South32

Illawarra Metallurgical Coal

SOUTH32 ILLAWARRA METALLURGICAL COAL:

Dendrobium – Area 3C – Longwall 21

End of Panel Subsidence Monitoring Review Report for Dendrobium Longwall 21

DOCUMENT REGISTER

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Report produced for: Compliance with conditions attached to the Extraction Plan Approval set by the Department of Planning and Environment.

Associated reports: MSEC978 (Rev. E, dated 27 August 2019) – Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the Proposed Longwalls 20 and 21 in Area 3C at Dendrobium Mine (in support of the Extraction Plan Application)

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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Figures

Figures are prefixed by the number of the section in which they are presented.

Drawings

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

Drawing No.	*Description*	*Rev.*
MSEC1378-01	General layout and monitoring lines	A
MSEC1378-02	Natural features	A
MSEC1378-03	Built features	A
MSEC1378-04	Measured incremental horizontal movement vectors due to LW21	A

1.1. Introduction

Illawarra Metallurgical Coal (IMC) has completed the mining of Longwall 21 (LW21) at Dendrobium Mine located in the Southern Coalfield of New South Wales. The longwalls in Area 3C at Dendrobium Mine are shown in Drawing No. MSEC1378-01, in Appendix A.

LW21 is the first longwall in Area 3C and therefore it is a single-isolated longwall. The mining of LW21 commenced on 25 April 2023 and the longwall was completed on 6 August 2023.

Mine Subsidence Engineering Consultants (MSEC) was previously commissioned by IMC to prepare subsidence predictions and impact assessments for LW20 and LW21. Report No. MSEC978 (Rev. E) was issued in August 2019 in support of the Extraction Plan Application for this longwall.

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

- comparisons between the measured and predicted subsidence effects at the monitoring lines and points in Dendrobium Area 3C due to the mining of LW21; 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 LW21.

Further details on the observed and assessed impacts for natural features due to the mining of LW21 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 LW21. 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 LW21. 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 LW21.

Appendix A includes all drawings associated with this report.

1.2. Mining geometry

The layout of the longwalls in Area 3C at Dendrobium Mine is shown in Drawing No. MSEC1378-01, in Appendix A. A summary of the as-extracted dimensions for LW21 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 3C	LW21	872	256	-

The mined length of LW21 excluding the installation heading is approximately 9 m shorter than the overall void length provided in Table 1.1. The length of longwall mining for LW21, therefore, is approximately 863 m. The longwall face width excluding the first workings is approximately 246 m.

LW21 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 LW21 are illustrated in Fig. 1.1.

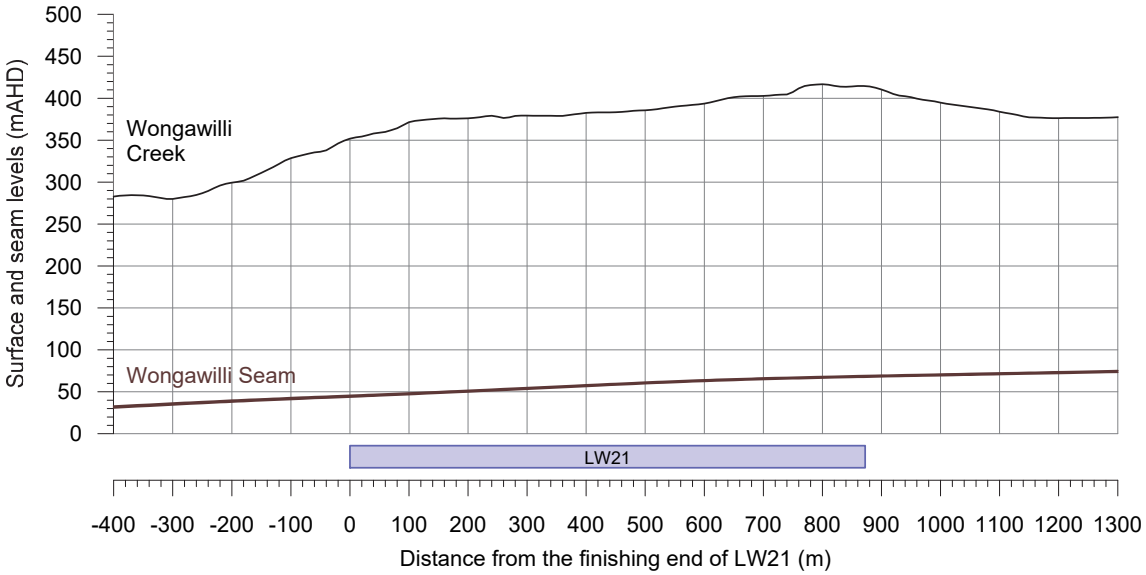


Fig. 1.1 Surface and seam levels along the centreline of LW21

The depths of cover to the Wongawilli Seam directly above LW21 vary between 290 m and 390 m. The minimum depth of cover occurs at the finishing (i.e. western) end of LW21 where it partially extends into the valley of Wongawilli Creek. The maximum depth of cover occurs where the ridgeline crosses LW21 near the commencing (i.e. eastern) end. The average depth of cover directly above LW21 is 345 m.

The seam floor generally dips from the east to the west. The average gradient of the seam within the extents of the mining area is approximately 3 %, or 1 in 33.

The mining height varies along the length of LW21, depending on the local roof conditions. The predictions provided in this report have been based on the maximum proposed mining height of 3.9 m, as adopted in Report No. MSEC978 which supported the Extraction Plan Application for this longwall.

2.1. Introduction

The mine subsidence effects due to the mining of Dendrobium LW21 were monitored along several monitoring lines and monitoring points including the following:

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

The locations of these survey lines and survey points are shown in Drawing No. MSEC1378-01, 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. MSEC978 which supported the Extraction Plan Application for LW21.

2.2. Wongawilli Creek closure lines

Closure movements across Wongawilli Creek have been measured by IMC using 2D survey techniques at the Wong A-Line, Wong B-Line, Wong Y-Line and Wong Z-Line. The Wong A-Line and Wong B-Line were installed in January 2013 and measured the movements due to the mining in Areas 3A, 3B and LW21. The Wong Y-Line and Wong Z-Line were installed in March 2023 and measured the movements due to the mining of LW21 only.

The locations of the Wongawilli Creek closure lines are shown in Drawing No. MSEC1378-01. 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 LW21

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Completion of LW21	24 January 2013 (base survey for Wong A-Line and Wong B-Line) 10 March 2023 (base survey for Wong Y-Line and Wong Z-Line) 11 May 2023 (during LW21) 9 September 2023 (end of LW21)	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.

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, 3B and 3C 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 LW21

Location	Longwalls	Measured total closure (mm)	Predicted total closure (mm)
Wong A-Line	LW6 to LW21	104	180
Wong B-Line	LW6 to LW21	77	200
Wong Y-Line	LW21 only	-5 (opening)	130
Wong Z-Line	LW21 only	-9 (opening)	50

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

The measured total closures at the Wong A-Line and B-Line are less than the predicted total closures after the completion of LW21. The Wong Y-Line and Wong Z-Line measured net opening movements which are likely due to survey tolerance and environmental effects, i.e. no measurable mining-related closure.

The incremental movements at the Wongawilli closure lines due to the mining of LW21 only are net extensions ranging between 5 mm and 25 mm. That is the net closures measured at the Wong A-Line and Wong B-Line reduced and the base readings at the Wong Y-Line and Wong Z-Line increased (i.e. opened) during the mining of LW21.

It is considered that the ground movements measured using the Wongawilli Creek closure lines are consistent with the predictions provided in Report No. MSEC978 which supported the Extraction Plan Application for LW21.

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. MSEC1378-01. 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 LW21

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Base survey before the commencement of LW21, monthly surveys during mining and then final survey at completion of LW21	24 October 2010 (base survey) 8 August 2011 (end of LW6) 17 May 2012 (end of LW7) 18 September 2014 (end of LW8) 12 April 2023 (end of LW19) 6 June 2023 then monthly surveys to 20 October 2023 (end of LW21)	Monthly surveys until the Technical Committee agree to the cessation of monitoring

The development of the measured incremental movements for the HRS SCW closure lines is illustrated in Fig. 2.1. This figure illustrates the additional movements since the base survey carried out on 12 April 2023 before the commencement of LW21.

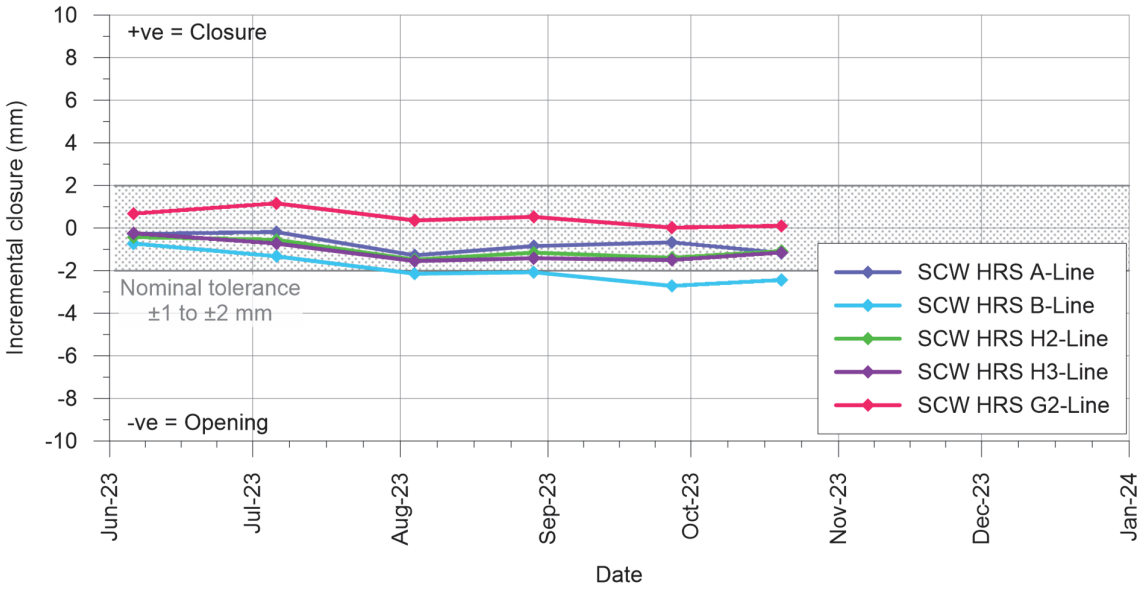


Fig. 2.1 Measured incremental closures for the HRS SCW closure lines due to LW21 only

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 20 October 2023.

Table 2.4 Maximum measured and maximum predicted incremental movements for the HRS SCW closure lines due to the mining of LW21

Location	Measured incremental closure (mm)	Predicted incremental closure (mm)
A-Line	-1.2 (opening)	±2
B-Line	-2.4 (opening)	
H2-Line	-1.1 (opening)	
H3-Line	-1.1 (opening)	
G2-Line	+0.1	

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

In the latest survey, very low-level opening movements were measured along the HRS SCW A-Line, B-Line, H2-Line and H3-Line. It is likely that these movements are due to environmental effects where natural valley opening occurs during and shortly after the winter periods each year.

The maximum measured incremental closure is +0.1 mm at the G2-Line. This movement is within the order of the nominal tolerance of ±2 mm when considering survey tolerance and environmental effects. That is, the mining-related movements are not measurable outside the nominal accuracy.

It is considered that the ground movements measured using the HRS SCW closure lines are consistent with the predictions provided in Report No. MSEC978 which supported the Extraction Plan Application for LW21.

2.4. Dendrobium Area 3B three-dimensional monitoring points

Far-field horizontal movements near LW21 have been measured by IMC using the Dendrobium Area 3C 3D monitoring points (DA3C 3D) monitoring points. The locations of these monitoring points are shown in Drawing No. MSEC1378-01.

The survey dates for the DA3C 3D monitoring points are provided in Table 2.5.

Table 2.5 Survey dates for the DA3C 3D monitoring points for LW21

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Completion of LW21	01 April 2023 (base survey) 01 September 2023 (end of LW21)	Completion of each future longwall in Area 3C

The measured incremental horizontal movement vectors for DA3C 3D monitoring points due to the mining of LW21 are shown in Drawing No. MSEC1378-04. 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 LW21. The maximum measured incremental value is 439 mm at Mark DA3c-42 located on the side of a ridgeline above LW21 towards the longwall finishing end. The vector is orientated towards the south in the downslope direction.

The next greatest measured incremental value is 193 mm at Mark DA3c-35 located near the top of a ridgeline above LW21 near the mid-length of the longwall. The vector is orientated towards the west in the direction of longwall retreat.

The predicted horizontal movements above the mining area (i.e. conventional horizontal movements) were expected to be in the range of the horizontal movements previously measured above the longwalls at Dendrobium Mine. The horizontal movements previously measured at the Mine varied up to 600 mm with an average measured value of approximately 300 mm. The maximum predicted conventional horizontal movement, based on applying a factor of 15 to the maximum predicted conventional tilt, was 450 mm.

The maximum measured horizontal movements due to the mining of LW21 therefore were within the range of horizontal movements previously measured at the Mine and less than the maximum predicted conventional value. Elsewhere, the measured incremental horizontal movements outside of LW21 are less than 50 mm.

The comparison between the maximum measured incremental horizontal movements at the DA3C 3D monitoring points located outside the mining area with those previously measured in Dendrobium Area 1 (DA1 3D) and Dendrobium Area 2 (DA2 3D), Dendrobium Area 3A (DA3A 3D) and Dendrobium Area 3B (DA3B 3D) is provided in Fig. 2.2. The mean and the 95 % confidence level for the 3D monitoring data in Dendrobium Areas 1, 2, 3A and 3B are also shown in this figure.

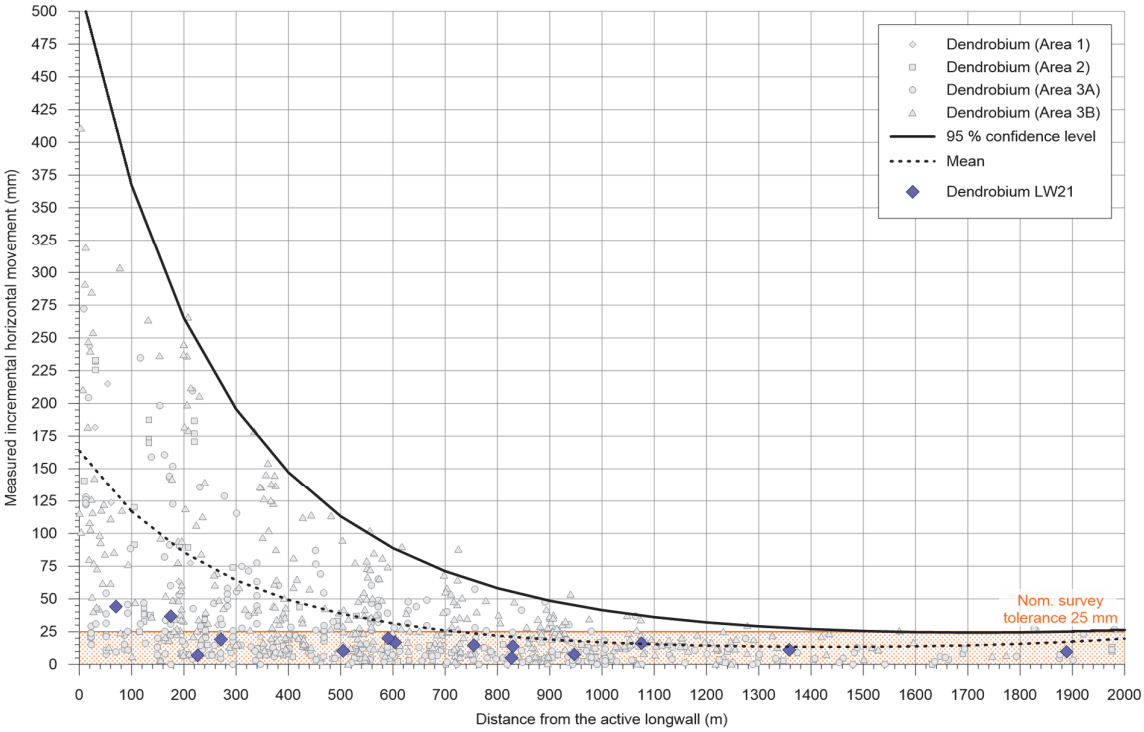


Fig. 2.2 Measured incremental horizontal movements outside the mining area at Dendrobium Areas 1, 2, 3A, 3B and 3C

The measured incremental horizontal movements due to the mining of LW21 (i.e. blue diamonds) are within the range of those measured at similar distances from previously mined longwalls in Dendrobium Areas 1, 2, 3A and 3B (i.e. grey diamonds, squares, circles and triangles).

It is therefore considered that the ground movements measured using DA3C 3D monitoring points are consistent with the predictions provided in Report No. MSEC978 which supported the Extraction Plan Application for LW21.

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 TWR17-17 to TWR17-21. The locations of the transmission towers are shown in Drawing No. MSEC1378-03. The survey dates for the 330 kV transmission line for LW21 are provided in Table 2.6.

Table 2.6 Survey dates for the 330 kV transmission line for LW21

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Before the commencement of LW21, then monthly surveys until 600 m of longwall retreat and then at the completion of LW21	19 April 2023 (base survey) then weekly surveys to 30 August 2023 (end of LW21)	Monitoring as per the 330 kV transmission line management plan for LW22 and LW23

The monitoring results were included in the subsidence review reports (MSEC1336, Rev. R01 to R18) which were issued during and after the mining of LW21. 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 TWR17-17 to TWR17-21 are illustrated in Fig. 2.3. This figure presents the additional movements due to the mining of LW21 only since the base survey.

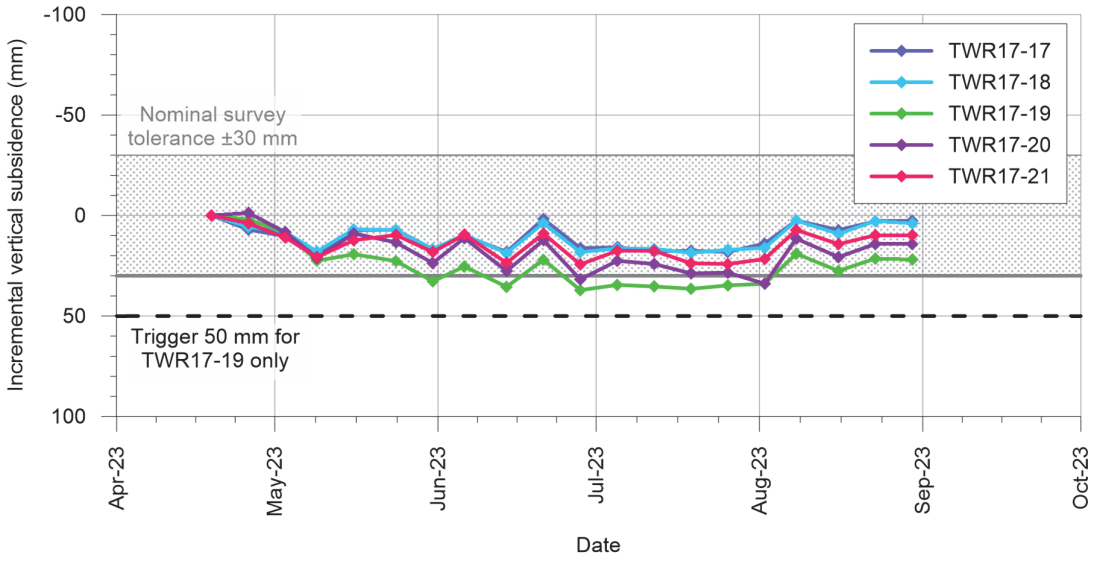


Fig. 2.3 Measured incremental vertical subsidence for TWR17-17 to TWR17-21 due to the mining of LW21 only

In the final survey, the measured vertical subsidence movements at the towers were less than 30 mm which is in the order of survey tolerance for absolute height. Low-level vertical subsidence was measured at Tower TWR17-19 during mining which reduced to less than survey tolerance at the completion of mining.

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 LW21 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 LW21

Monitoring	Current measured value	Predicted final value	Level 1 trigger level	Comments
Maximum incremental vertical subsidence at Tower TWR17-19 due to the mining of LW21 (mm)	21	50	50	Low-level vertical subsidence with no measurable change over the last three months
Maximum incremental change in relative levels of the tower legs at TWR17-19 due to the mining of LW21 (mm)	2.0	-	±4	Low-level differential levels between the tower legs that are in the order of survey tolerance
Maximum incremental tilt at TWR17-19 due to the mining of LW21 (mm/m)	0.2	0.5	-	Low-level tilt at the tower that is in the order of survey tolerance
Maximum incremental change in distance between the tower legs for Towers TWR17-18, TWR17-19 and TWR17-20 due to the mining of LW21 (mm)	+0.8 -1.2	-	±4	Maximum extension between tower legs at Tower TWR17-19 and maximum contraction between tower legs at Tower TWR17-20 are in the order of survey tolerance
Maximum incremental change in distances between the bases of adjacent towers due to the mining of LW21 (mm)	+2 -23	±20	-	Very small changes in the two months. The contraction measured between Towers TWR17-19 and TWR17-20 has exceeded the predicted value; however, the change in distance is very small and represents less than 0.01 % of the overall distance between the towers. The exceedance is in the order of survey tolerance
Visual observations of ground and tower deformations	None	-	Impacts	No visually apparent ground or tower deformations

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 change in distance between Towers TWR17-19 and TWR17-20 was -23 mm (contraction). The movement slightly exceeded the predicted value of 20 mm; however, the change in distance is very small when compared to the overall distance between the two towers, of approximately 370 m, and therefore it represents a change of less than 0.01 %. The exceedance of 3 mm is in the order of survey tolerance. IMC, TransGrid and MSEC reviewed the exceedance and agreed that no specific management measured were required.

Otherwise, the measured incremental subsidence effects for the transmission line were less than the predicted values and 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. MSEC978 which supported the Extraction Plan Application for LW21.

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 WC20 Line. The location of this monitoring line is shown in Drawing No. MSEC1378-01. The survey dates for the WC20 Line for LW21 are provided in Table 2.8.

Table 2.8 Survey dates for the WC20 Line for LW21

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Completion of LW21	20 March 2023 (base survey) 11 May 2023 30 May 2023 22 June 2023 20 July 2023 16 August 2023 9 September 2023 (end of LW21)	Completion of LW22

A summary of the maximum measured and predicted vertical subsidence and closure for the WC20 Line after the completion of LW21 are provided in Table 2.9. The predicted subsidence value has been derived from the predicted subsidence contours illustrated in Report No. MSEC978. 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 WC20 Line due to the mining of LW21

Type	Maximum incremental vertical subsidence (mm)	Maximum incremental closure (mm)
Measured	67	29
Predicted	< 50	200

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 at the WC20 Line of 67 mm is slightly greater than the maximum predicted vertical subsidence of less than 50 mm. However, the exceedance of 17 mm is within the order of survey accuracy for absolute height of ±30 mm. The measured incremental closure at the monitoring line of 29 mm is less than the predicted closure of 200 mm.

It is therefore considered that the ground movements measured using the WC20 cross line are consistent with the predictions provided in Report No. MSEC978 which supported the Extraction Plan Application for LW21.

2.7. ALS / LiDAR surveys

Changes in surface level due to the mining of LW21 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 April 2023 before the commencement of LW21. The post-mining surface level contours have been determined from the subsequent survey carried out in October 2023 after the completion of LW21.

The measured incremental changes in surface level due to the mining of LW21 only are shown in Fig. 2.4. 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 35° angle of draw have been removed for clarity.

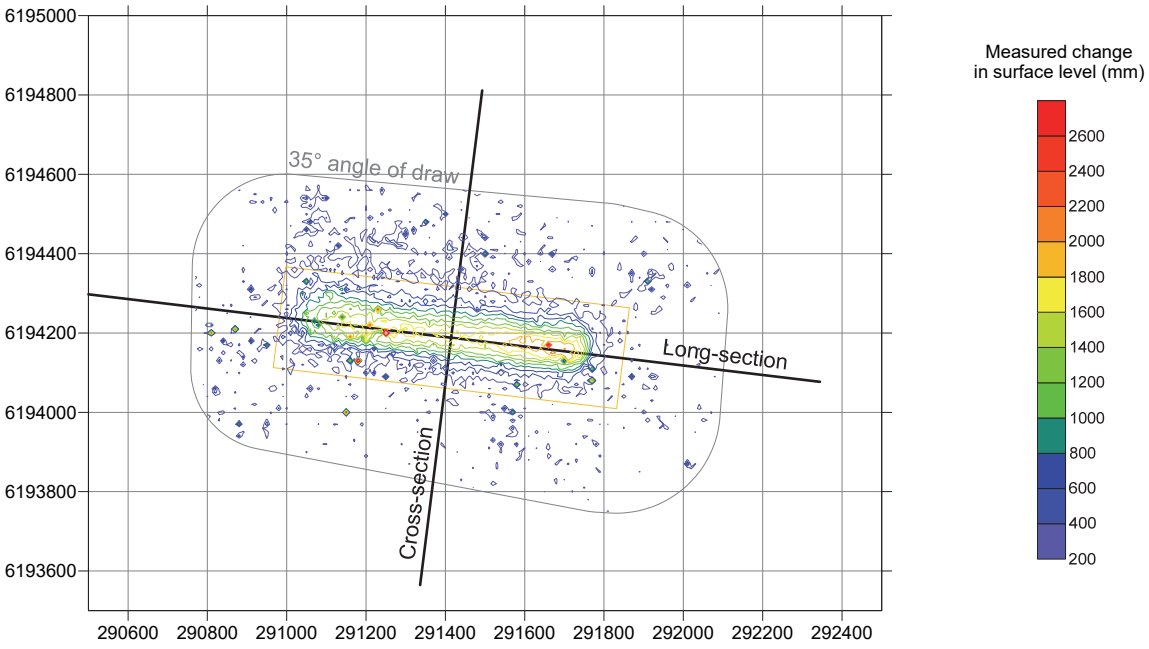


Fig. 2.4 Measured incremental changes in surface level due to the mining LW21

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. 2.4 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 the cross-section and long-section are provided in Fig. 2.5 and Fig. 2.6. The locations of these sections are indicated in Fig. 2.4. The predicted profiles of vertical subsidence have been derived from the predicted subsidence contours illustrated in Report No. MSEC978.

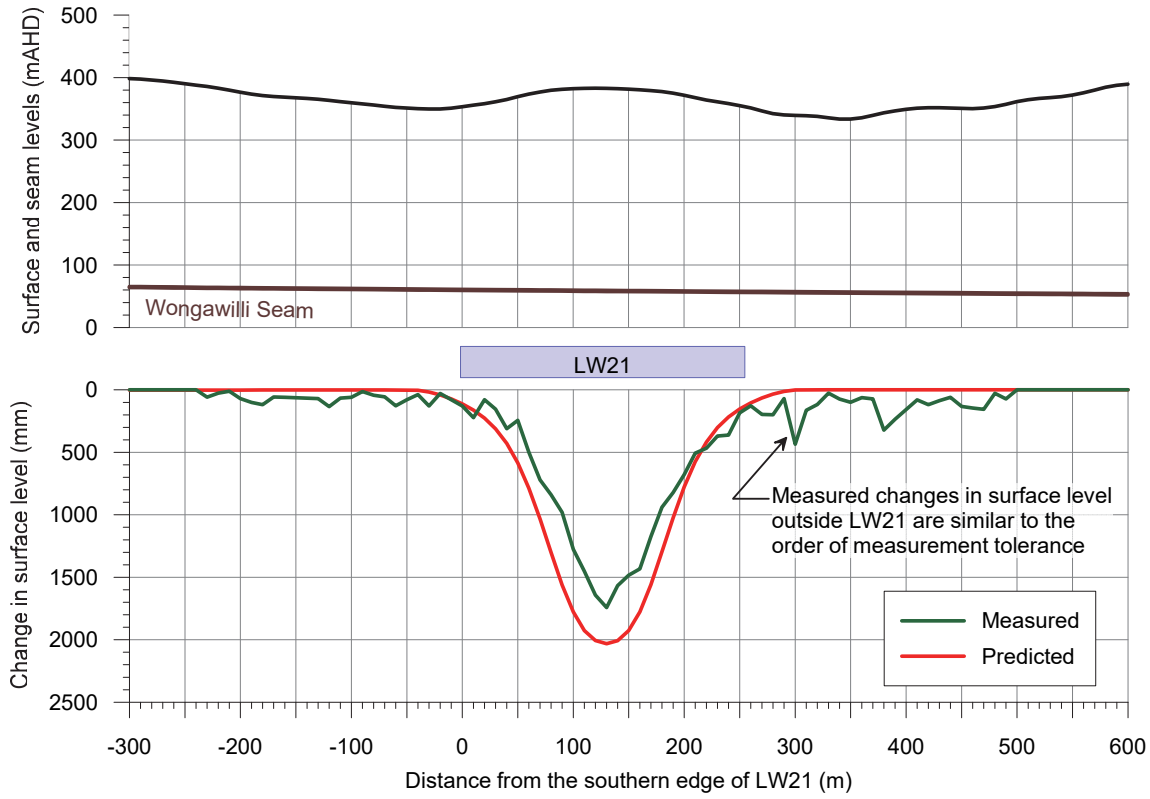


Fig. 2.5 Measured changes in surface level and predicted vertical subsidence for the Cross-section across LW21 near the mid-length of the longwall

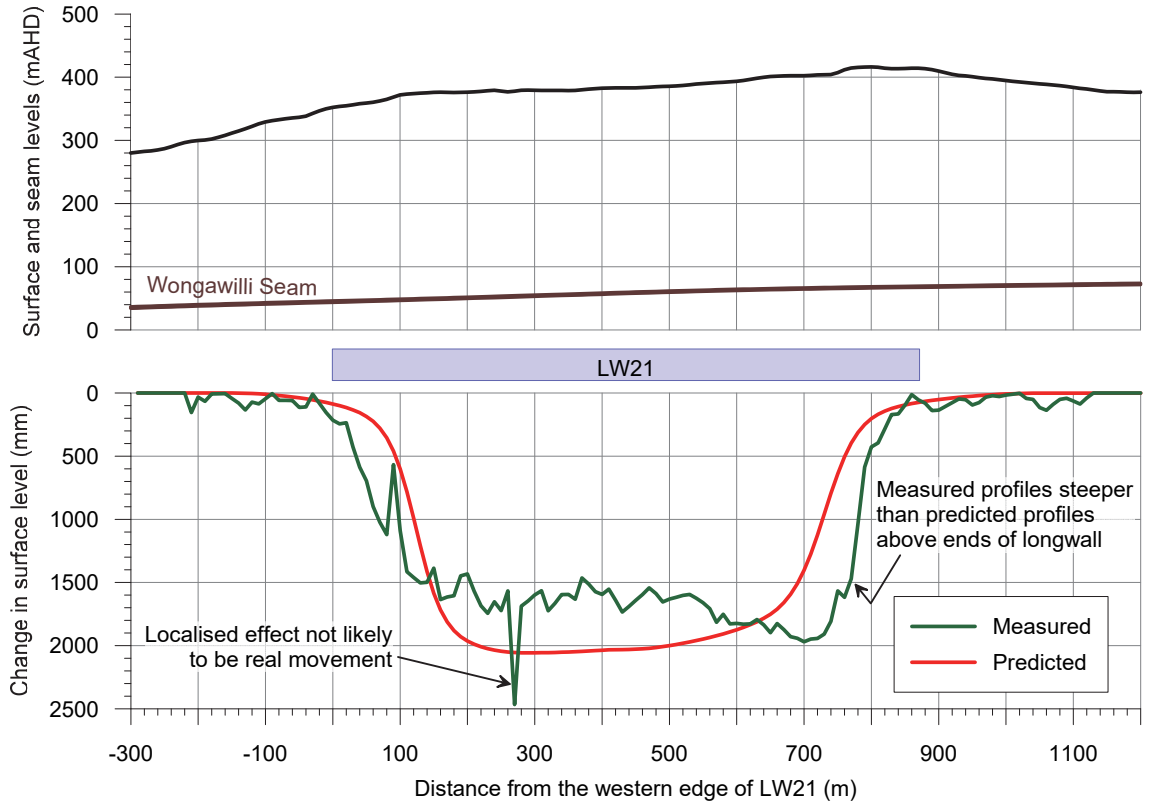


Fig. 2.6 Measured changes in surface level and predicted vertical subsidence for the Long-section along the centreline of LW21

The profiles of the measured change 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 LW21 is typically less than the maximum predicted values. The measured change in surface level locally exceeds the predicted vertical subsidence along the long-section (refer Fig. 2.6); however, this is likely to be a localised effect and is not a real movement.

The measured changes in surface level above the commencing and finishing ends of LW21 for the long-section (refer Fig. 2.6) are greater than the predicted subsidence in these locations. The measured profiles of change in surface level above the ends of the longwall are therefore steeper than the predicted subsidence profiles. The measured profiles above the ends of the longwall are also steeper than the measured profiles across the longwall (refer Fig. 2.5) which reasonably match the predicted profiles.

It can be inferred from the slopes of the profiles across LW21 (refer Fig. 2.5), 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.

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 is considered that the ground movements measured using the LiDAR surveys are consistent with the predictions provided in Report No. MSEC978 which supported the Extraction Plan Application for LW21.

3.1. Surface deformations

Surface deformations due to the mining of LW21 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 LW21 are illustrated in Fig. 3.1.

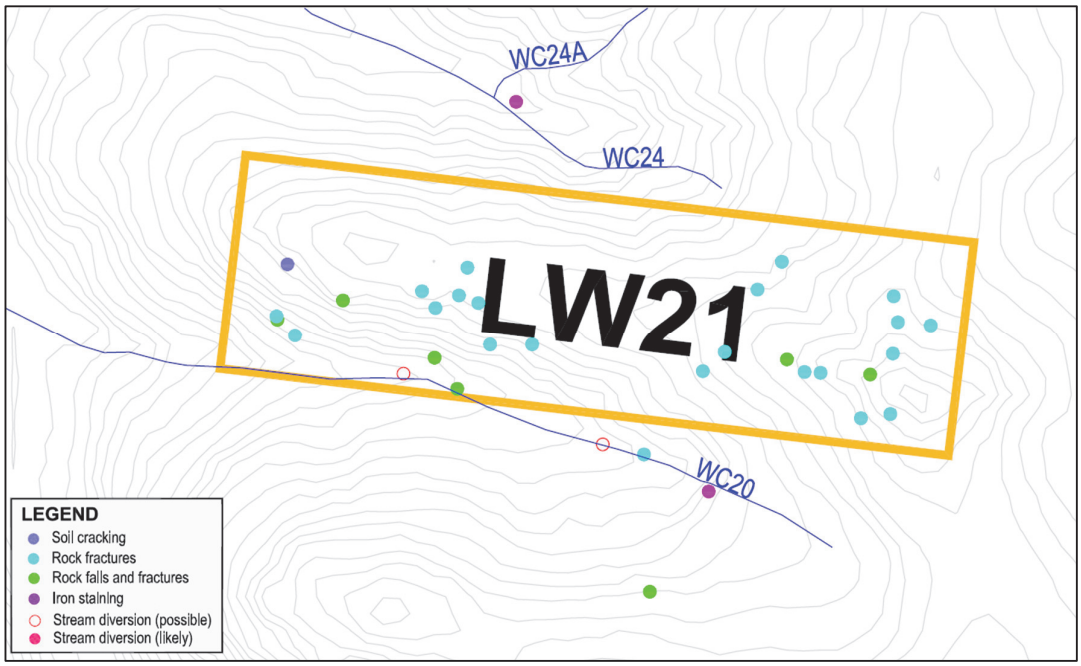


Fig. 3.1 Surface deformations due to the mining of LW21

Soil cracking (i.e. blue circles) and rock fracturing (i.e. cyan circles) were identified in 31 locations predominately above but also adjacent to LW21. Rockfalls (i.e. green circles) were also identified in 7 locations in the rock outcropping predominately located above but also adjacent to the longwall.

The soil crack and rock fracture widths were typically less than 50 mm in 16 locations (i.e. 73 % of cases), ranged between 50 mm and 100 mm in 3 locations (i.e. 14 % of cases) and were greater than 100 mm in 3 locations (i.e. 14 % of cases). The maximum fracture width was 260 mm (LW21_003) which occurred in a rock outcrop above the eastern end of LW21.

It was assessed that the range of soil crack and fracture widths due to LW21 would be similar to that observed above the existing longwalls in Areas 2, 3A and 3B which were typically less than 50 mm (i.e. 86 % of cases) but also between 50 mm and 150 mm in 8 % of cases, between 150 mm and 300 mm in 4 % of cases and greater than 300 mm in 2 % of cases. The maximum measured crack width in Areas 2, 3A and 3B was approximately 500 mm.

It is considered that the range of soil cracking and fracture widths due to the mining of LW21 is similar to the range of soil cracking and fracture widths previously measured in Areas 2, 3A and 3B.

Fracturing occurred in three locations along stream WC20 where it is located near the southern edge of LW21 (LW21_014, LW21_015 and LW21_017) with lengths up to 3.5 m and widths up to 60 mm. Surface water flows were not present downstream of these fracturing locations at the time of the site visit but there were signs of previous flows. It is possible therefore that surface water flow diversions have occurred in two locations along WC20 (LW21_014 and LW21_015).

Iron staining was observed in one location along stream WC20 (LW21_021) and one location along stream WC24 (LW21_020). Fracturing was not identified within these creeks near the areas of iron staining.

No fracturing was observed along Wongawilli Creek due to the mining of LW21. Iron staining and suspended iron oxides were evident in September 2023 from pool *WC_Pool 50* downstream to pool *WC_Pool 20*. The extent of iron staining has fluctuated but it was less extensive in September 2023 than when it was first reported in August 2021 before the mining of LW21.

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

3.2. Natural features

The natural features near LW21 are shown in Drawing No. MSEC1378-02, in Appendix A, and include:

- Wongawilli Creek;
- tributaries;
- Sandy Creek Waterfall;
- minor cliffs and rock outcrops;
- steep slopes; and
- swamps.

The MSEC assessed impacts for the natural features due to the mining of LW21 are provided in Report No. MSEC978 which supported the Extraction Plan Application for that longwall. More detailed assessments for the natural features are also provided in other consultants' reports that supported the Extraction Plan Application.

Comparisons between the MSEC assessments and the reported impacts for the natural features listed above due to the mining of LW21 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 LW21

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 of ponding or flooding due to the mining-induced vertical subsidence or tilt for LW21.
	Minor **fracturing** of the bedrock within 400 m of the longwalls due to strain.	No fracturing identified along the creek due to the mining of LW21. Iron staining from two iron seeps were observed adjacent to pool *WC_Pool 50*.
	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 LW21. 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.	Fracturing occurred in three locations along stream WC20 (LW21_014, LW21_015 and LW21_017) where it is located near the southern edge of LW21 with lengths up to 3.5 m and widths up to 60 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 WC20 (LW21_014 and LW21_015) downstream of where fracturing was observed along the tributary.
	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.	
Sandy Creek Waterfall	No adverse impacts anticipated.	No reported impacts.
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 cliffs identified within the Study Area for LW21. No reported impacts to the cliffs within the valley of Wongawilli Creek upstream or downstream of the mining area.

Natural feature	MSEC assessed impacts	Reported impacts
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 minor rockfalls in the rock outcrops identified in 7 locations. 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 31 locations in the steep slopes and rock outcrops. Crack widths typically less than 100 mm with a maximum crack width of 260 mm. Refer to the IMC landscape report for further details.
Swamps	**Fracturing** of the underlying strata which could result in the **diversion of surface water**.	Groundwater levels lower than baseline at Swamp 144 (144_01) and Swamp 9 (09_02) and soil moisture levels lower than baseline at Swamp 9 (S09_01 and S09_02), Swamp 144 (S144_01) and Swamp 145 (S145_01) in Area 3C during the mining of LW21. The groundwater and/or soil moisture levels were also less than baseline at Swamps 12, 15a, 15b and 150; however, these swamps are located in Areas 3A and 3B, well away from LW21.

It is considered that the observed impacts on the natural features due to the mining of LW21 are consistent with the MSEC assessments provided in Report No. MSEC978 which supported the Extraction Plan 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 LW21 are shown in Drawing No. MSEC1378-03, in Appendix A, and include:

- Fire trails and four-wheel drive tracks;
- 330 kV transmission line;
- 33 kV powerline;
- Cordeaux Dam;
- Survey control marks; and
- Aboriginal heritage sites.

The MSEC assessed impacts for the built features due to the mining of LW21 are provided in Report No. MSEC978 which supported the Extraction Plan Application for that longwall.

Comparisons between the MSEC assessments and the reported impacts for the built features due to the mining of LW21 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 LW21

Built feature	MSEC assessed impacts	Reported impacts
Fire trails and four-wheel drive tracks	Cracking of unsealed road surfaces.	No soil cracking reported along Fire Road 6F. Rock fracturing observed in rock outcrops located west of this road and directly above LW21. Refer to the IMC landscape report for further details.
330 kV transmission line	No impacts on safety and serviceability with the implementation of the required preventive measures.	No reported impacts.
33 kV powerline	No impacts on safety or serviceability.	No reported impacts.
Cordeaux Dam	No adverse impacts 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.
Aboriginal heritage sites	Impacts on overhang sites including fracturing of sandstone, rock falls, or water seepage through joints which may affect artwork.	No physical impacts (i.e. fracturing or rockfalls) reported near Sites 52-2-1647 and 52-2-4500. Refer to the accompanying cultural heritage report.

It is considered that the observed impacts on the built features due to the mining of LW21 are similar to or less than the MSEC assessments provided in Report No. MSEC978 which supported the Extraction Plan Application for that longwall.

4.0 SUMMARY

The mine subsidence effects due to the mining of LW21 were measured using the Wongawilli Creek closure lines, Sandy Creek Waterfall closure lines, Area 3C 3D monitoring points, 330 kV transmission line monitoring points, WC20 cross-line and LiDAR scans of the area.

The measured ground movements after the mining of LW21 are similar to or less than the predicted values based on the subsidence contours presented in Report No. MSEC978 which supported the Extraction Plan Application for LW21. The measured changes in surface level above the commencing and finishing ends of LW21, obtained from the LiDAR scans, are greater than predicted; however, the maximum measured changes in surface level above the longwall are less than the maximum predicted.

Soil cracking and rock fracturing were observed directly above and adjacent to LW21. The crack and fracture widths were typically less than 50 mm (i.e. 73 % of cases) with a maximum measured width of 260 mm. The range of soil cracking and fracture widths due to the mining of LW21 is similar to the range of soil cracking and fracture widths previously measured in Areas 2, 3A and 3B.

There were no surface water diversions (i.e. Type 3 impact) observed along Wongawilli Creek due to the mining of LW21. Iron staining and suspended iron oxides were evident in September 2023 from pool *WC_Pool 50* downstream to pool *WC_Pool 20*. The extent of iron staining has fluctuated but it was less extensive in September 2023 than when it was first reported in August 2021 before the mining of LW21.

Two possible surface water diversions were identified along stream WC20 where fracturing was observed adjacent to and above the southern edge of LW21. It was assessed that surface water flow diversions could occur where the drainage lines are directly mined beneath.

It is considered, therefore, that the observed surface impacts on the natural and built features due to the mining of LW21 are consistent with the MSEC assessments provided in Report No. MSEC978 which supported the Extraction Plan Application for LW21. 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

I:\Projects\Dendrobium\Area 3\MSEC1378 - Area 3C - Longwall 21 End of Panel Report\AcadData\MSEC1378-01 General Layout.dwg

msec mine subsidence ENGINEERING CONSULTANTS
Suite 402, 13 Spring Street, Chatswood NSW 2067
PO Box 302, Chatswood NSW 2057
Tel +61 2 9413 3777
www.minesubsidence.com

SOUTH32

ILLAWARRA METALLURGICAL COAL

DENDROBIUM COLLIERY - AREA 3C
LONGWALL 21 END OF PANEL
GENERAL LAYOUT & MONITORING LINES

DATE:	SCALE:	DRAWING No:	Rev No
22 Nov 2023	as shown	MSEC1378-01	A

LEGEND
- MONITORING LINES
- 3D MONITORING POINTS
- WATERCOURSES
- 5m SURFACE LEVEL CONTOURS

SCALE 0m 100m 200m

AREA 3C

Study Area based on 35° Angle of Draw

LW21

LW21 End : 6-Aug-2023

LW21 Start : 25-Apr-2023

LW20

LW22

LW21A

LW6

LW7

AREA 3A

WONG Y-Line

WONG Z-Line

WONG A-Line

WONG B-Line

WONGAWILLI CREEK

330kV Transmission Line

33kV Powerline

Fire Road No 6C

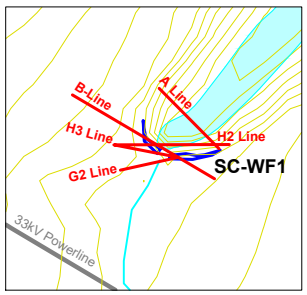
Fire Road No 6F

Lake Cordeaux

Sandy Creek (see inset map)

DA3c-40
DA3c-45
DA3c-6C
DA3c-36
DA3c-42
DA3c-35
DA3c-43
DA3c-37
DA3c-44
DA3a-6
DA3a-15A
DA3c-41
DA3a-8
TS10825

WC2001
WC2002
WC2003
WC2004



SANDY CREEK WATERFALL
HIGH RESOLUTION
MONITORING LINES

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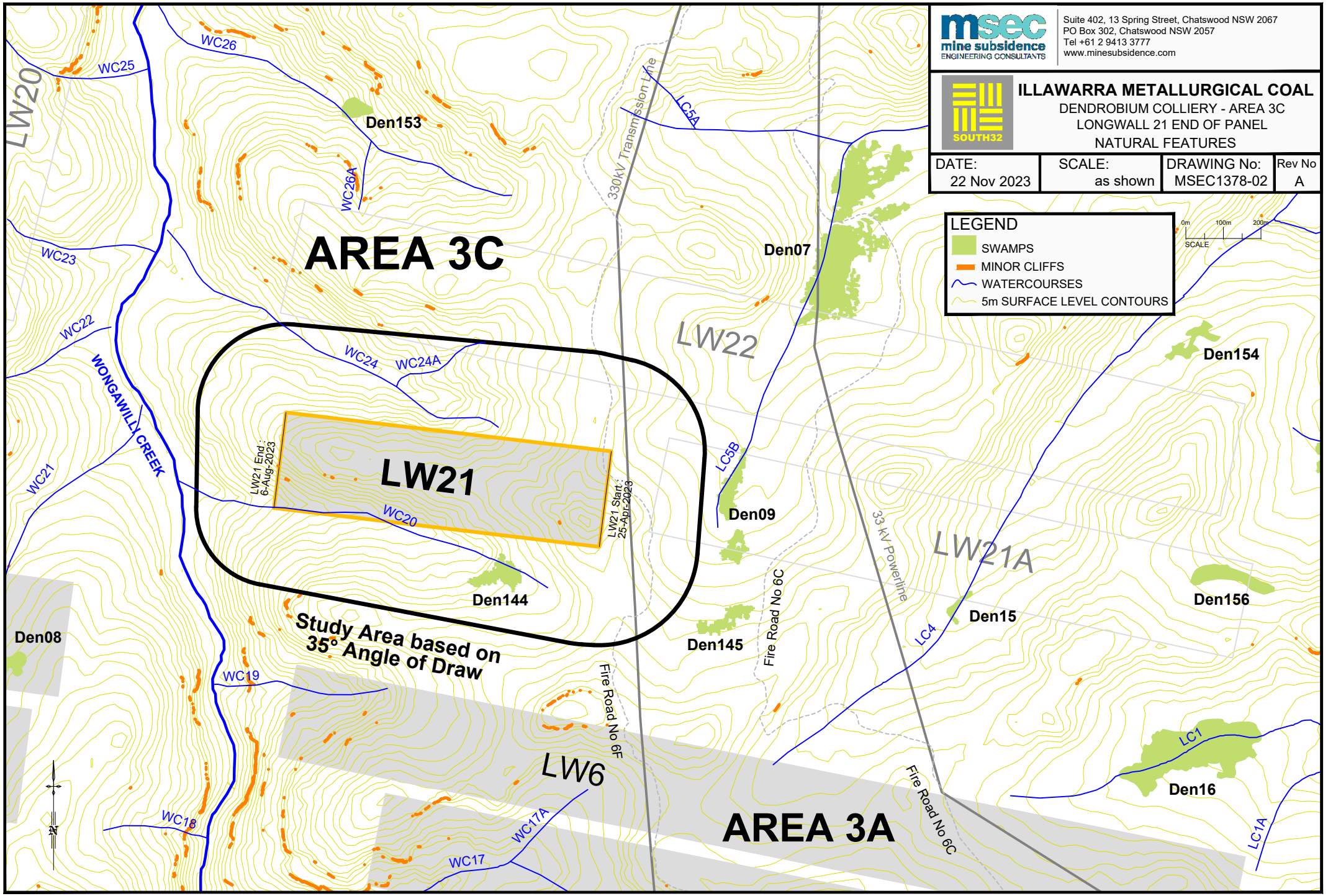

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Suite 402, 13 Spring Street, Chatswood NSW 2067
PO Box 302, Chatswood NSW 2057
Tel +61 2 9413 3777
www.minesubsidence.com

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ILLAWARRA METALLURGICAL COAL

DENDROBIUM COLLIERY - AREA 3C
LONGWALL 21 END OF PANEL
NATURAL FEATURES

DATE:	SCALE:	DRAWING No:	Rev No
22 Nov 2023	as shown	MSEC1378-02	A

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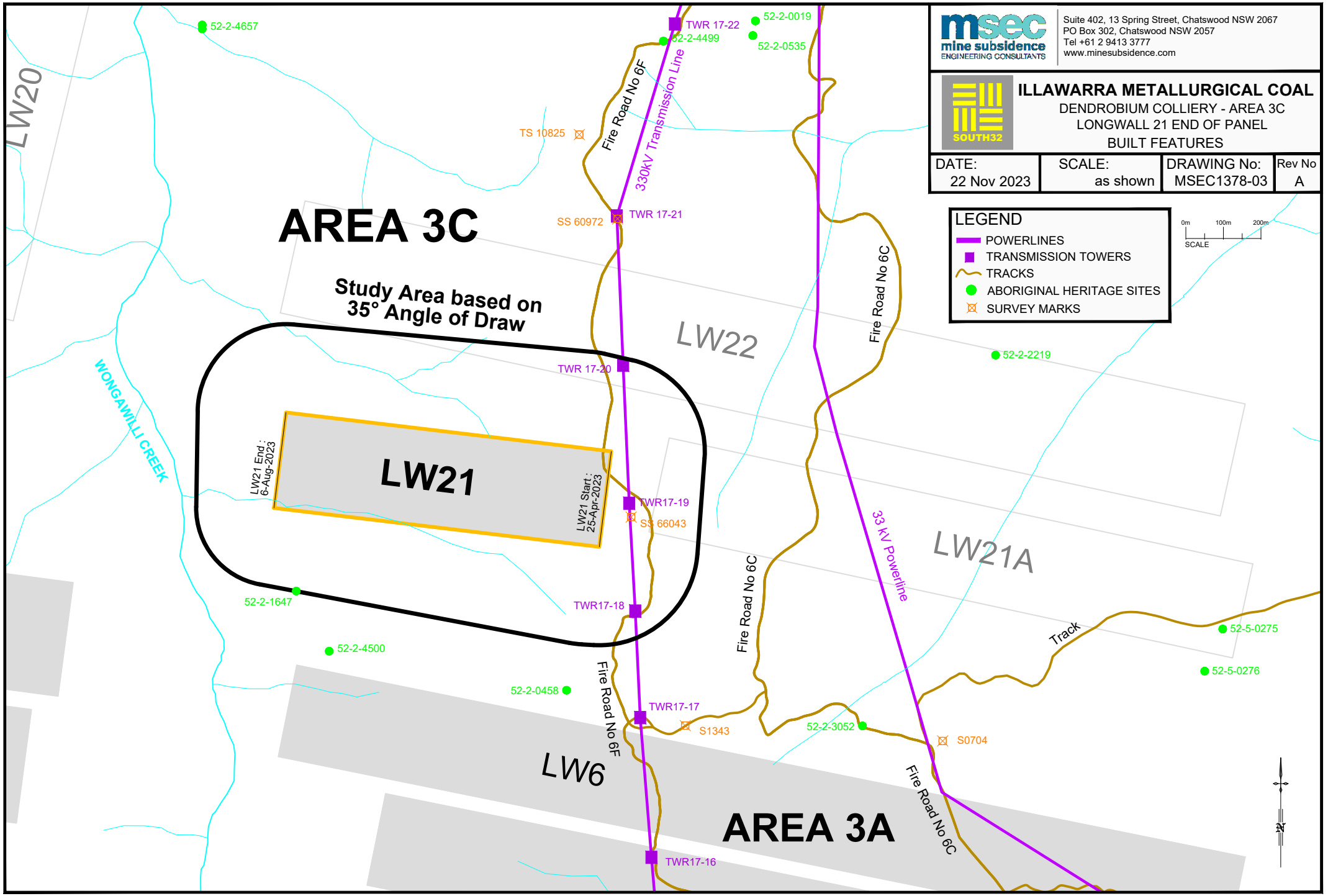

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Suite 402, 13 Spring Street, Chatswood NSW 2067
PO Box 302, Chatswood NSW 2057
Tel +61 2 9413 3777
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DENDROBIUM COLLIERY - AREA 3C
LONGWALL 21 END OF PANEL
BUILT FEATURES

DATE:	SCALE:	DRAWING No:	Rev No
22 Nov 2023	as shown	MSEC1378-03	A

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PO Box 302, Chatswood NSW 2057
Tel +61 2 9413 3777
www.minesubsidence.com

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ILLAWARRA METALLURGICAL COAL

DENDROBIUM COLLIERY - AREA 3C
LONGWALL 21 END OF PANEL
MEASURED INCREMENTAL HORIZONTAL MOVEMENT VECTORS DUE TO LW21

DATE:	SCALE:	DRAWING No:	Rev No
22 Nov 2023	as shown	MSEC1378-04	A

SURFACE LEVEL CONTOURS

AREA 3C

AREA 3B

AREA 3A

LW20

LW21

LW22

LW21A

LW6

Study Area based on 35° Angle of Draw

LW21 End : 6-Aug-2023

LW21 Start : 25-Apr-2023

WONGAWILLI CREEK

833kV Transmission Line

33 kV Powerline

Fire Road No 6F

Fire Road No 6C

Fire Road No 6C

TS10825

DA3c-40

DA3c-45

DA3c-6C

DA3c-36

DA3c-42

DA3c-35

DA3c-43

DA3c-37

DA3c-44

DA3a-6

DA3a-15A

DA3c-41

DA3a-8

WC2001
WC2002
WC2003
WC2004

VECTOR & MAGNITUDE OF MEASURED HORIZONTAL MOVEMENT (mm)

SCALE 0m 100m 200m

Grid to MGA co-ordinates