-Line	LW6 to LW19A	233	210 at Wong X C-Line *(220 mm downstream)*
Wong X D-Line	LW13 to LW19A	72	110
Wong X E-Line	LW15 to LW19A	46	50

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

The measured total closure at the Wong X C-Line of 233 mm is greater than the predicted total closure of 210 mm in that location. The exceedance by +23 mm at this monitoring line represents +11 % of the predicted 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 of 220 mm located slightly downstream and adjacent to the previous LW19. The exceedance by +13 mm represents +6 % of the maximum predicted value and it is within the order of the accuracy of the prediction method.

The measured total closures at the remaining monitoring lines are less than the predicted total values. It is noted that the measured and predicted closures at the Wong X A-Line and Wong X B-Line are after the completion of LW19 and the measured and predicted closures at the Wong X D-Line and Wong X E-Line are after the completion of LW19A.

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 Nos. MSEC1234 and MSEC1384 which supported the SMP and Modification Applications, respectively, for LW19A.

2.3. Sandy Creek Waterfall closure lines

Closure across Sandy Creek Waterfall (SCW) has been measured by GM[3] 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. MSEC1436-01. 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 2.4. 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 and LW19A with the base survey carried out on 2 September 2021.

Table 2.4 Survey dates for the HRS SCW closure lines for LW19A

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Base survey before the commencement of LW19A, fortnightly surveys for the first 600 m of mining and then final survey at the completion of LW19A	2 September 2021 (base survey) 12 April 2023 (end of LW19) 27 September 2023 (end of LW21) 20 October 2023 (before start of LW19A), then approximate fortnightly surveys to 2 July 2024 (end of LW19A)	Monthly surveys during LW22 until the Technical Committee agree to the cessation of monitoring

The monitoring results were included in the subsidence review reports (MSEC1387, Rev. R01 to R07) which were issued during and after the mining of LW19A. 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 due to the mining of LW19A only is illustrated in Fig. 2.3. This figure illustrates the additional movements since the base survey carried out on 20 October 2023 before the commencement of LW19A.

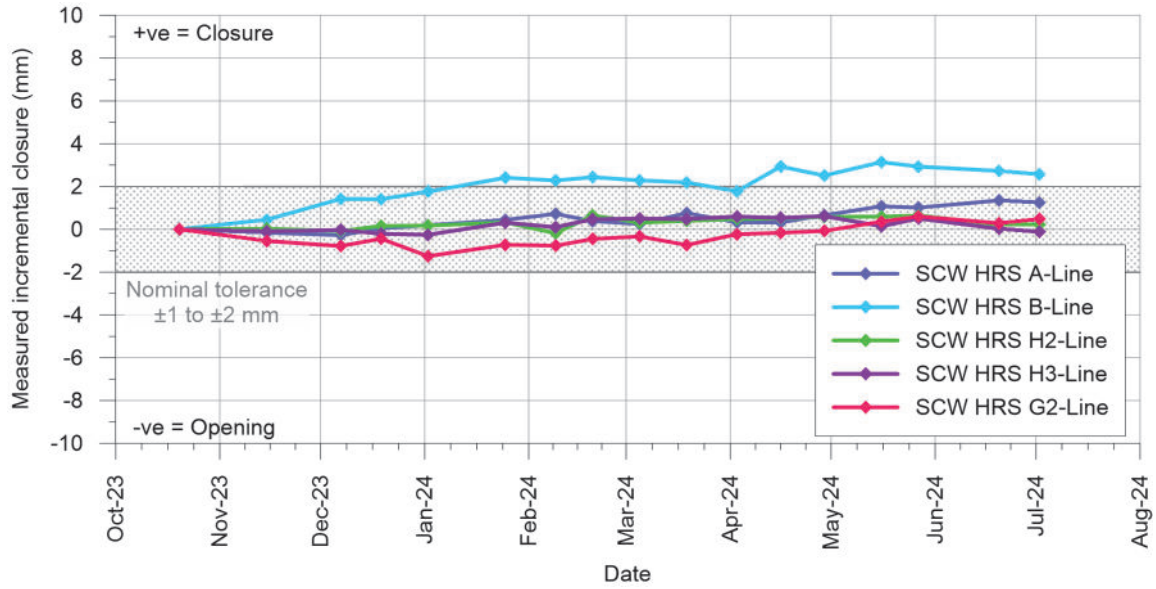

Fig. 2.3 Measured incremental closures for the HRS SCW closure lines due to LW19A only

A summary of the maximum measured and predicted incremental movements for each of the HRS SCW closure lines due to the mining of LW19A is provided in Table 2.5. The measured incremental values are based on the latest survey carried out on 2 July 2024.

Table 2.5 Maximum measured and maximum predicted incremental movements for the HRS SCW closure lines due to the mining of LW19A

Location	Measured incremental closure (mm)	Predicted incremental closure (mm)
A-Line	+1.3	±2
B-Line	+2.6	
H2-Line	+0.2	
H3-Line	-0.1 (opening)	
G2-Line	+0.5	

The accuracies of the measured closure movements are in the order of ±1 mm to ±2 mm. The historical monitoring data also indicates natural valley closure occurs during and after the summer periods and natural valley opening occurs during and after the winter periods. The seasonal variation is the order of ±1 mm to ±2 mm.

In the latest survey, the measured incremental closure at the SCW HRS B-Line was 2.6 mm. The measured value is similar to or slightly greater than the predicted incremental closure of ±2 mm consisting of survey tolerance and environmental effects.

The closure measured at the SCW HRS B-Line increased by +1.2 mm between the surveys carried out on 3 April and 16 April 2024. Very heavy rainfall occurred between these two surveys with the maximum 24 hour rolling cumulative rainfall measured at Vent Shaft 6 of 119 mm on 6 April 2024. It is likely that the step change in the closure was influenced by this heavy rainfall event. There has little to no measurable change in the closure measured at the SCW HRS B-Line since the survey carried out on 16 April 2024. There have been small variations which are in the order of survey tolerance.

Elsewhere, the measured incremental movements for the HRS SCW closure lines were less than ±2 mm and are within the nominal tolerance consisting of survey tolerance and environmental effects. That is, the mining-related movements for the SCW HRS A-Line, H2-Line, H3-Line and G2-Line were not measurable outside the nominal accuracy.

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, LW19 and LW19A.

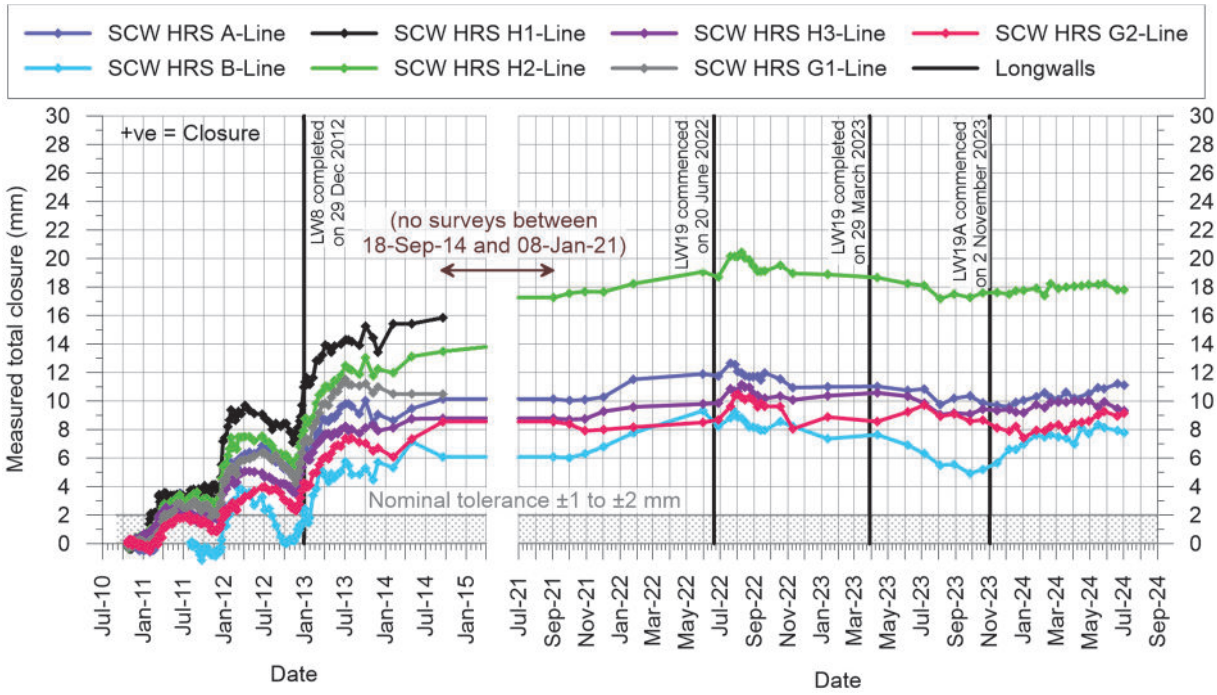

Fig. 2.4 Measured total closures for the HRS SCW closure lines due to LW6 to LW8, LW19 and LW19A

A summary of the maximum measured and predicted total movements for each of the HRS SCW closure lines due to the mining of LW6 to LW8, LW19 and LW19A is provided in Table 2.6. The measured total values are based on the latest survey carried out on 2 July 2024.

Table 2.6 Maximum measured and maximum predicted total movements for the HRS SCW closure lines due to the mining of LW6 to LW8, LW19 and LW19A

Location	Measured total closure (mm)	Predicted total closure (mm)
A-Line	+11	+20
B-Line	+8	
H2-Line	+18	
H3-Line	+9	
G2-Line	+9	

The maximum measured total closure is +18 mm at the HRS H2-Line and it is less than the predicted total closure of 20 mm. The majority of the measured closure occurred during the mining of the previous LW6 to LW8. There has been no measurable change to the maximum measured total closure since the commencement of the previous LW19.

It is considered that the ground movements measured using the SCW HRS closure lines are consistent with the predictions provided in Report Nos. MSEC1234 and MSEC1384 which supported the SMP and Modification Applications, respectively, for LW19A.

2.4. Dendrobium Area 3A three-dimensional monitoring points

Far-field horizontal movements near LW19A have been measured by GM[3] using the Dendrobium Area 3A 3D monitoring points (DA3A 3D) monitoring points. The locations of these monitoring points are shown in Drawing No. MSEC1436-01.

The survey dates for the DA3A 3D monitoring points are provided in Table 2.7.

Table 2.7 Survey dates for the DA3A 3D monitoring points for LW19A

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Completion of LW19A	15 January 2010 (base survey) 14 April 2011 (end of LW6) 31 January 2012 (end of LW7) 25 January 2013 (end of LW8) 05 May 2023 (end of LW19) 26 July 2024 (end of LW19A)	None for Area 3A

The measured incremental horizontal movement vectors for DA3A 3D monitoring points due to the mining of LW19A are shown in Drawing No. MSEC1436-04. The accuracies of the measured absolute positions (i.e. eastings and northings) are in the order of ±20 mm.

The maximum measured incremental horizontal movement is 270 mm at Mark DA3a-32 located directly above LW19A. The next greatest measured incremental horizontal movement is 251 mm at Mark DA3a-34 located above the adjacent LW19. These two survey marks are located near the top of a north-south orientated ridgeline that crosses directly above the longwalls. The orientations of the vectors are in the downslope direction and skewed towards the direction of longwall retreat.

Elsewhere, the measured incremental horizontal movements are 68 mm or less. The orientations of these vectors are generally towards the mining area. However, where the magnitudes are small (i.e. 25 mm or less), the orientations are less reliable.

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.

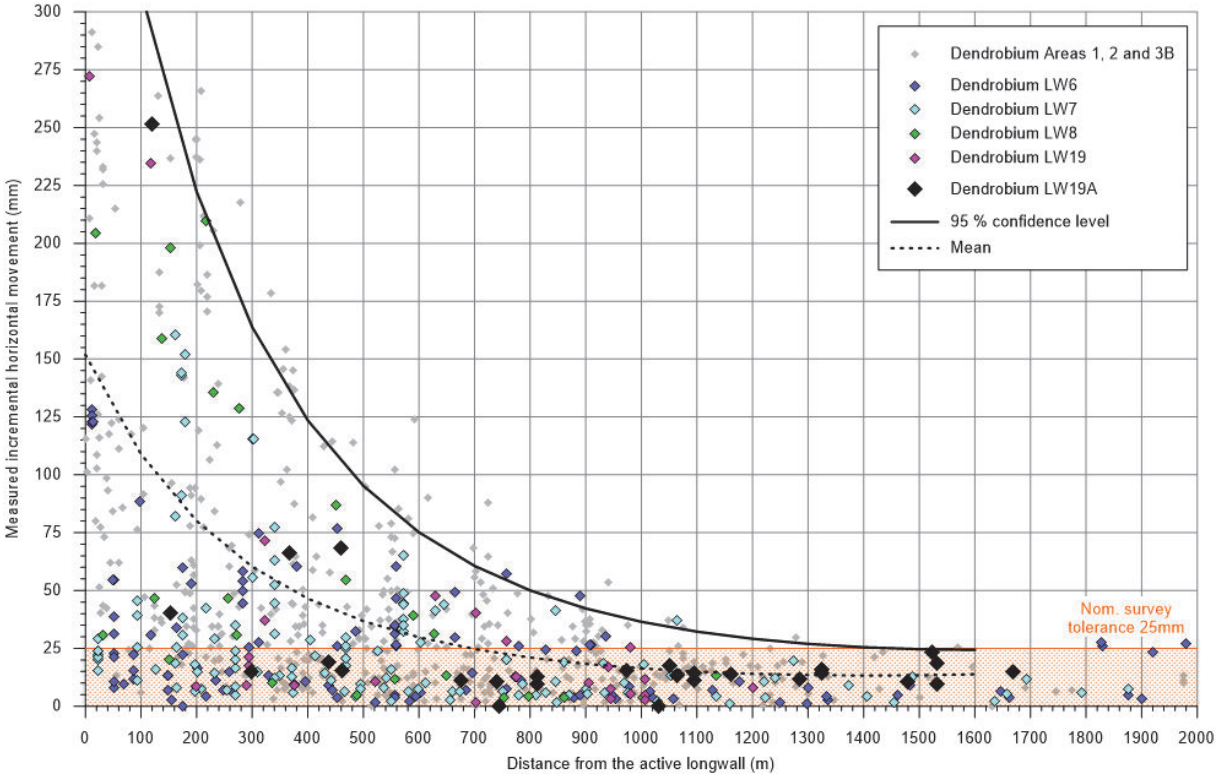

Fig. 2.5 Measured incremental horizontal movements in Area 3A at Dendrobium Mine

The measured incremental horizontal movements due to the mining of LW19A (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, green and magenta diamonds).

2.5. 330 kV transmission line monitoring

The mine subsidence effects for the 330 kV transmission line have been measured by GM[3] using 2D monitoring points located on and around Towers TWR17-13 to TWR17-16. The locations of the transmission towers are shown in Drawing No. MSEC1436-03. The survey dates for the 330 kV transmission line for LW19A are provided in Table 2.8.

Table 2.8 Survey dates for the 330 kV transmission line for LW19A

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Before the influence of LW19A, then monthly surveys when the longwall is 100 m before to 400 m beyond the transmission line and then at the completion of LW19A	8 August 2022 (base survey) 26 April 2023 (end of LW19) 9 November 2023 (start of LW19A), then approximate weekly* surveys until 2 July 2024 (end of LW19A)	Monitoring as per the 330 kV transmission line management plan for LW22

Note: * denotes surveys were subject to access restrictions to the drinking water catchment after heavy rainfall.

The monitoring results were included in the subsidence review reports (MSEC1396, Rev. R01 to R23) which were issued during and after the mining of LW19A. The monitoring data was reviewed by GM[3], MSEC and Transgrid and no additional management measures were required during mining.

The measured incremental vertical subsidence movements for Towers TWR17-13 to TWR17-16 due to the mining of LW19A only are illustrated in Fig. 2.6. This figure illustrates the additional movements since the base survey carried out on 9 November 2023 shortly after the commencement of LW19A.

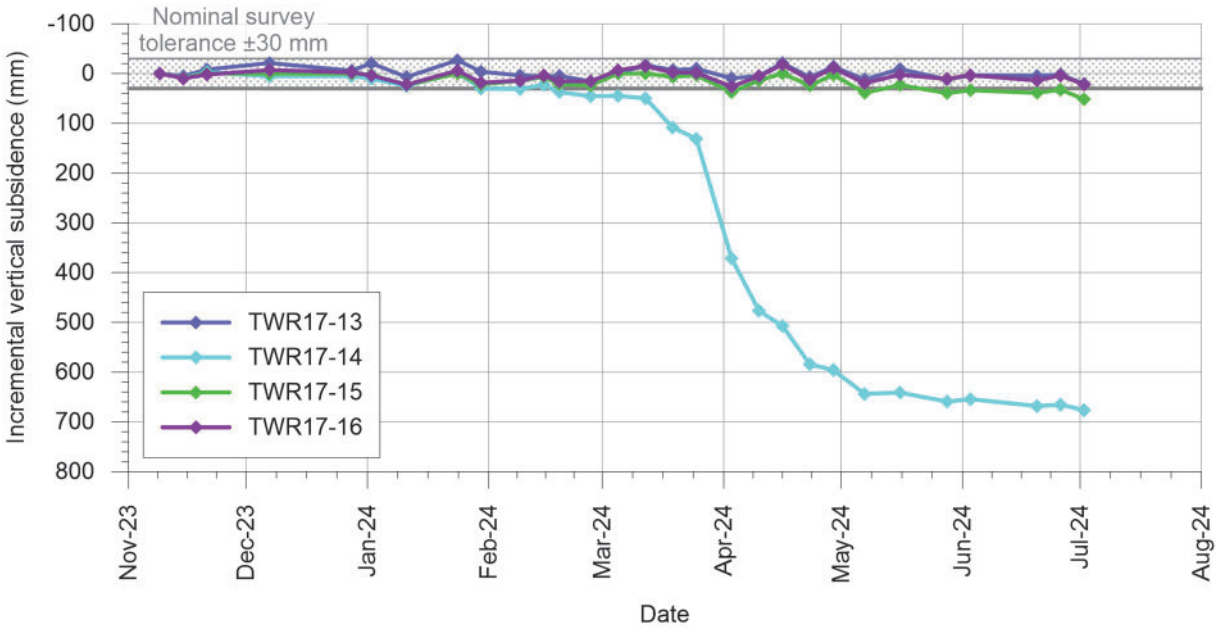

Fig. 2.6 Measured incremental vertical subsidence for TWR17-13 to TWR17-16 due to the mining of LW19A only

The vertical subsidence developed progressively at Tower TWR17-14 as LW19A mined directly beneath and beyond it. Only low-level vertical subsidence was measured at the remaining towers which were similar to 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 2 triggers for the 330 kV transmission line is provided in Table 2.9. This table provides the additional movements due to the mining of LW19A only.

Table 2.9 Maximum measured and predicted incremental subsidence effects and Level 2 triggers for the 330 kV transmission line due to the mining of LW19A only

Monitoring	Final measured value	Predicted final value	Level 2 trigger level
Maximum incremental vertical subsidence due to the mining of LW19A only (mm)	677	2000	1600
Maximum incremental tilt due to the mining of LW19A only (mm/m)	16.3	30	25
Maximum incremental changes in distances between the bases of adjacent towers due to the mining of LW19A only (mm)	+214 -301	+1900 -1900	-

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 677 mm at Tower TWR17-14 is approximately one-third the predicted incremental value. The reason is that the subsidence model is conservative especially at points located away from the centreline of the longwall where the predicted subsidence is greatest.

The measured incremental tilt, changes in distance between tower legs and changes in distance between the bases of adjacent towers were less than the predicted values and the Level 2 triggers.

The measured total vertical subsidence movements for Towers TWR17-13 to TWR17-16 due to the mining of LW19 and LW19A only are illustrated in Fig. 2.7. This figure illustrates the accumulated movements since the base survey carried out on 8 August 2022 before the commencement of LW19.

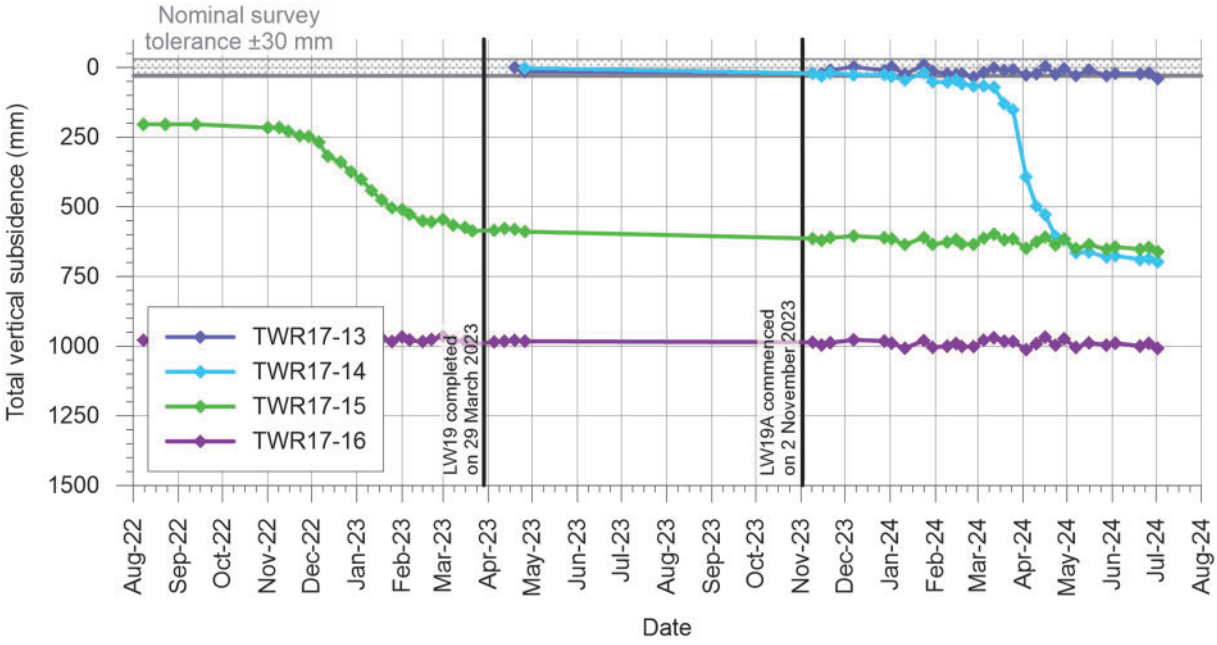

Fig. 2.7 Measured total vertical subsidence for TWR17-13 to TWR17-16 due to the mining of LW19 and LW19A

A summary of the maximum measured and predicted total subsidence effects and the Level 2 triggers for the 330 kV transmission line is provided in Table 2.10. This table provides the accumulated movements due to the mining of LW19 and LW19A.

Table 2.10 Maximum measured and predicted total subsidence effects and Level 2 triggers for the 330 kV transmission line due to the mining of LW19 and LW19A

Monitoring	Final measured value	Predicted final value	Level 2 trigger level
Maximum total vertical subsidence due to the mining of LW19 and LW19A (mm)	1008	2100	-
Maximum total tilt due to the mining of LW19 and LW19A (mm/m)	16.4	35	-
Maximum total change in distance between the tower legs due to the mining of LW19 and LW19A (mm)	+1.8 -3.8	-	±4
Maximum total change in distances between the bases of adjacent towers due to the mining of LW19 and LW19A (mm)	+211 -510	+1950 -1600	-

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 measured total vertical subsidence, tilt and changes in distance between the bases of adjacent towers were less than the predicted values and the measured total changes in distance between tower legs were similar to or less than the Level 2 trigger.

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 Nos. MSEC1234 and MSEC1384 which supported the SMP and Modification Applications, respectively, for LW19A.

2.6. Tributary cross lines

The mine subsidence effects for a tributary to Wongawilli Creek have been measured by GM[3] using 2D survey techniques at the WC14 cross line. The location of this monitoring line is shown in Drawing No. MSEC1436-01. The survey dates for the WC14 cross line for LW19A are provided in Table 2.11.

Table 2.11 Survey dates for the WC14 cross line for LW19A

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Completion of LW19A	21 October 2015 (base survey) 5 May 2023 (end of LW19)	None for Area 3A
	12 September 2023 15 April 2024 27 May 2024 24 June 2024 31 July 2024 (end of LW19A)	

The development of the measured total closure at the WC14 cross line is illustrated in Fig. 2.8. The cross line was established after the completion of LW8 and, therefore, the measured movements represent the accumulated movements due to LW19 and LW19A only. This monitoring line has a short length and it is located near the valley base and, therefore, it may not measure the maximum closure within the valley.

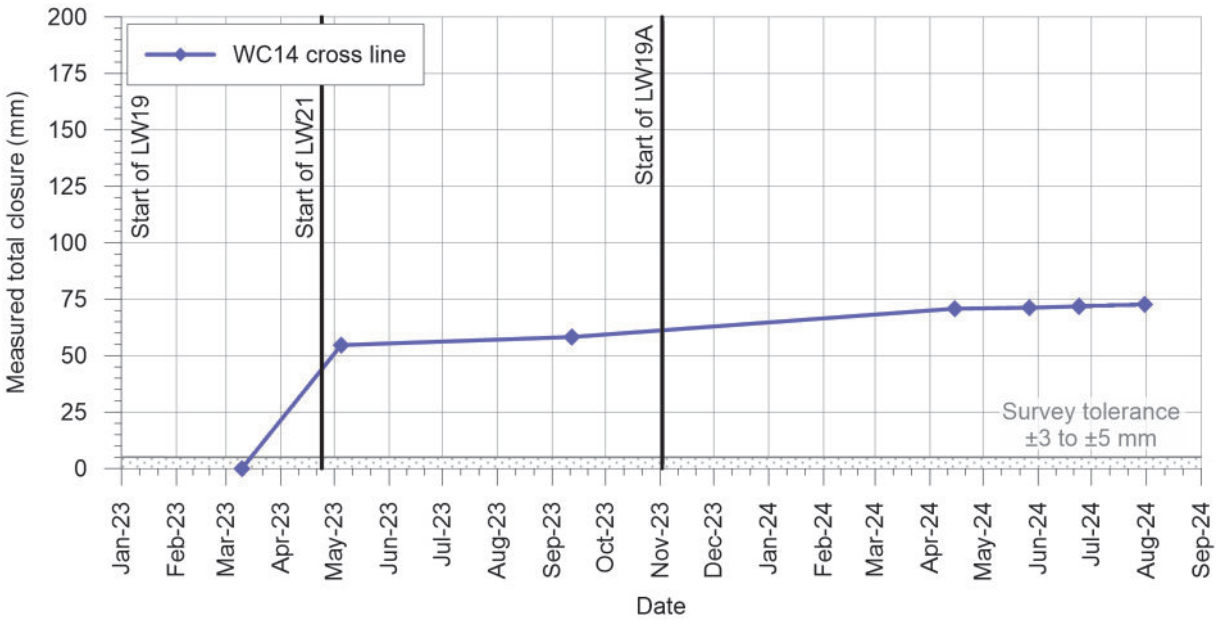

Fig. 2.8 Measured total closure for the WC14 cross line due to the mining of LW19 and LW19A

A summary of the maximum measured and predicted total subsidence and closure at the WC14 cross line is provided in Table 2.12. The values represent the accumulated movements due to the mining of LW19 and LW19A based on the final surveys carried out on 31 July 2024.

Table 2.12 Maximum measured and predicted total vertical subsidence and closure at the WC14 cross line due to the mining of LW19 and LW19A

Type	Maximum total vertical subsidence (mm)	Maximum total closure (mm)
Measured	288	73
Predicted	400	500

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

It is therefore considered that the ground movements measured using the WC14 cross line are consistent with the predictions provided in Report Nos. MSEC1234 and MSEC1384 which supported the SMP and Modification Applications, respectively, for LW19A.

2.7. Swamp cross lines

The mine subsidence effects at the swamps and their associated drainage lines have been measured by GM[3] using 2D survey techniques at the Swamp 15A 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. MSEC1436-01. The survey dates for the swamp cross lines are provided in Table 2.13.

Table 2.13 Survey dates for the swamp cross lines during LW19A

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Completion of LW19A	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) 17 August 2023 (Swamp 15A only) 14 September 2023 27 October 2023 (Swamp 15A only) 23 November 2023 (Swamp 15A only) 18 December 2023 (Swamp 15A only) 25 January 2024 (Swamp 15A only) 20 February 2024 (Swamp 15A only) 21 March 2024 (Swamp 15A only) 15 April 2024 (Swamp 148 only) 27 May 2024 (Swamp 148 only) 24 June 2024 (Swamp 148 only) 24 July 2024 (end of LW19A)	None for Area 3A

The development of the measured total closure at the Swamp 15A and Swamp 148 cross lines is illustrated in Fig. 2.9. The cross lines were established after the completion of LW8 and, therefore, the measured movements represent the accumulated movements due to LW19 and LW19A only. These two 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.

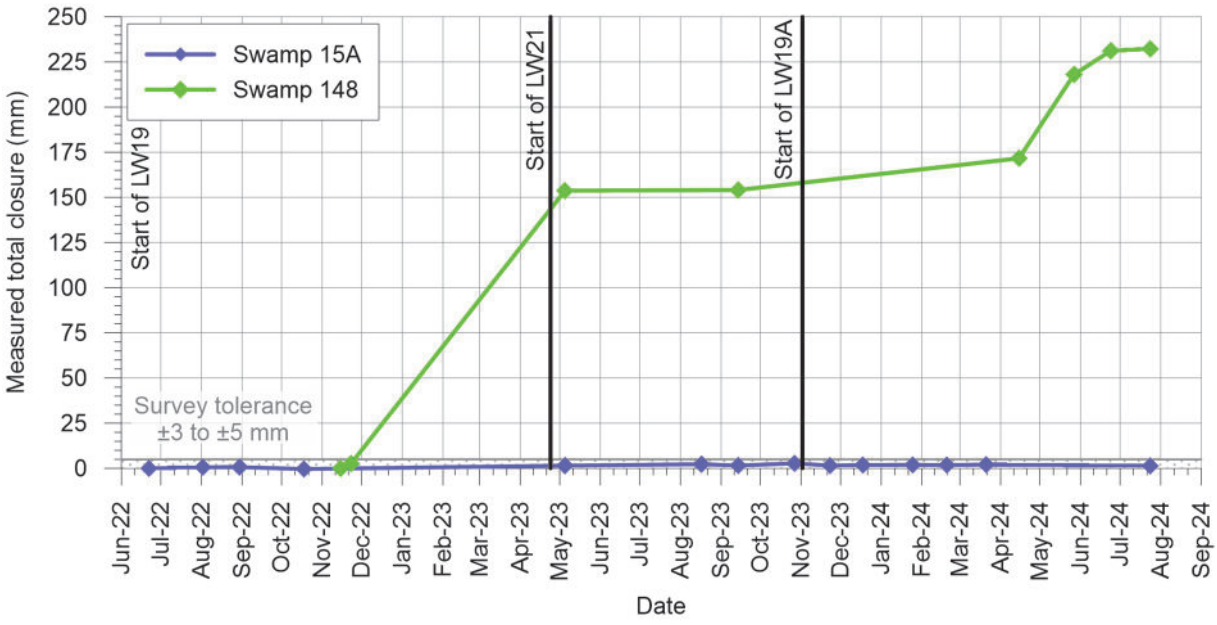

Fig. 2.9 Measured total closure for the Swamp 15A and Swamp 148 cross lines due to the mining of LW19 and LW19A

Summaries of the maximum measured and predicted total vertical subsidence and closure for the Swamp 15A and Swamp 148 cross lines are provided in Table 2.14 and Table 2.15, respectively. The values represent the accumulated movements due to the mining of LW19 and LW19A based on the final surveys carried out on 24 July 2024.

Table 2.14 Maximum measured and predicted total vertical subsidence and closure at the Swamp 15A cross line due to the mining of LW19 and LW19A

Type	Maximum total vertical subsidence (mm)	Maximum total closure (mm)
Measured	5	1
Predicted	< 20	100

Table 2.15 Maximum measured and predicted total vertical subsidence and closure at the Swamp 148 cross line due to the mining of LW19 and LW19A

Type	Maximum total vertical subsidence (mm)	Maximum total closure (mm)
Measured	518	232
Predicted	1300	300

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 total vertical subsidence and closure at the Swamp 15A and Swamp 148 cross lines are less than the maximum predicted total values.

It is therefore considered that the ground movements measured using the swamp cross lines are consistent with the predictions provided in Report Nos. MSEC1234 and MSEC1384 which supported the SMP and Modification Applications, respectively, for LW19A.

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, April 2023 after the completion of LW19 and August 2024 after the completion of LW19A.

The measured incremental changes in surface level due to the mining of LW19A only are shown in Fig. 2.10. 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.

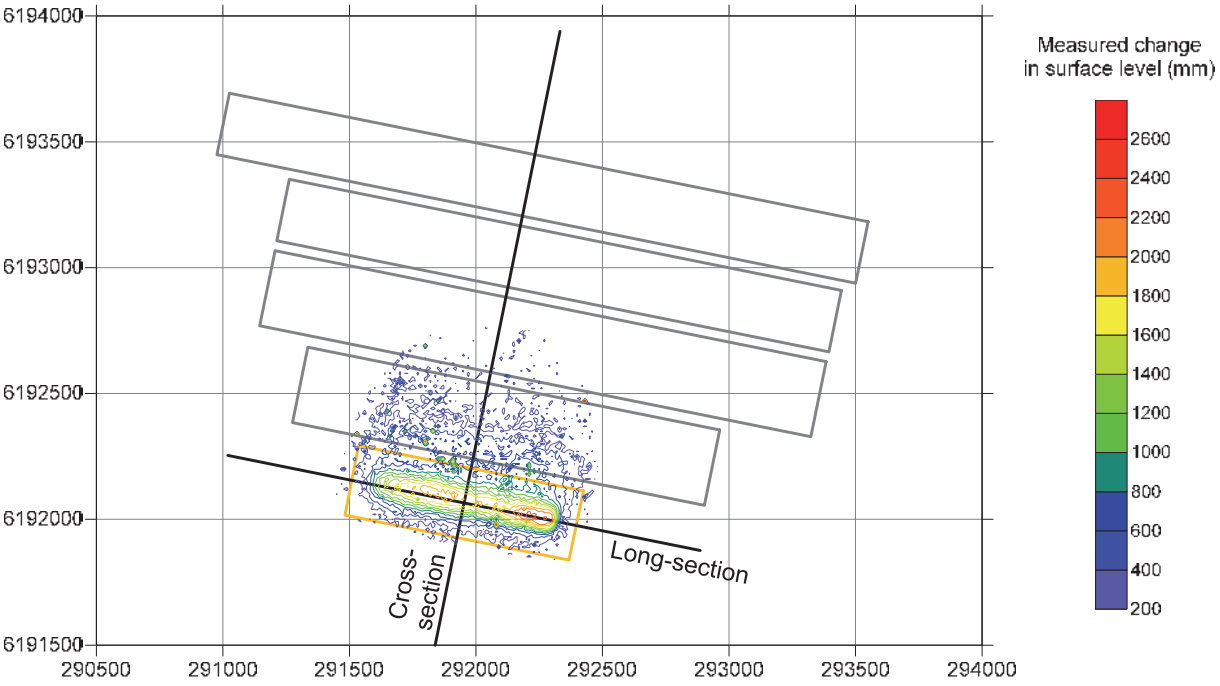

Fig. 2.10 Measured incremental changes in surface level due to the mining LW19A

The measured total changes in surface level due to the mining of LW6 to LW8, LW19 and LW19A are shown in Fig. 2.11. These contours have been determined by taking the differences between the surface levels measured after the completion of LW19A 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.

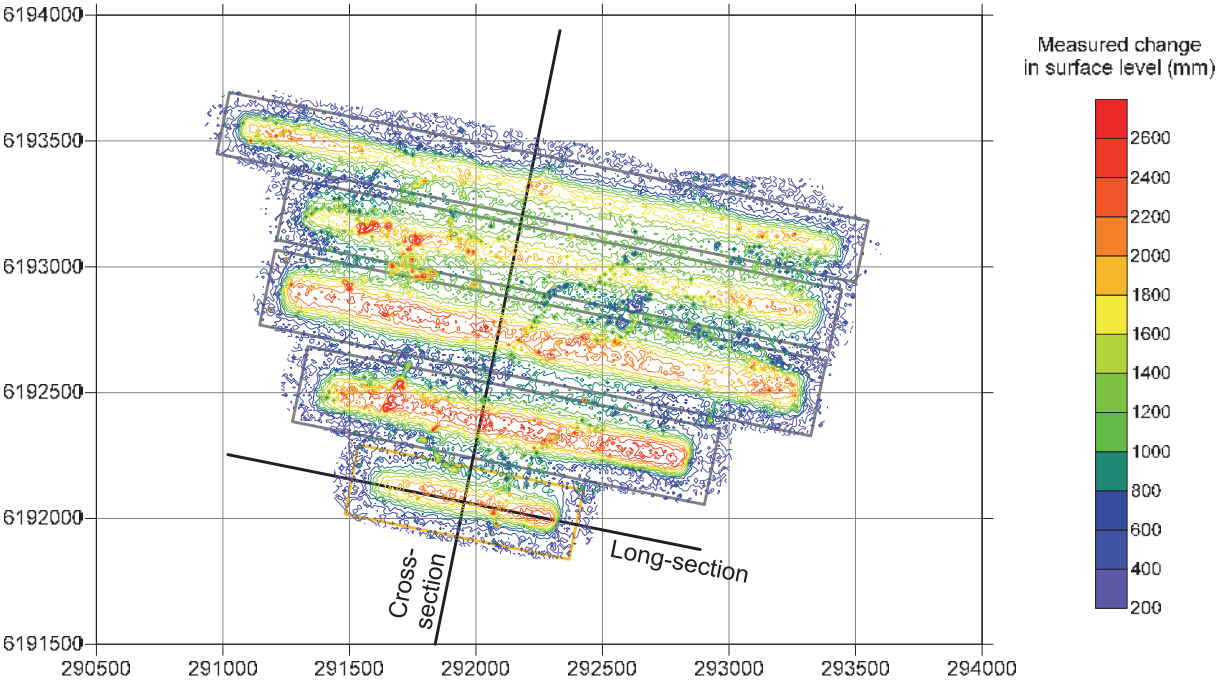

Fig. 2.11 Measured total changes in surface level due to the mining of LW6 to LW8, LW19 and LW19A

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 developed from the LiDAR surveys 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. 2.10 and Fig. 2.11 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 a cross-section and long-section are provided in Fig. 2.12 and Fig. 2.13, respectively. The locations of these sections are indicated in Fig. 2.10 and Fig. 2.11. The predicted profiles of vertical subsidence have been derived from the predicted subsidence contours illustrated in Report Nos. MSEC1234 and MSEC1384 which supported the SMP and Modification Applications, respectively, for LW19A.

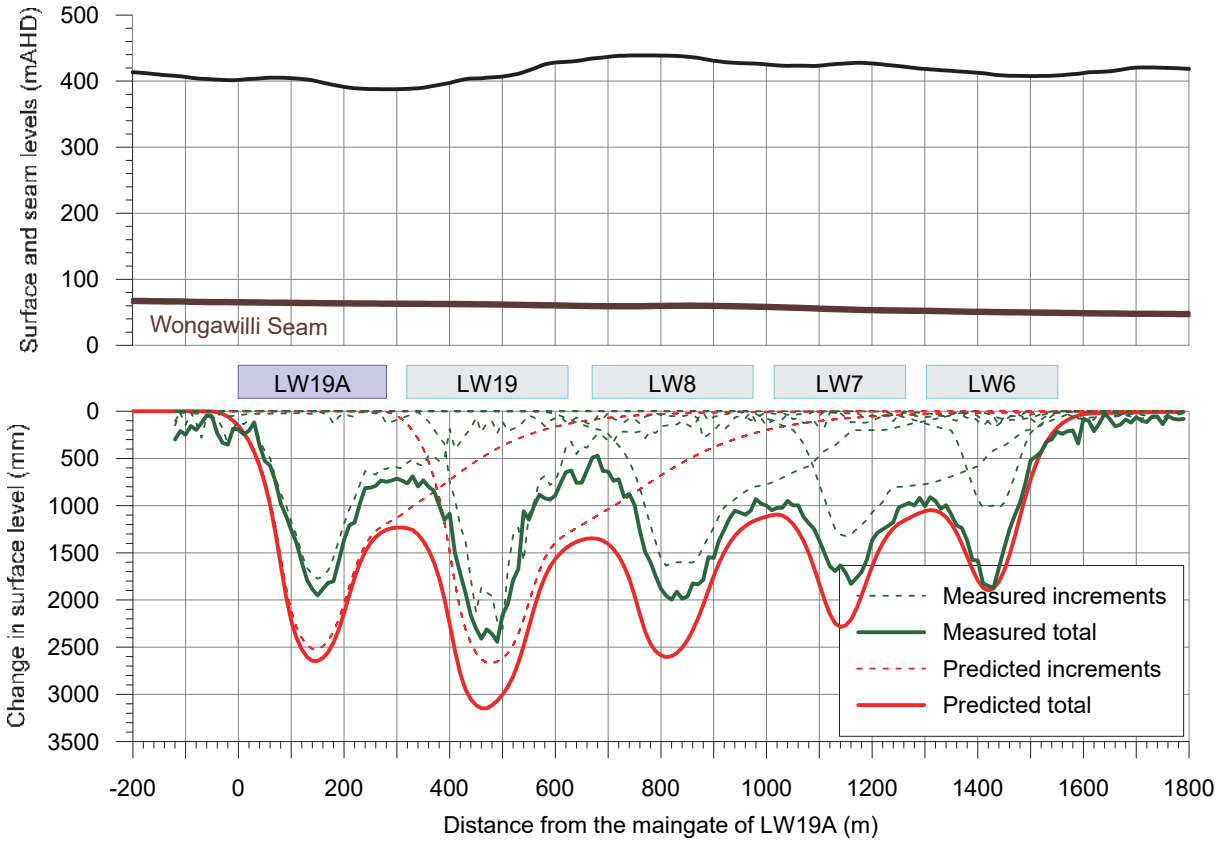

Fig. 2.12 Measured changes in surface level and predicted vertical subsidence along the Cross-section

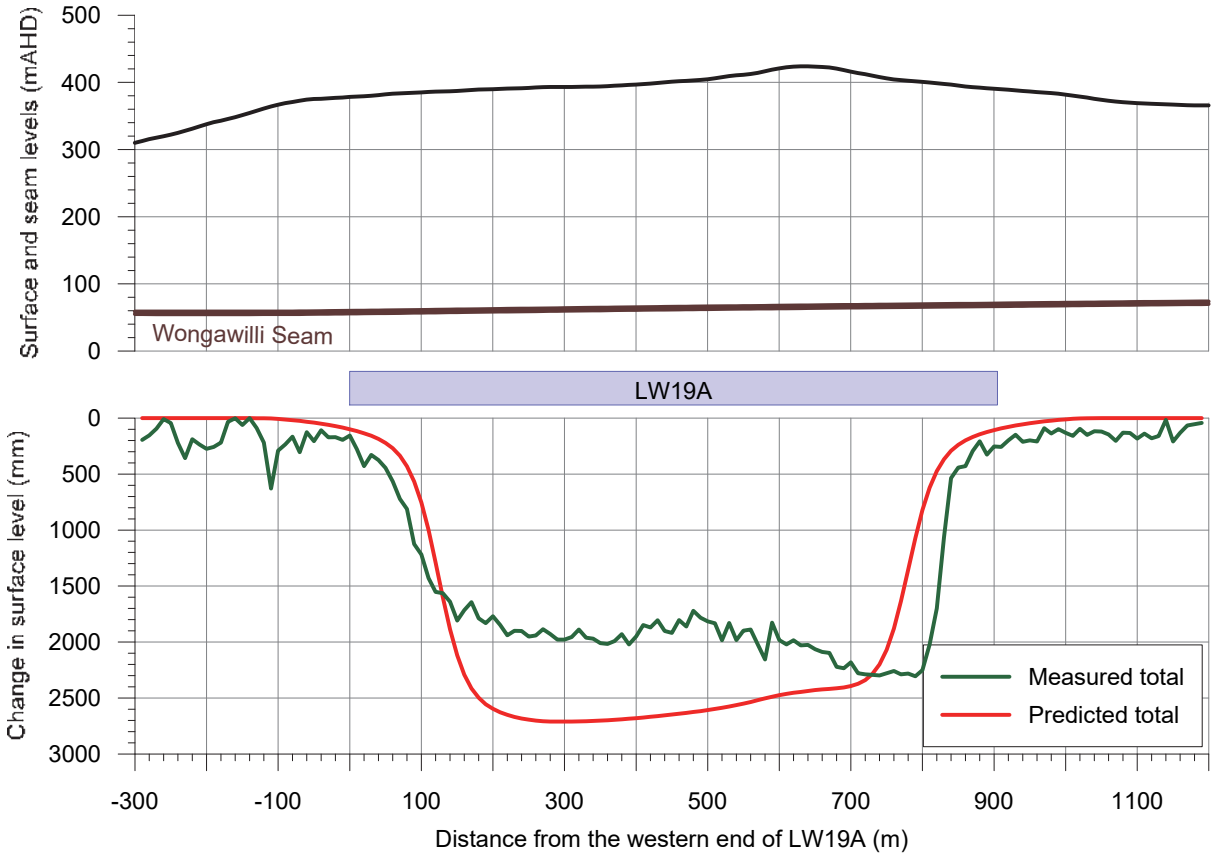

Fig. 2.13 Measured changes in surface level and predicted vertical subsidence along the Long-section

The profiles of the measured changes in surface level reasonably match the predicted profiles of vertical subsidence along the cross-section 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 change in surface level at the western end of LW19A (i.e. left-hand side of Fig. 2.13) is less than that measured at the eastern end of the longwall (i.e. right-hand side of Fig. 2.13). LW19A was mined from the east towards the west (i.e. from right to left in Fig. 2.13). The lesser change in surface level at the western end of LW19A could be due to the horizontal movements in the downslope direction and following the longwall face reducing the apparent change in level. The change in surface level at the eastern end of LW19A is less affected by the horizontal movements because the downslope direction and the mining direction oppose each other and the ridgeline is located near the longwall commencing end.

The measured changes in surface level are greater than the predicted vertical subsidence outside the mining area for the cross-section 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 shapes of the measured changes in surface level profiles and the predicted subsidence profiles, that the measured changes in grade are similar to the predicted tilts along the cross-section 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 Nos. MSEC1234 and MSEC1384 which supported the SMP and Modification Applications, respectively, for LW19A.

3.1. Surface deformations

Surface deformations due to the mining of LW19A have been identified by the GM[3] Environmental Field Team and are described in the accompanying GM[3] landscape report. The locations of the surface deformations identified during and after the mining of LW19A are illustrated in Fig. 3.1.

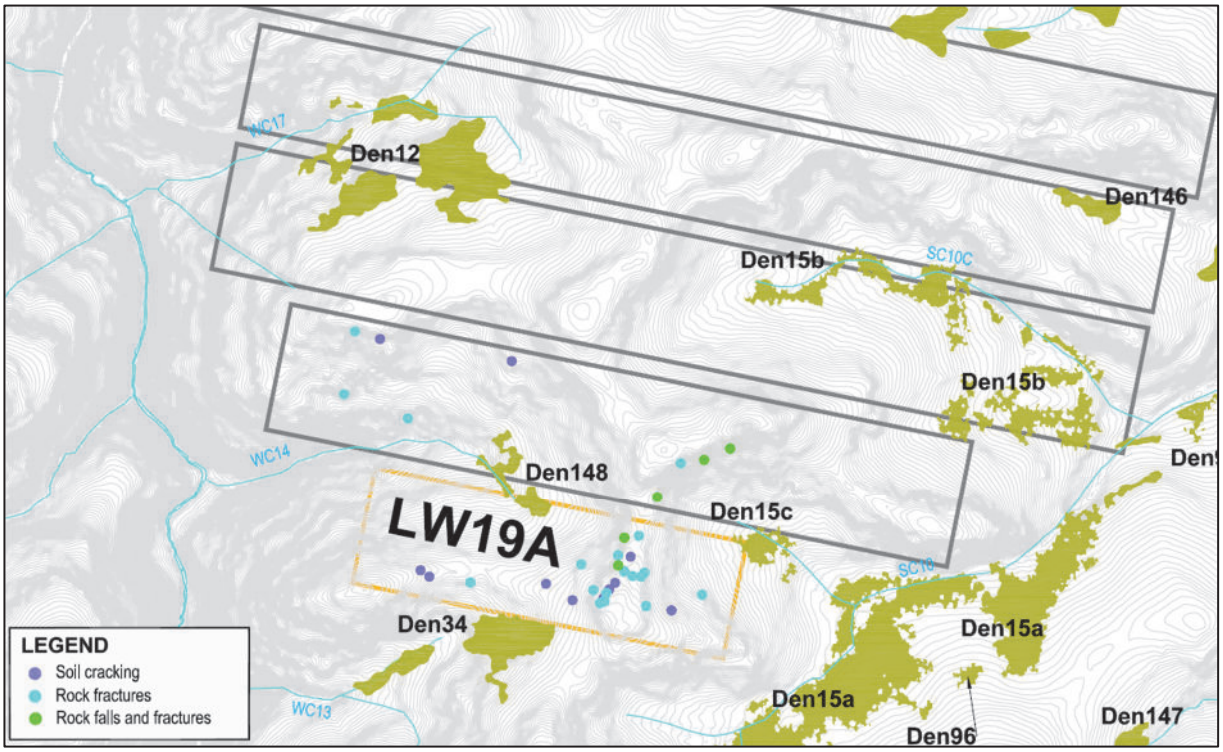

Fig. 3.1 Surface deformations due to the mining of LW19A

Soil cracking (i.e. blue circles) and/or rock fracturing (i.e. cyan circles) was identified in 29 locations above LW19A and in six locations above the previous LW19. Soil cracking was identified along and near the fire trails along the top of the ridgelines and on the steep slopes of the side of the ridgelines. Rock fracturing occurred at the rock outcropping and minor cliffs.

The soil crack and rock fracture widths were recorded in 14 locations and they were typically less than 50 mm in 9 locations (i.e. 64 % of cases), ranged between 50 mm and 100 mm in two locations (i.e. 14 % of cases) and were greater than 100 mm in three locations (i.e. 21 % of cases). The maximum measured crack width was 160 mm (LW19A_026) at the top of the ridgeling above the western end of LW19A.

Rockfalls (i.e. green circles) were identified in two locations above LW19A and three locations above the previous LW19. The rockfalls occurred at the minor cliffs and rock outcrops on the side of the ridgeline above the eastern end of LW19A and above the mid-length of LW19. The rockfalls had estimated volumes of less than 0.5 m^3.

No fracturing was recorded along Wongawilli Creek, Sandy Creek or their associated tributaries. There were no surface water flow diversions identified along the streams due to the mining of LW19A. However, the water level was below baseline at SC10_Pool 23 and the rates of recession were below baseline at SC10_Pool 26a and SC10_Pool 29 following the start of LW19A.

Further details of these surface deformations are provided in the accompanying GM[3] landscape report.

3.2. Natural features

The natural features near LW19A are shown in Drawing No. MSEC1436-02, in Appendix A, and include:

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

The MSEC assessed impacts for the natural features due to the mining of LW19A are provided in Report Nos. MSEC1234 and MSEC1384 which supported the SMP and Modification Applications, respectively, for this 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 LW19A are provided in Table 3.1. The reported impacts are based on those recorded by GM[3] Environmental Field Team, that are described in the accompanying landscape report.

Table 3.1 Assessed and reported impacts for the natural features due to LW19A

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 to date 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 LW19A.
	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 LW19A. One Type 3 impact was previously observed between LW6 and LW9, where fracturing was first observed during the mining of LW9.
Sandy Creek	No adverse physical impacts (i.e. fracturing) anticipated.	No reported physical impacts to the creek due to the mining of LW19A. There was one water quality trigger for electrical conductivity (SCk_Rockbar5). Refer to the GM[3] landscape report for further details.
Sandy Creek Waterfall	No adverse physical impacts (i.e. fracturing or rockfalls) anticipated.	No reported physical impacts to the waterfall due to the mining of LW19A.
Drainage lines (tributaries)	Localised additional **ponding**, **flooding** or **scouring** along sections of the drainage lines located directly above the longwall.	No reported adverse impacts.
	Buckling and **fracturing** of the bedrock along the drainage lines above or within 400 m of the longwalls.	No fracturing observed in the bases of WC13, WC14, WC17, SC10 and SC10C due to the mining of LW19A.
	Surface water flow diversions into the dilated strata beneath the drainage lines which are directly mined beneath.	No surface water flow diversions identified due to the mining of LW19A. However, water level was below baseline at SC10_Pool 23 and rates of recession below baseline at SC10_Pool 26a and SC10_Pool 29 following the start of LW19A.

Natural feature	MSEC assessed impacts	Reported impacts
Drainage lines (tributaries) (continued)	**Water quality** – refer to the accompanying surface and shallow groundwater 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 above and adjacent to 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 and DA3-CF24) 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.	Rock fracturing identified in 20 locations and localised rock falls identified in five locations at the rock outcrops and minor cliffs on the sides of the ridgelines located above LW19 and LW19A. Refer to the GM[3] 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 35 locations above LW19 and LW19A. Crack widths measured up to 160 mm but typically less than 50 mm. Refer to Section 3.1 and to the GM[3] landscape report for further details.
Swamps	**Fracturing** of the underlying strata which could result in the **diversion of surface water** at the swamps located above and adjacent to the mining area.	No fracturing observed within or near the swamps. Soil moisture lower than baseline at Swamp 15A and groundwater recession rate greater than baseline at Swamp 15A and Swamp 148. Refer to the GM[3] 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 for sites located above and adjacent to the mining area.	Rock fracturing and small rockfalls (LW19_037) occurred near cultural heritage site Sandy Creek 21 (AHIMS Ref. 52-5-0273) during the previous mining of LW19. An additional rock fracture and rockfall occurred during the mining of LW19A. Refer to the accompanying cultural heritage report.

It is considered that the observed impacts on the natural features due to the mining of LW19A are consistent with the MSEC assessments provided in Report Nos. MSEC1234 and MSEC1384 which supported the SMP and Modification Applications, respectively, for this 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 LW19A are shown in Drawing No. MSEC1436-03, in Appendix A, and include:

- Fire trails and four-wheel drive tracks;
- 330 kV transmission line;
- Cordeaux Dam; and
- Survey control marks.

The MSEC assessed impacts for the built features due to the mining of LW19A are provided in Report Nos. MSEC1234 and MSEC1384 which supported the SMP and Modification Applications, respectively, for this longwall.

Comparisons between the MSEC assessments and the reported impacts for the built features due to the mining of LW19A are provided in Table 3.2. The reported impacts are based on those recorded by GM[3] Environmental Field Team, that are described in the accompanying landscape report.

Table 3.2 Assessed and reported impacts for the built features due to LW19A

Built feature	MSEC assessed impacts	Reported impacts
Fire trails and four-wheel drive tracks	Cracking of unsealed road surfaces.	Soil cracking observed along or near to Fire Road 6F (DA3A_LW19A_005, 006, 007 and 012) and along the access tracks (DA3A_LW19A_010, 025, 027 and 035). Refer to the GM[3] landscape report for further details.
330 kV transmission line	No adverse impacts to the safety or serviceability of the transmission line	Cracking of the ground and concrete infill slab around the cruciform base of Tower TWR17-14; however, no cracking observed in the cruciform base itself. The transmission line remained safe and serviceable.
Cordeaux Dam	No adverse impacts anticipated.	No reported impacts on the dam wall. 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 LW19A are similar to or less than the MSEC assessments provided in Report Nos. MSEC1234 and MSEC1384 which supported the SMP and Modification Applications, respectively, for this longwall.

4.0 SUMMARY

The mine subsidence effects due to the mining of LW19A 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 LW19A are generally similar to or less than the predicted values based on the subsidence model outlined in Report Nos. MSEC1234 and MSEC1384 which supported the SMP and Modification Applications, respectively, for LW19A.

The measured total closure at the Wong X C-Line of 233 mm is greater than the maximum predicted value of 220 mm that occurs slightly downstream of the monitoring line. However, the exceedance by +13 mm is within the order of the accuracy of the prediction method. The measured incremental closure at the SCW HRS B-Line of 2.6 mm is similar to but slightly greater than the predicted value of 2 mm. There was a step change in the closure measured in early-April 2024 after a heavy rainfall event and no measurable changes after that event.

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 LW19A are consistent with the predictions provided in Report Nos. MSEC1234 and MSEC1384 which supported the SMP and Modification Applications, respectively, for LW19A.

Soil cracking and rock fracturing were observed directly above the existing LW19 and current LW19A. The crack and fracture widths were up to 160 mm but typically less than 50 mm. 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, Sandy Creek or their tributaries due to the mining of LW19A. However, the water level was below baseline at SC10_Pool 23 and the rates of recession were below baseline at SC10_Pool 26a and SC10_Pool 29 following the start of LW19A.

It is considered, therefore, that the observed surface impacts on the natural and built features due to the mining of LW19A are consistent with the MSEC assessments provided in Report Nos. MSEC1234 and MSEC1384 which supported the SMP and Modification Applications, respectively, for LW19A. 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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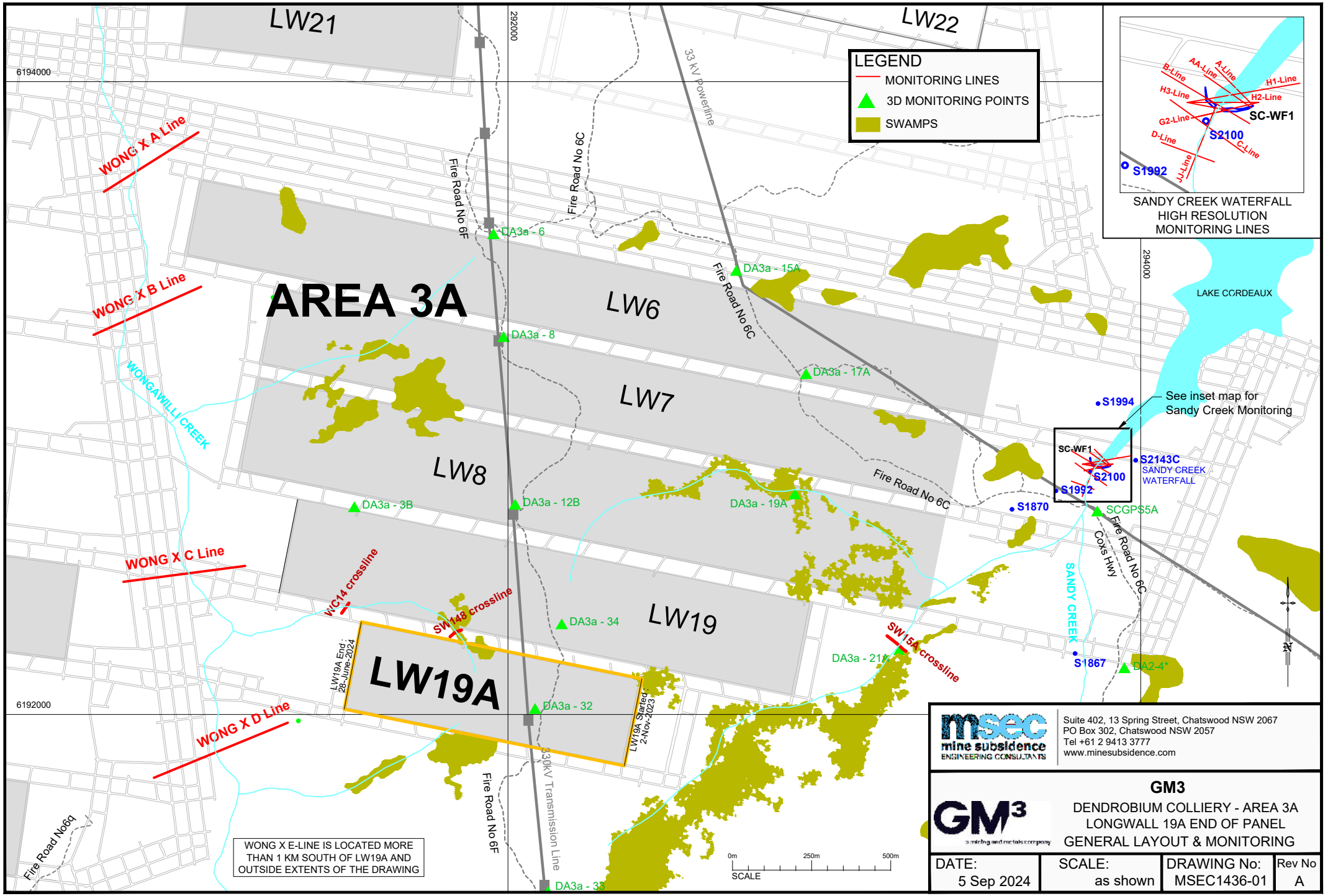

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GM3

GM3 mining and metals company

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

DATE:	SCALE:	DRAWING No:	Rev No
5 Sep 2024	as shown	MSEC1436-01	A

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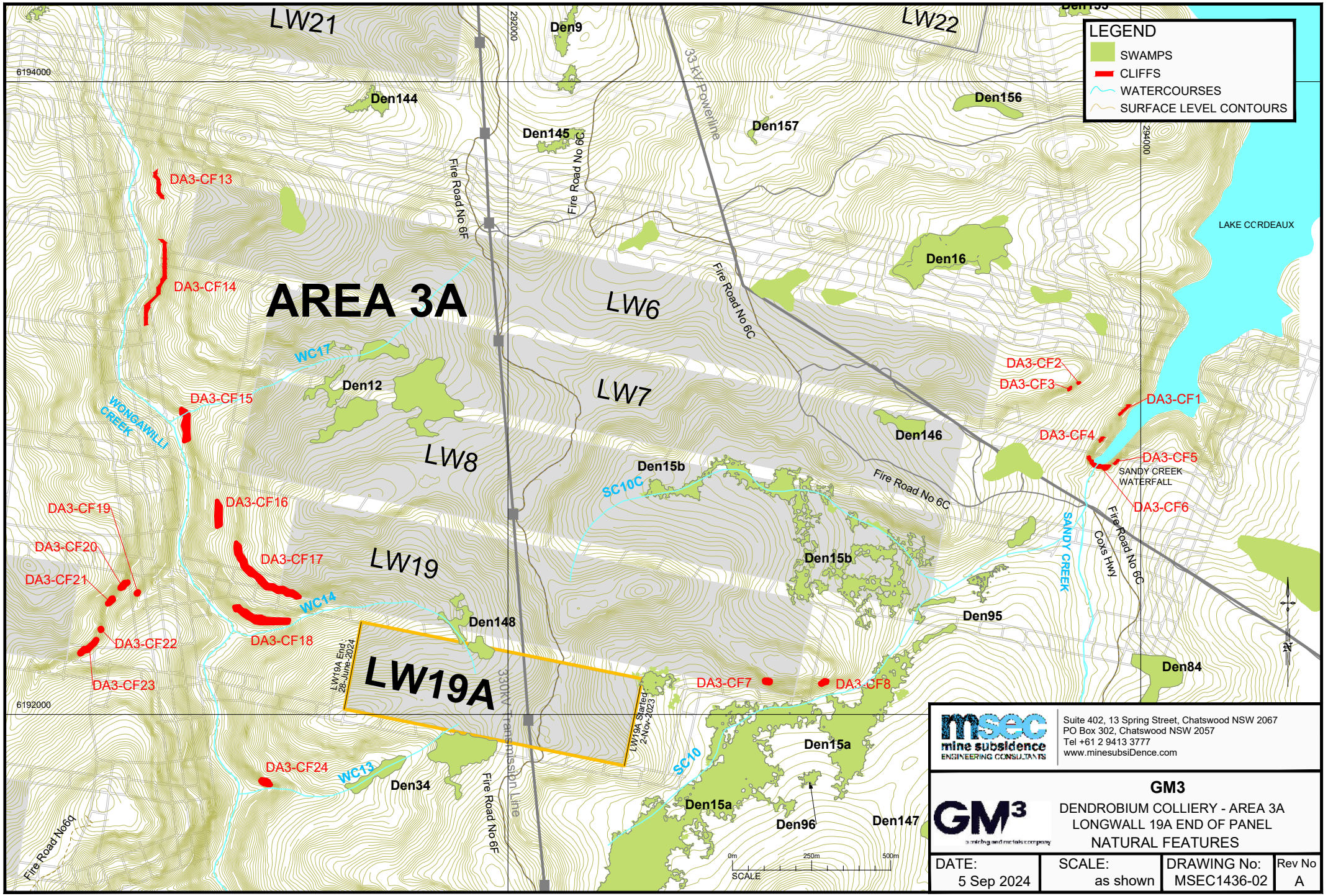

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DENDROBIUM COLLIERY - AREA 3A
LONGWALL 19A END OF PANEL
NATURAL FEATURES

DATE:	SCALE:	DRAWING No:	Rev No
5 Sep 2024	as shown	MSEC1436-02	A

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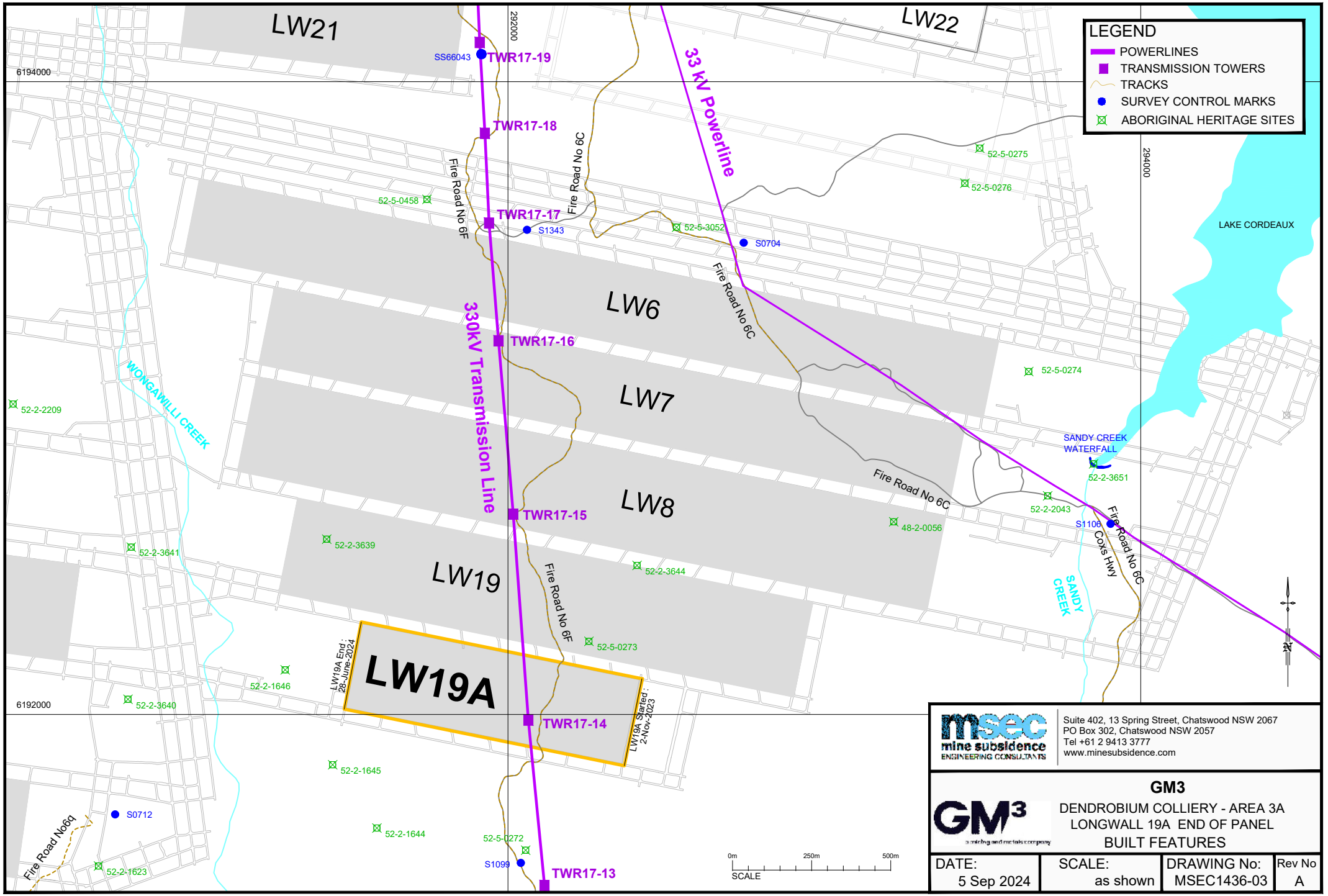

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DENDROBIUM COLLIERY - AREA 3A
LONGWALL 19A END OF PANEL
BUILT FEATURES

DATE:	SCALE:	DRAWING No:	Rev No
5 Sep 2024	as shown	MSEC1436-03	A

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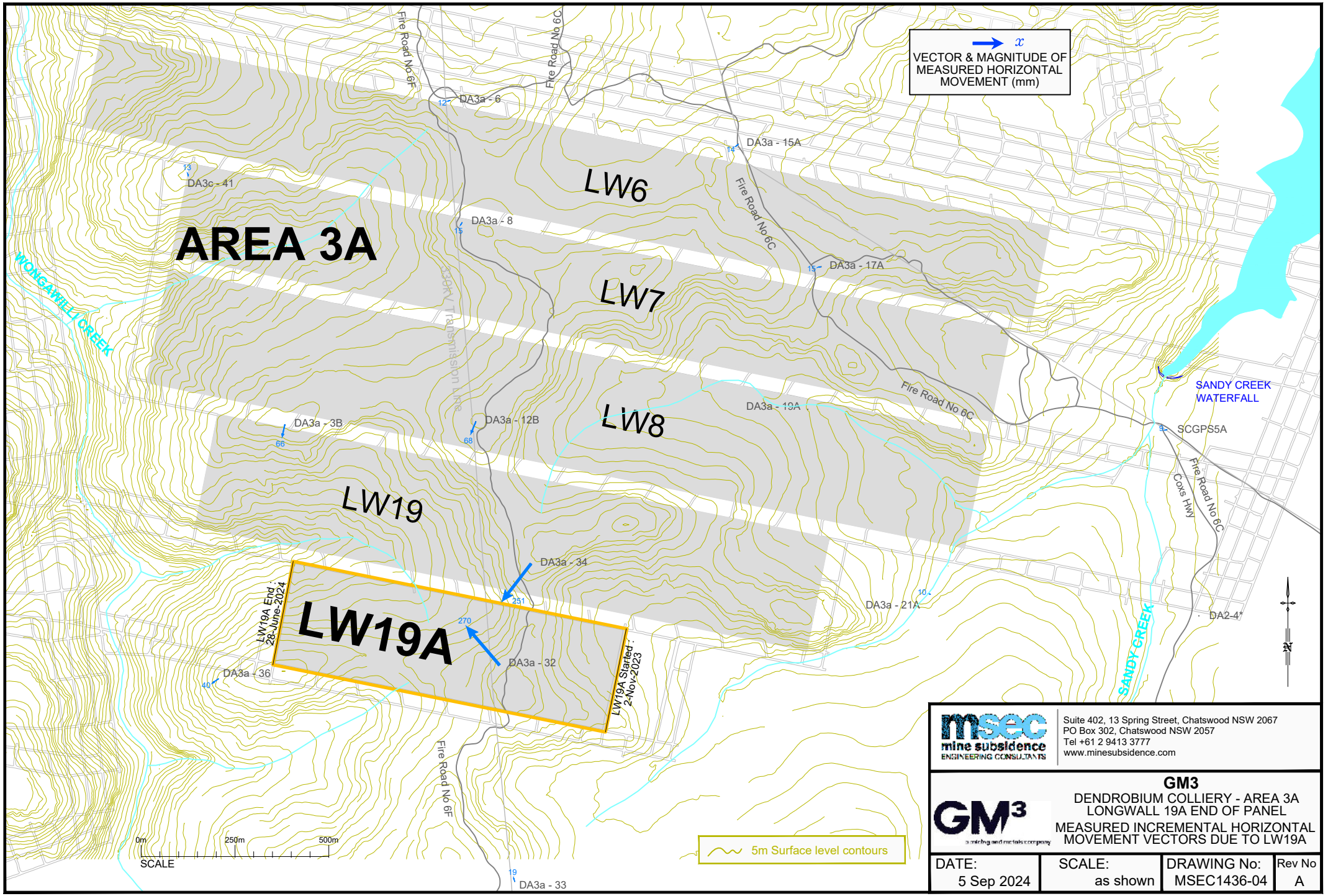

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DENDROBIUM COLLIERY - AREA 3A
LONGWALL 19A END OF PANEL
MEASURED INCREMENTAL HORIZONTAL MOVEMENT VECTORS DUE TO LW19A

DATE:	SCALE:	DRAWING No:	Rev No
5 Sep 2024	as shown	MSEC1436-04	A