REPORT: END OF PANEL SUBSIDENCE MONITORING REPORT

mine subsidence
ENGINEERING CONSULTANTS

# South32

Illawarra Coal

SOUTH32 ILLAWARRA COAL:

# Dendrobium - Area 3B - Longwall 12

End of Panel Subsidence Monitoring Review Report for Dendrobium Longwall 12

## DOCUMENT REGISTER

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

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).

MSEC459 (September 2012) – Dendrobium Area 3B – Longwalls 9 to 18 – subsidence predictions and impact assessments for natural features and surface infrastructure in support of the SMP Application.

MSEC652 (May 2014) – Dendrobium Area 3B – The effects of the proposed modifications to the commencing end of Longwall 11 and to the widths of Longwalls 12 to 18 in Area 3B at Dendrobium Mine on the subsidence predictions and impact assessments.

MSEC785 (July 2015) – The effects of the proposed modifications to the finishing end of Longwall 11 and to the commencing end of Longwall 12 in Area 3B at Dendrobium Mine on the subsidence predictions and impact assessments.

MSEC792 (December 2015) – Dendrobium Area 3B – Longwalls 12 to 18 – Review of the subsidence predictions and impact assessments for natural and built features in Dendrobium Area 3B based on observed movements and impacts during Longwalls 9 and 10.

MSEC865 (November 2016) – The effects of the proposed modifications to the ends of Longwalls 12 to 18 in Area 3B at Dendrobium Mine on the subsidence predictions and impact assessments.

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 are prefixed by the number of the section or the letter of the appendix 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* | *Revision* |
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| MSEC888-01 | General layout and monitoring lines | A |
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## 1.1. Introduction

Illawarra Coal (IC) has completed the extraction of Longwall 12 at Dendrobium Mine, which is in the Southern Coalfield of New South Wales. The locations of the longwalls in Area 3B at Dendrobium Mine are shown in Drawing No. MSEC888-01, in Appendix A. The extraction of Longwall 12 commenced on the 22nd February 2016 and was completed on the 31st January 2017.

Mine Subsidence Engineering Consultants (MSEC) was previously commissioned by IC to prepare subsidence predictions and impact assessments for Dendrobium Longwalls 9 to 18 in Area 3B. Report No. MSEC459 (Revision B) was issued in September 2012 in support of the SMP Application for these longwalls.

IC modified the widths of Longwalls 12 to 18 by increasing them by 0.2 m from the widths adopted in the SMP Application. Report No. MSEC652 (Rev. B) was issued in May 2014 in support of the application for this modification. The modified widths of Longwalls 12 to 18 were approved by the Department of Industry – Division of Resources and Energy (DRE) on the 19th August 2014.

IC then shortened the commencing (western) end of Longwall 12 by 84 m and shortened the finishing end by 107 m from the extents indicated in the SMP Application. Reports Nos. MSEC785 (Rev. A) and MSEC865 (Rev. A) were issued in support of the applications for these modifications. The modified commencing and finishing ends of Longwall 12 were approved by DRE on the 4th September 2015 and the 11th January 2017, respectively.

The subsidence prediction model was reviewed and re-calibrated, based on the updated monitoring data from Longwalls 7 and 8 in Area 3A and Longwalls 9 and 10 in Area 3B. The subsidence predictions and impact assessments for the natural and built features were reviewed and updated based on the re-calibrated subsidence model and are provided in Report No. MSEC792 (Rev. C). The predictions provided in this End of Panel subsidence review report are based on the re-calibrated subsidence prediction model outlined in Reports Nos. MSEC792 and MSEC865.

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

- Comparisons between the observed and predicted subsidence movements at the monitoring lines and points in Dendrobium Area 3B resulting from the extraction of Longwall 12; and
- Comparisons between the observed and predicted effects and impacts on the natural and built features within the SMP Area resulting from the extraction of Longwall 12.

Further details on the predicted and observed impacts for natural features, resulting from the extraction of Longwall 12, are provided in the reports by other consultants. The observations 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 extraction of Longwall 12. This section also provides comparisons between the observed and predicted movements resulting from the extraction of Longwall 12.

Chapter 3 of this report describes the natural and built features near Longwall 12. This section also provides comparisons between the observed and predicted impacts for these features resulting from the extraction of Longwall 12. Further discussions on the observed and assessed impacts for natural features are provided in reports by other consultants.

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 extraction of Longwall 12.

Appendix A includes all drawings associated with this report.

## 1.2. Mining Geometry

The layout of the longwalls in Area 3B at Dendrobium Mine is shown in Drawing No. MSEC888-01, in Appendix A. A summary of the as-extracted dimensions for Longwalls 9 to 12 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 3B | Longwall 9 | 2162 | 305 | - |
| | Longwall 10 | 2219 | 305 | 45 |
| | Longwall 11 | 2204 | 305 | 45 |
| | Longwall 12 | 2602 | 305 | 45 |

The mined lengths of the longwalls excluding the installation headings are approximately 9 m shorter than the overall void lengths provided in Table 1.1. The length of extraction for Longwall 12, therefore, is approximately 2593 m. The longwall face widths excluding the first workings are approximately 294 m.

The longwalls in Area 3B have been extracted from the Wongawilli Seam, from the west towards the east, i.e. towards Wongawilli Creek. The natural surface and the seam levels along the centreline of Longwall 12 are illustrated in Fig. 1.1.

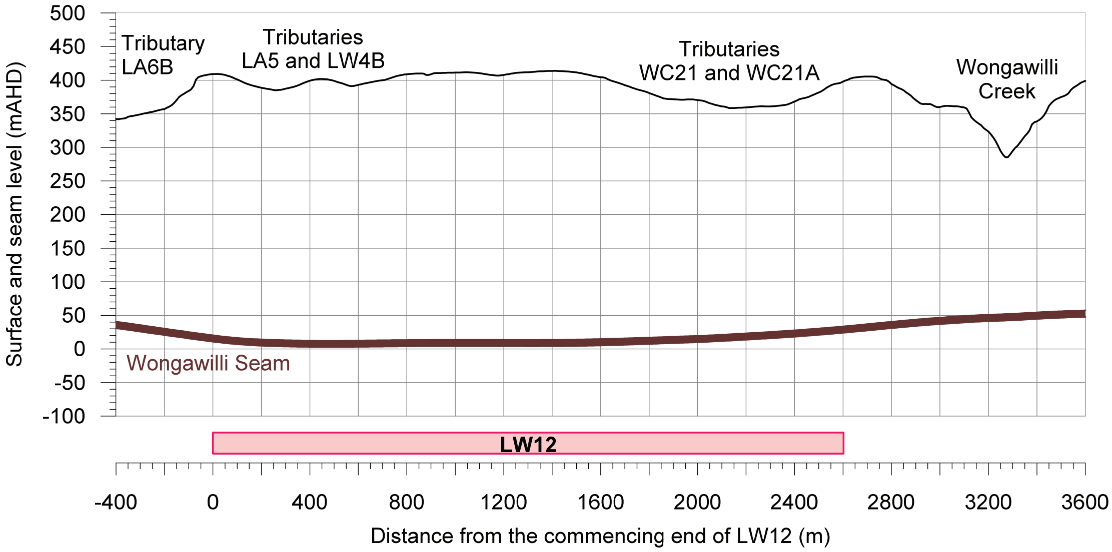


**Fig. 1.1 Surface and seam levels along the centreline of Longwall 12**

The depth of cover to the Wongawilli Seam, directly above Longwall 12, varies between a minimum of 330 m near the eastern (i.e. finishing) end of the longwall, and a maximum of 410 m near the mid-length of the longwall. The seam floor within the mining area generally dips from the south to the north, having an average dip around 2 %, or 1 in 50.

The extraction height varies along the length of Longwall 12, depending on the local roof conditions. The predictions provided in this report have been based on the maximum proposed extraction height of 4.6 metres, as adopted in Reports Nos. MSEC459, MSEC652, MSEC785, MSEC792 and MSEC865.

## 2.1. Introduction

The mine subsidence movements resulting from the extraction of Dendrobium Longwall 12 were monitored along several monitoring lines and monitoring points including the following:

- Wongawilli Creek closure lines;
- Avon Dam closure lines;
- Area 3B and Avon Dam 3D monitoring points;
- Tributary cross lines;
- Donalds Castle Creek 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. MSEC888-01, in Appendix A. Comparisons between the observed and predicted subsidence movements at these monitoring lines and points are provided in the following sections. The predicted subsidence parameters have been obtained using the re-calibrated subsidence model presented in Reports Nos. MSEC792 and MSEC865.

## 2.2. Wongawilli Creek closure lines

The closure movements across Wongawilli Creek have been measured by IC using 2D survey techniques at the Wong X A-Line, Wong X B-Line and Wong X C-Line. The locations of these monitoring lines are shown in Drawing No. MSEC888-01. The survey dates for the Wongawilli Creek closure lines for Longwall 12 are provided in Table 2.1.

**Table 2.1 Survey dates for the Wongawilli Creek closure lines for Longwall 12**

| Mining phase commitments | Mining phase survey dates | Post mining phase commitments |
|---|---|---|
| Completion of Longwall 12 | 13th February 2013 (base survey)<br>4th March 2016 (end of LW11)<br>28th April 2017 (end of LW12) | Completion of each of the future longwalls in Area 3B |

The monitoring lines each comprise two survey marks, with the marks located on either side of Wongawilli Creek and, therefore, they measure the closure between the valley sides. Survey marks could not be located near the base of the valley due to the difficult terrain. 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 extraction of Longwalls 6 to 12, is illustrated in Fig. 2.1. The Wong X A-Line was not measured at the completion of Longwall 12, due to its distance from that longwall and, therefore, the last survey for this monitoring line was carried out on the 4th March 2016 at the completion of Longwall 11.

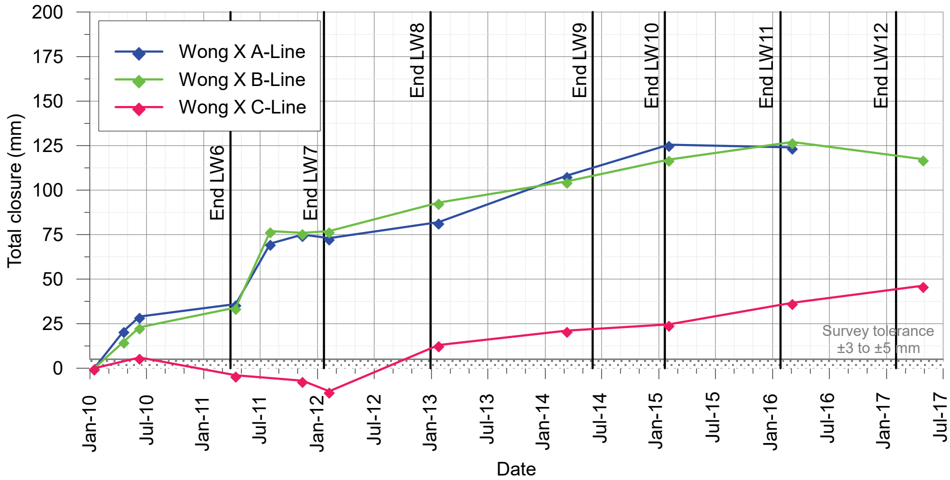


**Fig. 2.1 Development of total closure for the Wongawilli Creek closure lines**

The predictions of subsidence, upsidence and closure for Wongawilli Creek, resulting from the extraction of Dendrobium Longwalls 6 to 19, were provided in Report No. MSEC865. The measured and predicted total closures along Wongawilli Creek after the completion of Longwall 12 are illustrated in Fig. 2.2.

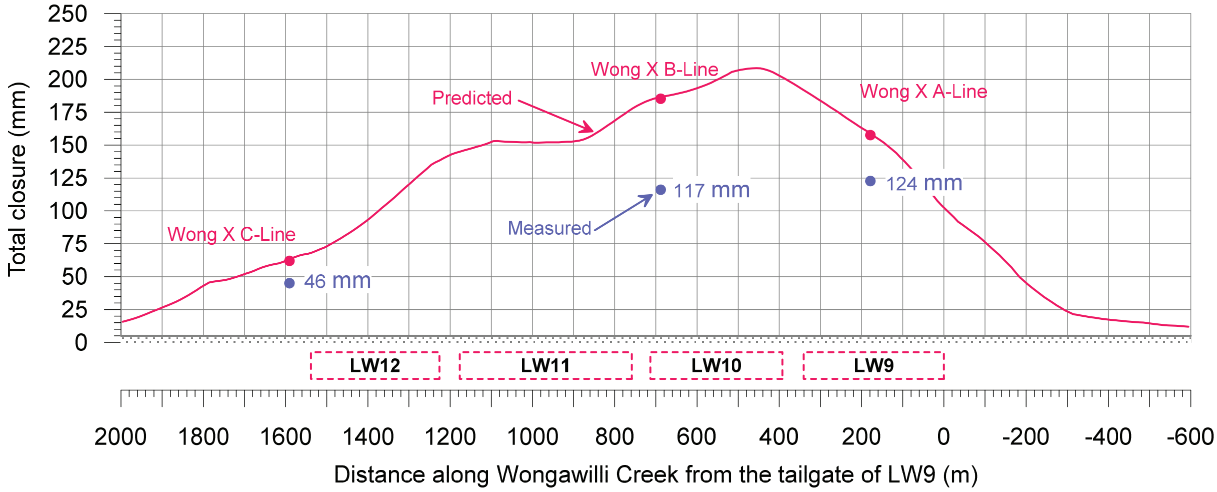


**Fig. 2.2 Measured and predicted total closure along Wongawilli Creek**

A summary of the maximum measured and maximum predicted total closure movements for each of the Wongawilli Creek closure lines, due to the extraction of Longwalls 6 to 12, is provided in Table 2.2. The predicted total closures consider the shortened finishing ends of Longwall 11 and 12.

**Table 2.2 Maximum measured and maximum predicted total closure at the Wongawilli Creek closure lines due to the extraction of Longwalls 6 to 12**

| Location | Measured total closure (mm) | Predicted total closure (mm) |
|---|---|---|
| Wong X A-Line | 124 (end of LW11) | 175 |
| Wong X B-Line | 117 | 200 |
| Wong X C-Line | 46 | 125 |

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

It can be seen from Fig. 2.2 and Table 2.2, that the maximum measured total closures at each of the Wongawilli Creek closure lines are less than the predictions after the completion of Longwall 12.

## 2.3. Avon Dam closure lines

The closure across the Avon Dam has been measured by IC using the Avon Dam A-Line to E-Line. The locations of these monitoring lines are shown in Drawing No. MSEC888-01. The discussions on the Avon Dam 3D monitoring points are included in Section 2.4.

The survey dates for the Avon Dam closure lines are provided in Table 2.3. The base surveys were carried out just prior to the commencement of Longwall 12 and, therefore, the closure lines have measured the incremental movements due to the extraction of this longwall only.

**Table 2.3 Survey dates for the Avon Dam closure lines during Longwall 12**

| Mining phase commitments | Mining phase survey dates | Post mining phase commitments |
|---|---|---|
| Completion of Longwall 12 | 12th February 16 (base survey)<br>23rd March 16<br>27th April 16<br>31st May 16<br>30th June 16<br>30th August 16<br>12th April 17 (end of LW12) | Completion of each of the future longwalls in Area 3B |

The monitoring lines each comprise two survey marks, with the marks located on either side of the Avon Dam and, therefore, they measure the closure between the valley sides. Survey marks could not be located near the base of the valley due to the stored water in the dam. The upsidence in the base of the valley, therefore, could not be measured.

The development of the measured incremental closures along Avon Dam closure lines during the extraction of Longwall 12 are illustrated in Fig. 2.3. The predicted final incremental closure for each of the monitoring lines is less than 20 mm.

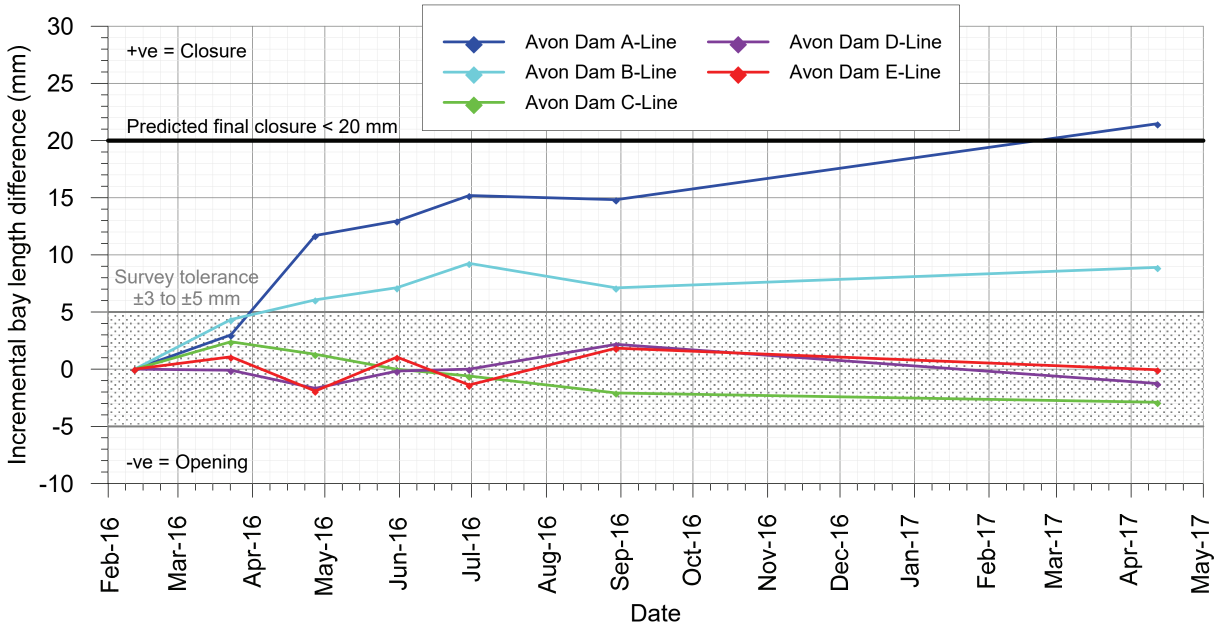


**Fig. 2.3 Measured and predicted incremental closure for the Avon Dam closure lines**

A summary of the maximum measured and maximum predicted incremental movements for each of the Avon Dam closure lines, due to the extraction of Longwall 12 only, is provided in Table 2.2.

**Table 2.4 Maximum measured and maximum predicted incremental movements for the Avon Dam closure lines due to the extraction of Longwalls 12**

| Location | Observed incremental closure (mm) | Predicted incremental closure (mm) |
|---|---|---|
| Avon Dam A-Line | 21 | < 20 |
| Avon Dam B-Line | 9 | < 20 |
| Avon Dam C-Line | -3 (opening) | < 20 |
| Avon Dam D-Line | -1 (opening) | < 20 |
| Avon Dam E-Line | 0 | < 20 |

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

It can be seen from Fig. 2.3 and Table 2.2, that the maximum measured incremental closures at the Avon Dam B-Line, C-Line, D-Line and E-Line are less than the predicted final closures after the completion of Longwall 12. The measured closure at the Avon Dam A-Line of 21 mm is similar to, but slightly larger than the predicted final closure. However, this exceedance is within the order of accuracy of the survey measurements.

The mine subsidence movements across a tributary to Avon Dam (Ref. LA4) have also been measured by IC using 2D survey techniques using the LA4-Line. The location of this monitoring line is shown in Drawing No. MSEC888-01. The base survey was carried out on the 26th February 2013, i.e. prior to the commencement of Longwall 9. There was one subsequent survey on the 30th August 2016 during the extraction of Longwall 12.

A summary of the total measured and total predicted closures along the LA4-Line is provided in Table 2.5. The measured closure is less than the predicted final closure at the completion of Longwall 12. The vertical subsidence was not measured.

**Table 2.5 Maximum measured and predicted total closure at the LA4-Line resulting from the extraction of Longwalls 9 to 12**

| Type | Maximum total subsidence (mm) | Maximum total closure (mm) |
|---|---|---|
| Measured | - Not measured - | 12 |
| Predicted | - N/A - | 90 |

It is considered that the ground movements measured using the Avon Dam closure lines and the LA4-Line are consistent with the predictions provided in Reports Nos. MSEC792 and MSEC865.

## 2.4. Dendrobium Area 3B 3D and the Avon Dam 3D monitoring points

The far-field horizontal movements near Longwall 12 have been measured by IC using the Dendrobium Area 3B 3D monitoring points (DA3B 3D) and the Avon Dam 3D monitoring points. The locations of these monitoring points are shown in Drawing No. MSEC888-01.

The survey dates for the DA3B 3D monitoring points for Longwall 12 are provided in Table 2.6. The survey dates and monitoring commitments for the Avon Dam 3D monitoring points are the same as the Avon Dam closure lines provided in Table 2.3.

**Table 2.6 Survey dates for the DA3B 3D monitoring points for Longwall 12**

| Mining phase commitments | Mining phase survey dates | Post mining phase commitments |
|---|---|---|
| Completion of Longwall 12 | 26th February 2013 (base survey)<br>4th March 2016 (end of LW11)<br>9th March 2017 (end of LW12) | Completion of each of the future longwalls in Area 3B |

The measured incremental horizontal movement vectors for DA3B 3D and the Avon Dam 3D monitoring points, due to the extraction of Longwall 12, are shown in Drawing No. MSEC888-04. The accuracies of the measured absolute positions (i.e. Eastings and Northings) are in the order of ±20 mm.

The vectors of incremental horizontal movement are typically orientated towards Longwall 12. The greatest movements have been measured directly above Longwall 12 and, to lesser extents, above the previously extracted longwalls in the series. Only low level incremental horizontal movements have been measured outside the extents of the mining area.

The comparison between the maximum measured incremental horizontal movements at the DA3B 3D and Avon Dam 3D monitoring points with those previously measured in Dendrobium Area 1 (DA1 3D) and Dendrobium Area 2 (DA2 3D), Dendrobium Area 3A (DA3A 3D), as well as other collieries in the Southern Coalfield, is provided in Fig. 2.4. The mean and the 95 % confidence level for the 3D monitoring data at Dendrobium Mine are also shown in this figure.

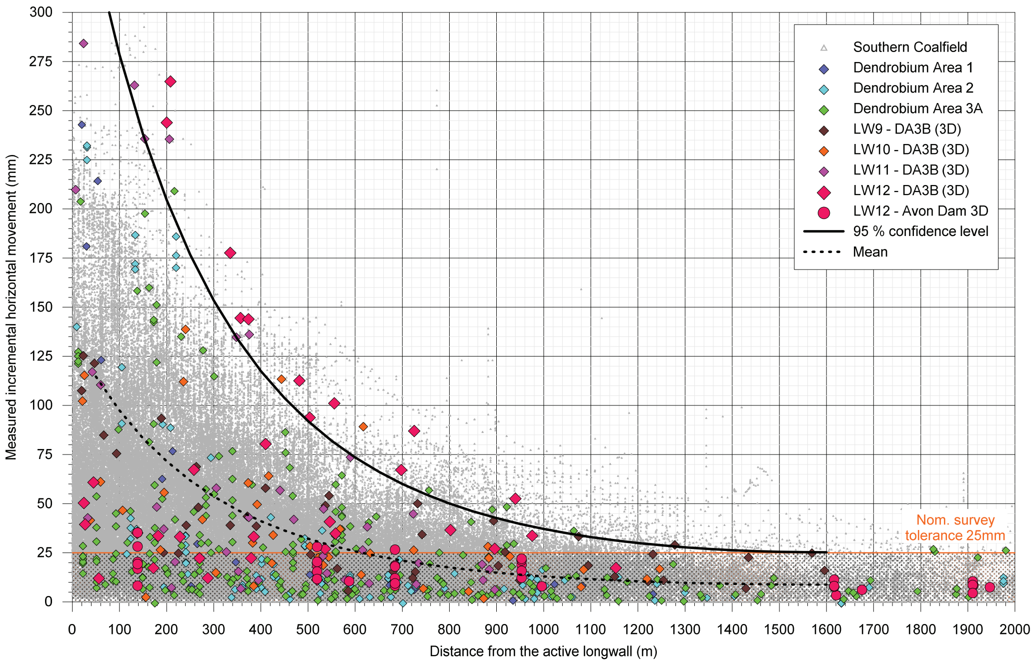


**Fig. 2.4 Measured incremental horizontal movements at Dendrobium Mine**

The measured incremental horizontal movements resulting from the extraction of Longwall 12 (i.e. red diamonds and circles) are within the range of those measured at similar distances from previously extracted longwalls at Dendrobium Mine (i.e. blue, cyan, green, brown, orange and magenta diamonds) and elsewhere in the Southern Coalfield (i.e. grey triangles).

## 2.5. Wongawilli Creek tributary cross lines

The mine subsidence movements across a tributary to Wongawilli Creek (Ref. WC21) have been measured by IC using 2D survey techniques using the WC21 D-Line, WC21 E-Line, WC21 F-Line, WC21 H-Line, WC21 I-Line, WC21 J-Line, WC21 K-Line, WC21 L-Line (lower) and WC21 L-Line (upper). The WC21 A-Line, B-Line, C-Line and G-Line were not measured during Longwall 12.

The locations of the tributary cross lines are shown in Drawing No. MSEC888-01. The survey dates for these monitoring lines for Longwall 12 are provided in Table 2.7.

**Table 2.7 Survey dates for the Wongawilli Creek tributary cross lines for Longwall 12**

| Mining phase commitments | Mining phase survey dates | Post mining phase commitments |
|---|---|---|
| First survey 100 m before lines, then monthly surveys. Final survey when mining 400 m past lines | 13th February 2013 (base survey)<br>4th March 2016 (end of LW11)<br>13th October 2016<br>8th November 2016<br>6th December 2016<br>10th January 2017<br>28th April 2017 (end of LW12) | First survey 100 m before lines, then monthly surveys. Final survey when mining 400 m past lines |

The development of the measured total closures along the tributary cross lines during the extraction of Longwalls 9 to 12 are illustrated in Fig. 2.5. The WC21 H-Line was established on the 21st October 2015 and, therefore, does not include the effects of Longwalls 9 and 10. The WC21 I-Line, J-Line, K-Line, L-Line (lower) and L-Line (upper) were established on the 5th October 2016 and, therefore, do not include the effects of Longwalls 9, 10 and 11.

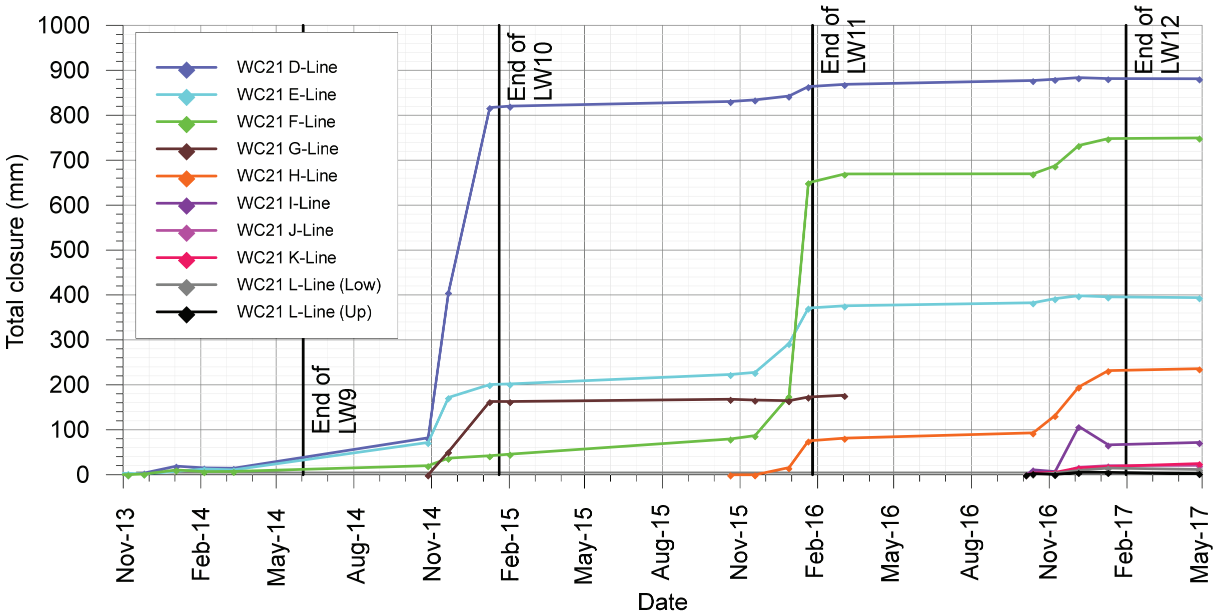


**Fig. 2.5 Measured total closure for the tributary cross lines**

Summaries of the maximum measured and predicted total subsidence and closure along the tributary cross lines, after the extraction of Longwall 12, are provided in Table 2.8 to Table 2.15. The predicted subsidence values have been derived from the predicted subsidence contours illustrated in Report No. MSEC865. The predicted closures are based on a combination of the conventional and valley related movements, taking the equivalent heights of the valleys within half-depths of cover from the valley bases.

**Table 2.8 Maximum measured and predicted total subsidence and closure at the WC21 D-Line resulting from the extraction of Longwalls 9 to 12**

| Type | Maximum total subsidence (mm) | Maximum total closure (mm) |
|---|---|---|
| Measured | 2096 | 881 |
| Predicted | 3125 | 975 |

**Table 2.9 Maximum measured and predicted total subsidence and closure at the WC21 E-Line resulting from the extraction of Longwalls 9 to 12**

| Type | Maximum total subsidence (mm) | Maximum total closure (mm) |
|---|---|---|
| Measured | 710 | 394 |
| Predicted | 1425 | 650 |

**Table 2.10 Maximum measured and predicted total subsidence and closure at the WC21 F-Line resulting from the extraction of Longwalls 9 to 12**

| Type | Maximum total subsidence (mm) | Maximum total closure (mm) |
|---|---|---|
| Measured | 1699 | 750 |
| Predicted | 3125 | 750 |

**Table 2.11 Maximum measured and predicted total subsidence and closure at the WC21 H-Line resulting from the extraction of Longwalls 11 and 12**

| Type | Maximum total subsidence (mm) | Maximum total closure (mm) |
|---|---|---|
| Measured | 602 | 236 |
| Predicted | 1425 | 225 |

**Table 2.12 Maximum measured and predicted total subsidence and closure at the WC21 I-Line (SW10-Line) resulting from the extraction of Longwalls 11 and 12**

| Type | Maximum total subsidence (mm) | Maximum total closure (mm) |
|---|---|---|
| Measured | 2047 | 72 |
| Predicted | 2875 | 300 |

**Table 2.13 Maximum measured and predicted total subsidence and closure at the WC21 J-Line resulting from the extraction of Longwall 12 only**

| Type | Maximum total subsidence (mm) | Maximum total closure (mm) |
|---|---|---|
| Measured | 97 | 21 |
| Predicted | 80 | 150 |

**Table 2.14 Maximum measured and predicted total subsidence and closure at the WC21 K-Line resulting from the extraction of Longwall 12 only**

| Type | Maximum total subsidence (mm) | Maximum total closure (mm) |
|---|---|---|
| Measured | 77 | 25 |
| Predicted | 20 | 125 |

**Table 2.15 Maximum measured and predicted total subsidence and closure at the WC21 L-Line (lower and upper) resulting from the extraction of Longwall 12 only**

| Type | Maximum total subsidence (mm) | Maximum total closure (mm) |
|---|---|---|
| Measured | 61 | 12 |
| Predicted | 20 | 100 |

The accuracies of the measured relative levels of the survey marks along the tributary cross lines are in the order of ±5 mm. 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 measured total closure for the WC21 H-Line of 236 mm is slightly greater than the predicted total closure of 225 mm. The exceedance of 11 mm represents 5 % of the predicted value and, therefore, is within the order of accuracy of the predictive method for valley closure of ±15 % to ±25 %. The measured total closure for the WC21 F-Line is the same as the predicted total closure.

The measured total vertical subsidence at the WC21 J-Line, K-Line and L-Lines are up to approximately 50 mm greater than the predicted total vertical subsidence. These monitoring lines are located outside and to the south of Longwall 12. The exceedances for vertical subsidence along these monitoring lines are similar to the order of accuracy of the predictive method for vertical subsidence, of ±50 mm, for low magnitudes measured outside the extents of mining.

The measured total vertical subsidence and closure for the remaining WC21 tributary cross lines are less than the predictive values. It is considered, therefore, that the ground movements measured using tributary cross lines are consistent with the predictions provided in Reports Nos. MSEC792 and MSEC865.

## 2.6. Donalds Castle Creek cross lines

The mine subsidence movements across Donalds Castle Creek were measured by IC using 2D survey techniques using the DCCXB-Line, DCCXC-Line, DCCXD-Line, DCCXE-Line and DCCXF-Line. DCCXA-Line was not measured during Longwall 12. The locations of the Donalds Castle Creek cross lines are shown in Drawing No. MSEC888-01. The survey dates for these monitoring lines are provided in Table 2.16.

**Table 2.16 Survey dates for the Donalds Castle Creek cross lines during Longwall 12**

| Mining phase commitments | Mining phase survey dates | Post mining phase commitments |
|---|---|---|
| First survey 100 m before lines, then monthly surveys. Final survey when mining 400 m past lines | 13th February 2013 (initial survey)<br>4th March 2016 (end of LW11)<br>13th June 2016<br>11th August 2016<br>14th September 2016<br>28th April 2017 (end of LW12) | Completion of each of the future longwalls in Area 3B |

Summaries of the maximum measured and predicted total subsidence and closure along the Donalds Castle Creek cross lines, after the extraction of Longwall 12, are provided in Table 2.17 to Table 2.21. The predicted subsidence values have been derived from the predicted subsidence contours illustrated in Report No. MSEC865. The predicted closures are based on a combination of the conventional and valley related movements, taking the equivalent heights of the valleys within half-depths of cover from the valley bases. Survey line DCCXF-Line was established on the 8th May 2015 and therefore does not include the effects of Longwalls 9 and 10.

**Table 2.17 Maximum measured and predicted total subsidence and closure at the DCCXB-Line resulting from the extraction of Longwalls 9 to 12**

| Location | Maximum total subsidence (mm) | Maximum total closure (mm) |
|---|---|---|
| Measured | 828 | -7 (opening) |
| Predicted | 1125 | 275 |

**Table 2.18 Maximum measured and predicted total subsidence and closure at the DCCXC-Line resulting from the extraction of Longwalls 9 to 12**

| Location | Maximum total subsidence (mm) | Maximum total closure (mm) |
|---|---|---|
| Measured | 2645 | 464 |
| Predicted | 2650 | 450 |

**Table 2.19 Maximum measured and predicted total subsidence and closure at the DCCXD-Line resulting from the extraction of Longwalls 9 to 12**

| Location | Maximum total subsidence (mm) | Maximum total closure (mm) |
|---|---|---|
| Measured | 1403 | 33 |
| Predicted | 1200 | 250 |

**Table 2.20 Maximum measured and predicted total subsidence and closure at the DCCXE-Line resulting from the extraction of Longwalls 9 to 12**

| Location | Maximum total subsidence (mm) | Maximum total closure (mm) |
|---|---|---|
| Measured | 2498 | 385 |
| Predicted | 2550 | 350 |

**Table 2.21 Maximum measured and predicted total subsidence and closure at the DCCXF-Line resulting from the extraction of Longwalls 11 and 12**

| Location | Maximum total subsidence (mm) | Maximum total closure (mm) |
|---|---|---|
| Measured | 834 | 133 |
| Predicted | 1175 | 150 |

The accuracies of the measured relative levels of the survey marks along the Donalds Castle Creek cross lines are in the order of ±5 mm. 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 total measured vertical subsidence for the DCCXD-Line of 1403 mm is greater than the predicted total vertical subsidence of 1200 mm. The exceedance of 203 mm represents 17 % of the predicted value and, therefore, is within the order of accuracy of the predictive method for vertical subsidence of ±15 % to ±25 %. This monitoring line is located above the chain pillar between Longwalls 10 and 11 and away from the location of the maximum vertical subsidence. The total vertical subsidence measured at the DCCXD-Line, therefore, is less than the maxima that occur directly above these longwalls.

The total measured closures for the DCCX C-Line and E-Line of 464 mm and 385 mm are greater than the predicted values of 450 mm and 350 mm, respectively. The exceedances of 14 mm and 35 mm represent 3 % and 10 % of the predicted values and, therefore, are within the order of accuracy of the predictive method for valley closure of ±15 % to ±25 %.

The exceedances in the total measured movements for the DCCX C-Line, D-Line and E-Line occurred during the extraction of Longwalls 9 to 11. Only small incremental movements were measured at these monitoring lines during the extraction of Longwall 12.

It is considered, therefore, that the ground movements measured using Donalds Castle Creek cross lines are consistent with the predictions provided in Reports Nos. MSEC792 and MSEC865.

## 2.7. Swamp cross lines

The mine subsidence movements across the swamps have been measured by IC using 2D survey techniques using the SW3-Line, SW4-Line and SW10-Line. The locations of the swamp cross lines are shown in Drawing No. MSEC888-01. The survey dates for these monitoring lines are provided in Table 2.22.

**Table 2.22 Survey dates for the swamp cross lines during Longwall 12**

| Mining phase commitments | Mining phase survey dates | Post mining phase commitments |
|---|---|---|
| First survey 100 m before lines then monthly surveys, final survey when mining 400 m past lines | 9th February 2015 (initial surveys all lines)<br>17th February 2016 (end of LW11 all lines)<br>22nd March 2016 (SW3 only)<br>29th April 2016 (SW3 and SW4)<br>31st May 2016 (SW4 only)<br>28th June 2016 (SW3 and SW4)<br>10th August 2016 (SW3 and SW4)<br>14th September 2016 (SW4 only)<br>13th October 2016 (SW10 only)<br>8th November 2016 (SW10 only)<br>6th December 2016 (SW10 only)<br>10th January 2017 (SW10 only)<br>28th February 2017 (SW3, SW4 & SW10) | First survey 100 m before lines then monthly surveys, final survey when mining 400 m past lines |

Summaries of the maximum measured and predicted total subsidence and closure along the swamp cross lines, resulting from the extraction of Longwalls 11 and 12, are provided in Table 2.23 to Table 2.25. The predicted subsidence values have been derived from the predicted subsidence contours illustrated in Report No. MSEC865. The predicted closures are based on a combination of the conventional and valley related movements, taking the equivalent heights within half-depths of cover from the valley bases.

**Table 2.23 Maximum measured and predicted total subsidence and closure at the SW3-Line resulting from the Extraction of Longwalls 11 and 12**

| Type | Maximum total subsidence (mm) | Maximum total closure (mm) |
|---|---|---|
| Measured | 1314 | 50 |
| Predicted | 2250 | 100 |

**Table 2.24 Maximum measured and predicted total subsidence and closure at the SW4-Line resulting from the Extraction of Longwalls 11 and 12**

| Type | Maximum total subsidence (mm) | Maximum total closure (mm) |
|---|---|---|
| Measured | 1990 | 188 |
| Predicted | 2575 | 375 |

**Table 2.25 Maximum measured and predicted total subsidence and closure at the SW10-Line resulting from the Extraction of Longwalls 11 and 12**

| Type | Maximum total subsidence (mm) | Maximum total closure (mm) |
|---|---|---|
| Measured | 2047 | 72 |
| Predicted | 2875 | 300 |

The accuracies of the measured relative levels of the survey marks along the swamp cross lines are in the order of ±5 mm. 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 vertical subsidence and closure are less than the maximum predicted values at each of the SW3, SW4 and SW10-Lines. It is noted, that the measured ground movements are also less than the predicted values based on Report No. MSEC459 (i.e. prior to the re-calibration of the subsidence model).

## 2.8. ALS / LiDAR surveys

The changes in surface level due to the extraction of Longwalls 9 to 12 have been measured using Airbourne Laser Scan (ALS) / Light Detection and Ranging (LiDAR) surveys. The initial surface level contours have been determined from the base survey carried out in January 2013, prior to the extraction of Longwall 9. The post mining surface level contours have been determined from the subsequent surveys carried out in February 2014 after the completion of Longwall 9, in January 2015 after the completion of Longwall 10, in April 2016 after the completion of Longwall 11, and in March 2017 after the completion of Longwall 12.

The measured incremental changes in surface level due to the extraction of Longwall 12 only are shown in Fig. 2.6. These contours have been determined by taking the differences between the surface levels measured before and after the extraction of this longwall. It is noted that the initial survey was carried out approximately two months after the commencement of Longwall 12 and, therefore, the measured contours do not include the first 530 m of extraction for this longwall.

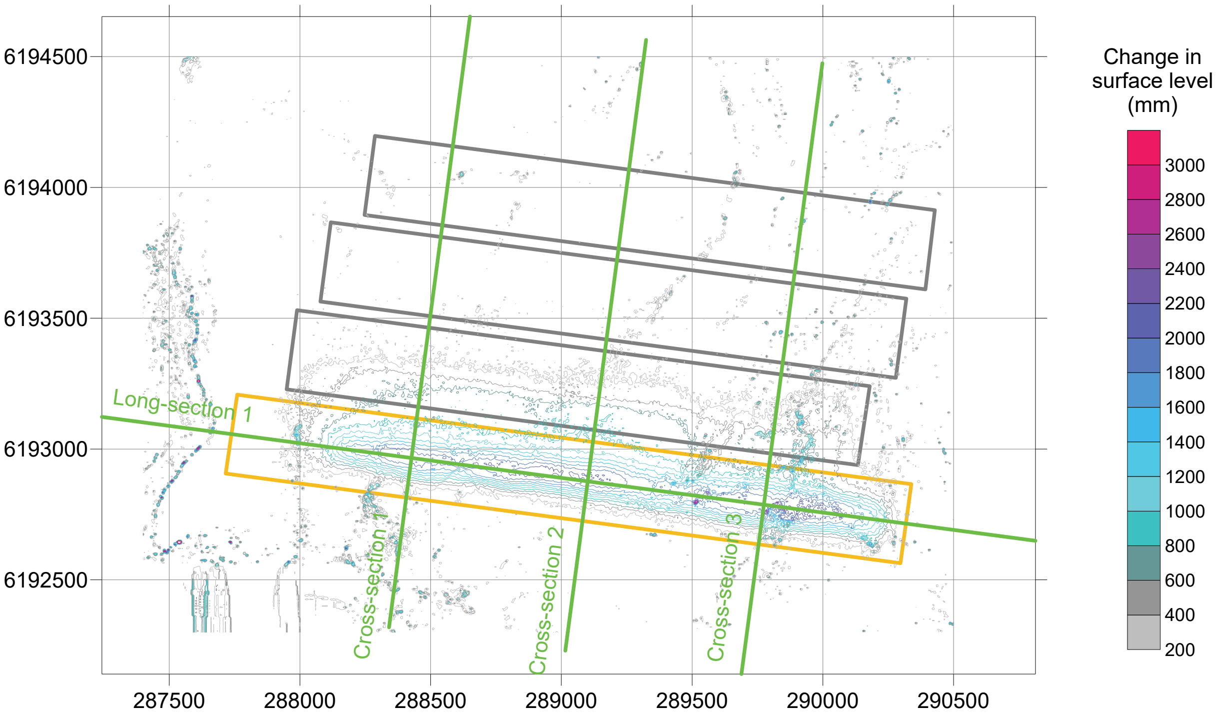


**Fig. 2.6 Measured incremental changes in surface level due to the extraction of Longwall 12**

The measured total changes in surface level due to the extraction of Longwalls 9 to 12 are shown in Fig. 2.7. These contours have been determined by taking the differences between the surface levels measured before the extraction of Longwall 9 and after the completion of Longwall 12.

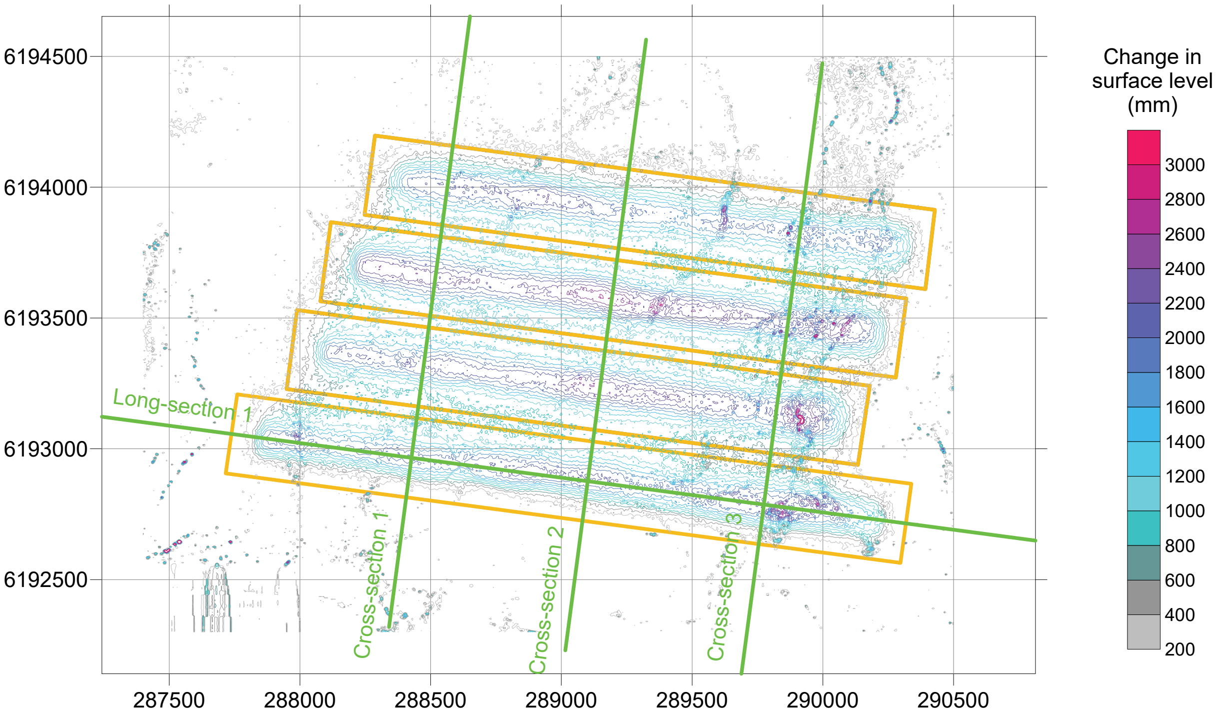


**Fig. 2.7 Measured total changes in surface level due to the extraction of Longwalls 9 to 12**

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. 2.6 and Fig. 2.7 as the localised areas of red hatching above the longwalls and 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.

The LiDAR surveys have an accuracy for absolute level in the order of ±50 to ±150 mm. The accuracy of the measured changes in surface level (i.e. the difference between two surveys), therefore, is in the order of ±100 to ±300 mm.

The comparisons of the measured changes in surface level and the predicted vertical subsidence along Cross-sections 1 to 3 and Long-section 1 are provided in Fig. 2.8 to Fig. 2.11. The locations of these sections are indicated in Fig. 2.6 and Fig. 2.7. The predicted profiles of vertical subsidence have been derived from the predicted subsidence contours illustrated in Report No. MSEC865.

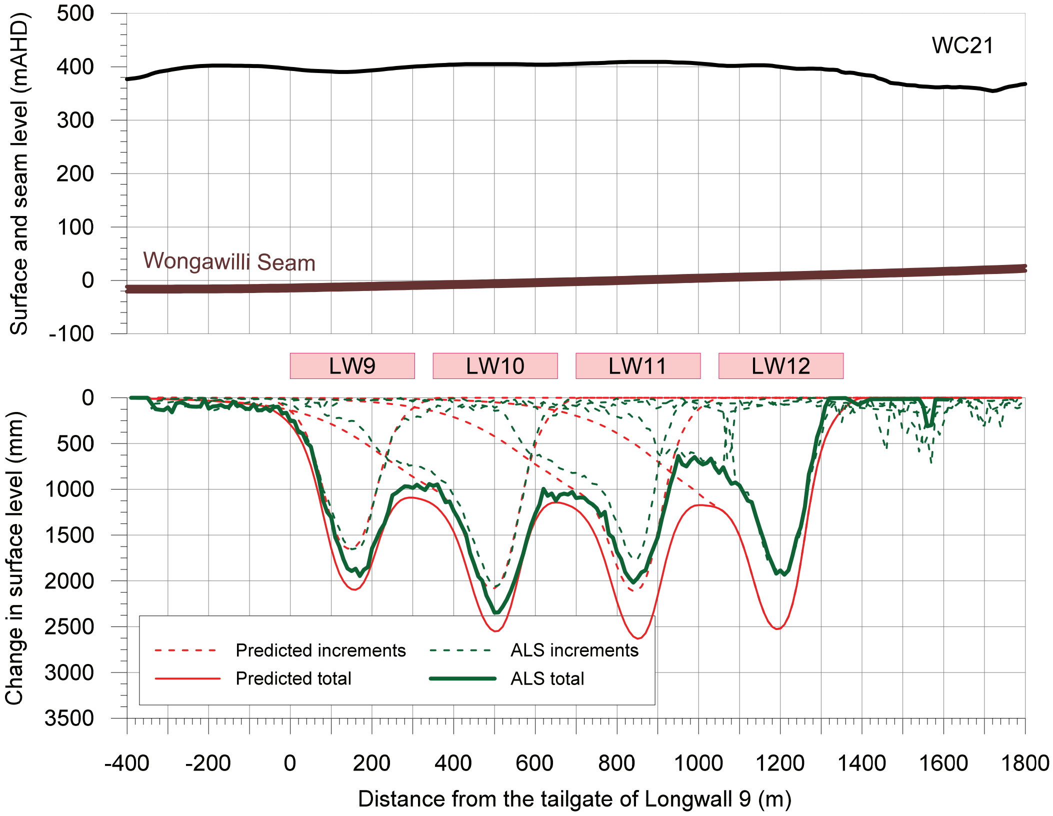


**Fig. 2.8 Measured changes in surface level and predicted vertical subsidence along Cross-section 1**

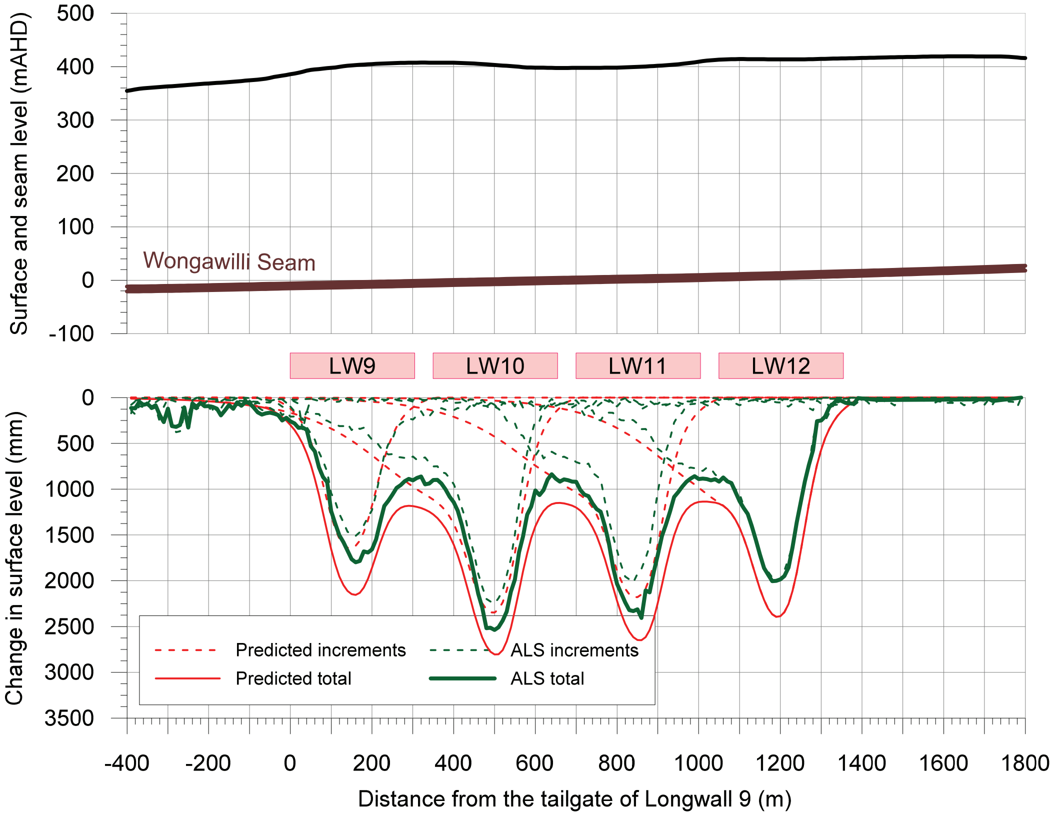


**Fig. 2.9 Measured changes in surface level and predicted vertical subsidence along Cross-section 2**

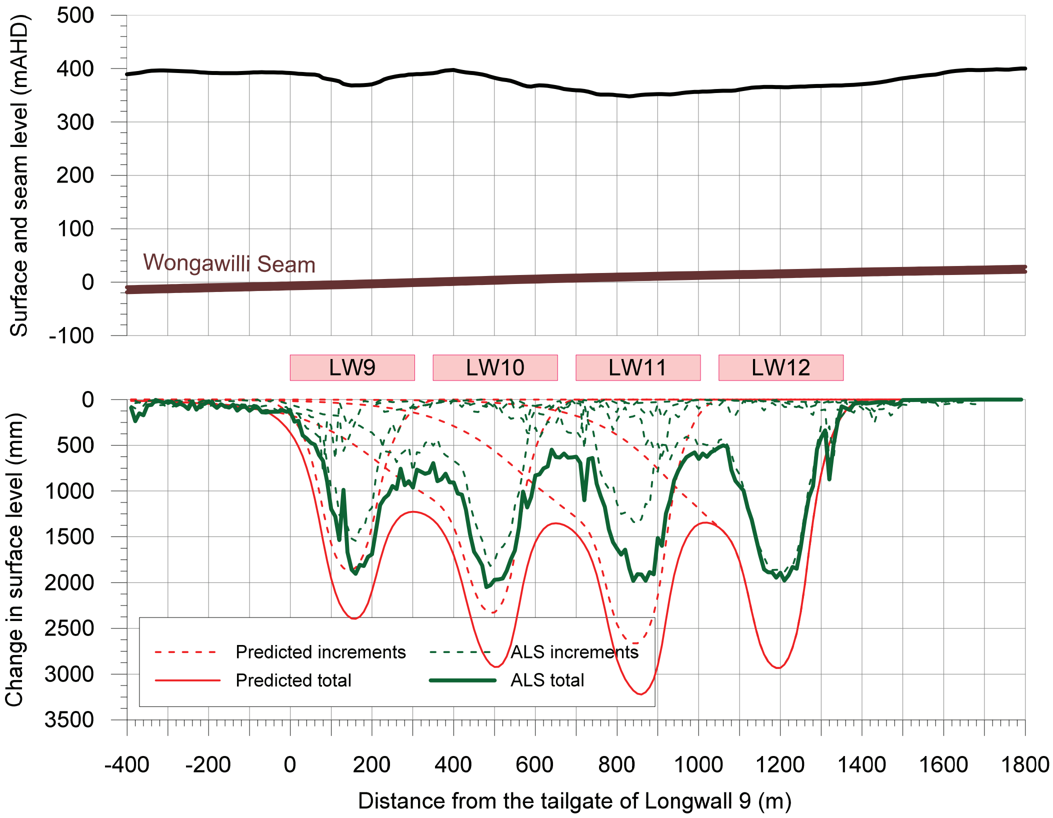


**Fig. 2.10 Measured changes in surface level and predicted vertical subsidence along Cross-section 3**

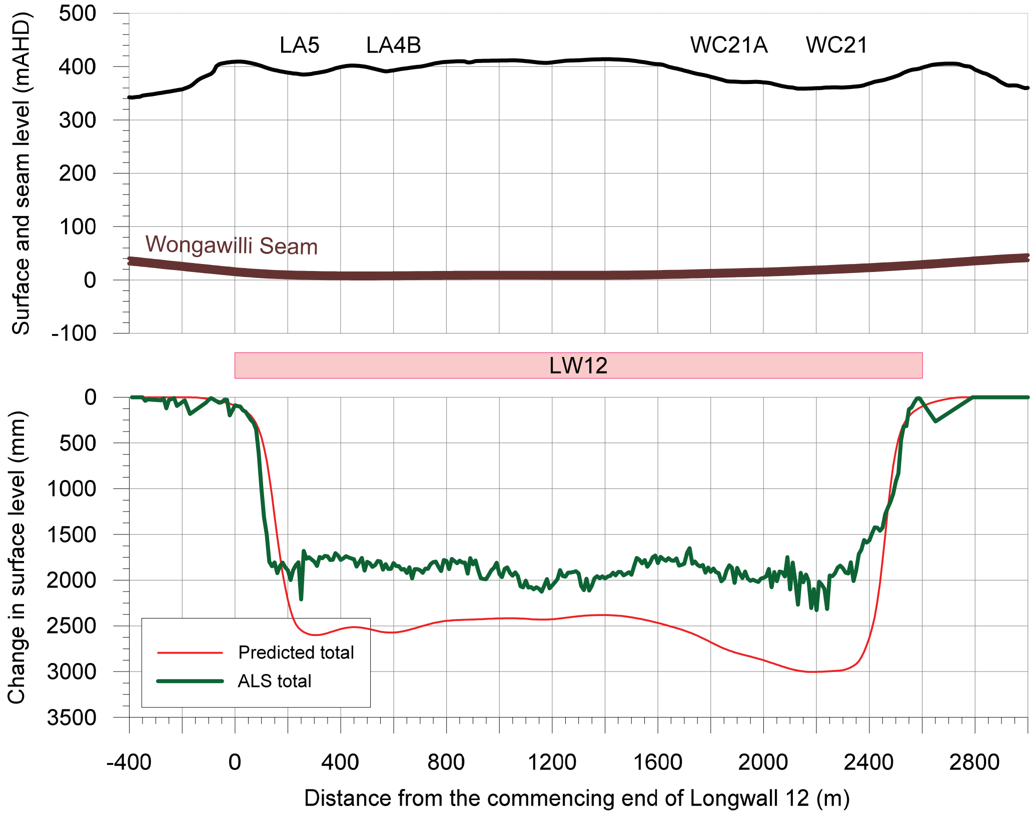


**Fig. 2.11 Measured changes in surface level and predicted vertical subsidence along Long-section 1**

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

There are localised areas outside of the longwalls where the measured changes in surface level exceed the predicted vertical subsidence. However, these are artefacts of the LiDAR surveys and are not real movements. Similarly, there is a measured localised change in the surface level above the maingate of Longwall 12 along Cross-section 3 (refer to Fig. 2.10) that is unlikely to be a real movement.

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

It is considered that the ground movements measured using the LiDAR surveys are consistent with the predictions provided in Report No. MSEC865.

## 3.1. Surface deformations

The surface deformations due to the extraction of Longwall 12 have been identified by the IC Environmental Field Team and are described in the attached landscape report. The locations of the soil cracking and rock fracturing identified as a result of the extraction of Longwall 12 is illustrated in Fig. 3.1.

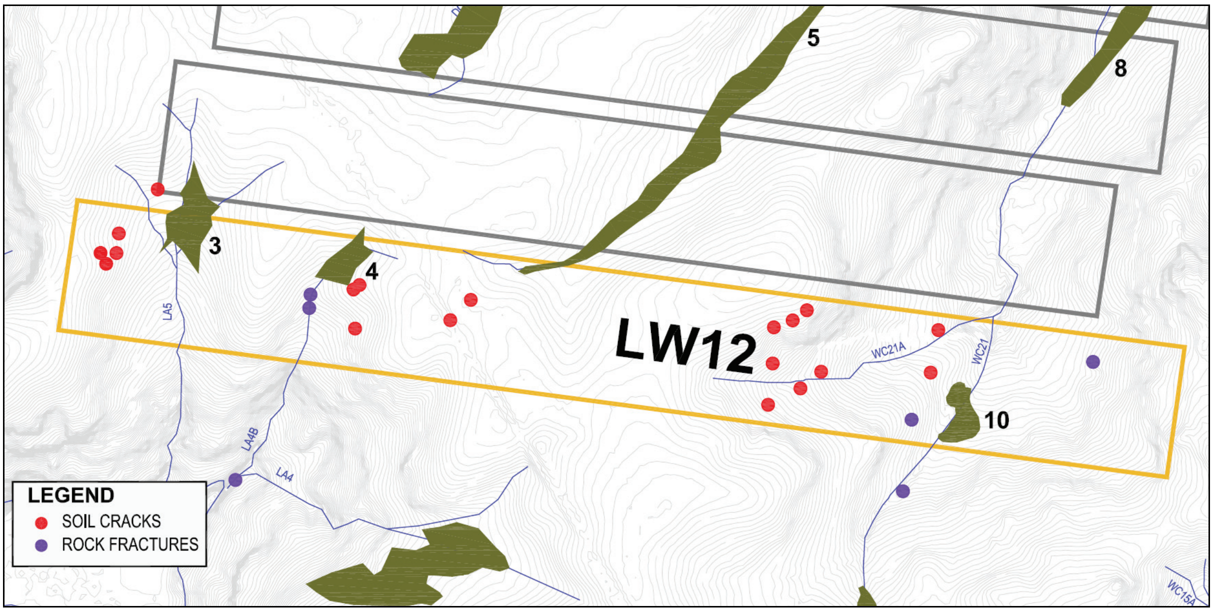


**Fig. 3.1 Surface deformations due to the extraction of Longwall 12**

The soil cracks were identified along or near the fire trails, seismic tracks and the railway corridor. The crack widths vary from less than 10 mm to approximately 110 mm and the lengths vary between 2 and 4 m. The measured depths of the soil cracks vary between approximately 0.5 and 2 m. The soil deformations comprise isolated cracks or a series of cracks, with compression heaving also observed at some locations.

The rock fractures and uplift were identified along the alignments of streams WC21, LA4 and LA4B, at the basal step of Swamp 4 and in a rock outcrop. The fracture widths vary from less than 1 mm to approximately 110 mm and the uplifts vary between 15 and 90 mm. Rock fragments were also dislodged along stream LA4.

Surface water flow diversion was identified along stream LA4. Surface water flow diversion is also expected to occur along stream LA4B during periods of low flow.

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

## 3.2. Natural features

The natural features near Dendrobium Longwall 12 are shown in Drawing No. MSEC888-02, in Appendix A, and include:

- Wongawilli Creek;
- Donalds Castle Creek;
- Drainage lines;
- Rockbars;
- Rock outcrops;
- Steep slopes;
- Swamps; and
- Archaeological sites.

The MSEC assessed impacts for the natural features resulting from the extraction of Dendrobium Longwalls 9 to 18 are provided in Report No. MSEC459, which supported the SMP Application. These assessments were reviewed and updated based on the re-calibrated subsidence model and are provided in Reports Nos. MSEC792 and MSEC865. More detailed assessments for the natural features were also provided in other consultants' reports.

Comparisons between the MSEC assessments and the reported impacts for the natural features listed above, resulting from the extraction of Longwall 12, are provided in Table 3.1. The reported impacts are based on those recorded by IC Environmental Field Team that are described in the accompanying landscape report.

**Table 3.1 Assessed and reported impacts for the natural features due to Longwall 12**

| 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 | No reported impacts |
| | Minor **fracturing** of the bedrock within 400 m of the longwalls | No reported impacts |
| | Unlikely that **surface water flow diversions** would occur | No reported impacts |
| Donalds Castle Creek | Localised additional **ponding** or **flooding** developing in the locations of existing pools, steps or cascades | No reported impacts |
| | Fracturing of the bedrock directly above the longwall, however, the majority of this section of the creek has soil accumulations (i.e. only isolated outcropping of bedrock above the longwall). Also, possible for some minor **fracturing** of the bedrock outside and within 400 m of the longwalls | No reported impacts |
| | **Surface water flow diversions** could occur directly above the longwall | No reported impacts |
| Drainage lines | 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 | Rock fractures and uplift identified along WC21, LA4 and LA4B with widths up to approx. 50 mm. Refer to the IC landscape report for further details |
| | **Surface water flow diversions** into the dilated strata beneath the drainage lines which are directly mined beneath | Loss of surface water flow along stream LA4 and possible diversion along stream LA4B. Refer to the IC landscape report for further details |
| | **Water quality** – refer to the attached water quality report<br>**Terrestrial ecology** – refer to the attached terrestrial ecology report<br>**Aquatic ecology** – refer to the attached aquatic ecology report | |
| 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 of a rock outcrop at one site with a width up to approximately 110 mm |
| Steep slopes | **Soil slippage** resulting in tension cracks and compression ridges. Soil cracks between approximately 100 and 400 mm previously observed at the Mine | Soil / surface cracking observed on or near the fire trails, seismic tracks and railway corridor, with widths up to approx. 110 mm. Refer to the IC 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 and recession rates greater than baseline for Swamp 10. Soil moisture levels below baseline also reported in Swamps 5 and 11. Refer to the IC landscape report for further details |
| Archaeological sites | Impacts on overhang sites include fracturing of sandstone, rock falls, or water seepage through joints which may affect artwork | No adverse impacts reported. Refer to the attached archaeological report for further details |

Most the surface impacts sites were located directly above Longwall 12. Fracturing and uplift was identified along stream LA4 at a distance of approximately 290 m from this longwall. It was assessed that isolated impacts could occur along the streams up to approximately 400 m from the extracted longwalls. It is considered, therefore, that the observed impacts due to the extraction of Longwall 12 are consistent with the MSEC assessments provided in Reports Nos. MSEC459, MSEC792 and MSEC865.

Further assessments of natural features have been provided by other specialist consultants on the project, which are described in the relevant reports attached to the *End of Panel* report.

## 3.3. Built features

The built features near Longwall 12 are shown in Drawing No. MSEC888-03, in Appendix A, and include:

- Fire trails and four-wheel drive tracks;
- Disused Maldon Dombarton Railway Corridor;
- Avon Dam; and
- Survey control marks.

Cordeaux Dam Wall is located more than 5 kilometres north of Longwall 12, at its closest point. The Upper Cordeaux No. 2 Dam Wall is located more than 6 km south-east of Longwall 12, at its closest point. It is unlikely that these dam walls would experience measurable far-field horizontal movements resulting from the extraction of Longwall 12 and, therefore, they have not been included in the following comparisons.

The MSEC assessed impacts for the built features resulting from the extraction of Dendrobium Longwalls 9 to 18 are provided in Report No. MSEC459, which supported the SMP Application. These assessments were reviewed and updated based on the re-calibrated subsidence model and are provided in Reports Nos. MSEC792 and MSEC865.

Comparisons between the MSEC assessments and the reported impacts for the built features listed above, resulting from the extraction of Longwall 12, are provided in Table 3.2. The reported impacts are based on those recorded by IC Environmental Field Team that are described in the accompanying landscape report.

**Table 3.2 Assessed and reported impacts for the built features due to Longwall 12**

| Built feature | MSEC assessed impacts | Reported impacts |
|---|---|---|
| Fire trails and four-wheel drive tracks | Cracking of unsealed road surfaces | Soil / surface cracking observed on or near the fire trails, seismic tracks and railway corridor, with widths up to approx. 110 mm. Refer to the IC landscape report for further details |
| Disused Maldon-Dombarton Railway | Possible fracturing of rock cuttings, spalling, and/or mobilisation of rock joints | Soil crack and uplift of ballast along railway corridor in one location |
| Avon Dam | Adverse impacts not anticipated | No reported impacts on stored waters. Refer to associated groundwater report for further details |
| 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 |

It can be seen from Table 3.2, that the observed impacts on the surface infrastructure, resulting from the extraction of Longwall 12, are similar to or less than the MSEC assessments provided in Reports Nos. MSEC459, MSEC792 and MSEC865.

# 4.0 SUMMARY

The mine subsidence movements due to the extraction of Longwall 12 were measured using the Wongawilli Creek closure lines, Avon Dam closure lines, Area 3B and Avon Dam 3D monitoring points, tributary cross lines, Donalds Castle Creek cross lines, swamp cross lines and airborne laser scans of the area.

The measured ground movements due to the extraction of Longwall 12 were generally less than the predicted values based on the re-calibrated subsidence model outlined in Reports Nos. MSEC792 and MSEC865.

The measured closure movements exceeded the predictions at the Avon Dam A-Line, WC21 H-Line, DCCX C-Line and DCCX E-Line. The measured vertical subsidence exceeded the predictions at the WC21 J-Line, WC21 K-Line, WC21 L-Line and DCCX D-Line. These exceedances represent between 3 % and 17 % of the predicted values, or the measured values were within 50 mm of the predicted values at low magnitudes. It is generally considered acceptable for the accuracies of subsidence predictions methods to be in the order of ±15 % to ±25 % directly above the longwalls and ±50 mm outside the extents of the longwalls.

It is considered, therefore, that the ground movements measured due to the extraction of Longwall 12 are consistent with the predictions provided in Reports Nos. MSEC792 and MSEC865.

Soil cracking and rock fracturing were observed directly above Longwall 12 and, in some cases, outside and up to 290 m from this longwall. The crack and fracture widths varied from less than 1 mm up to approximately 110 mm. Surface water flow diversion was identified along stream LA4. Surface water flow diversion is also expected to occur along stream LA4B during periods of low flow. It was assessed that soil and fracture widths between approximately 100 and 400 mm could occur directly above the extracted longwalls and that isolated surface impacts could occur up to 400 m outside of the longwalls.

It is considered, therefore, that the observed surface impacts on the natural and built features, resulting from the extraction of Longwall 12, are consistent with the MSEC assessments provided in Reports Nos. MSEC792 and MSEC865. 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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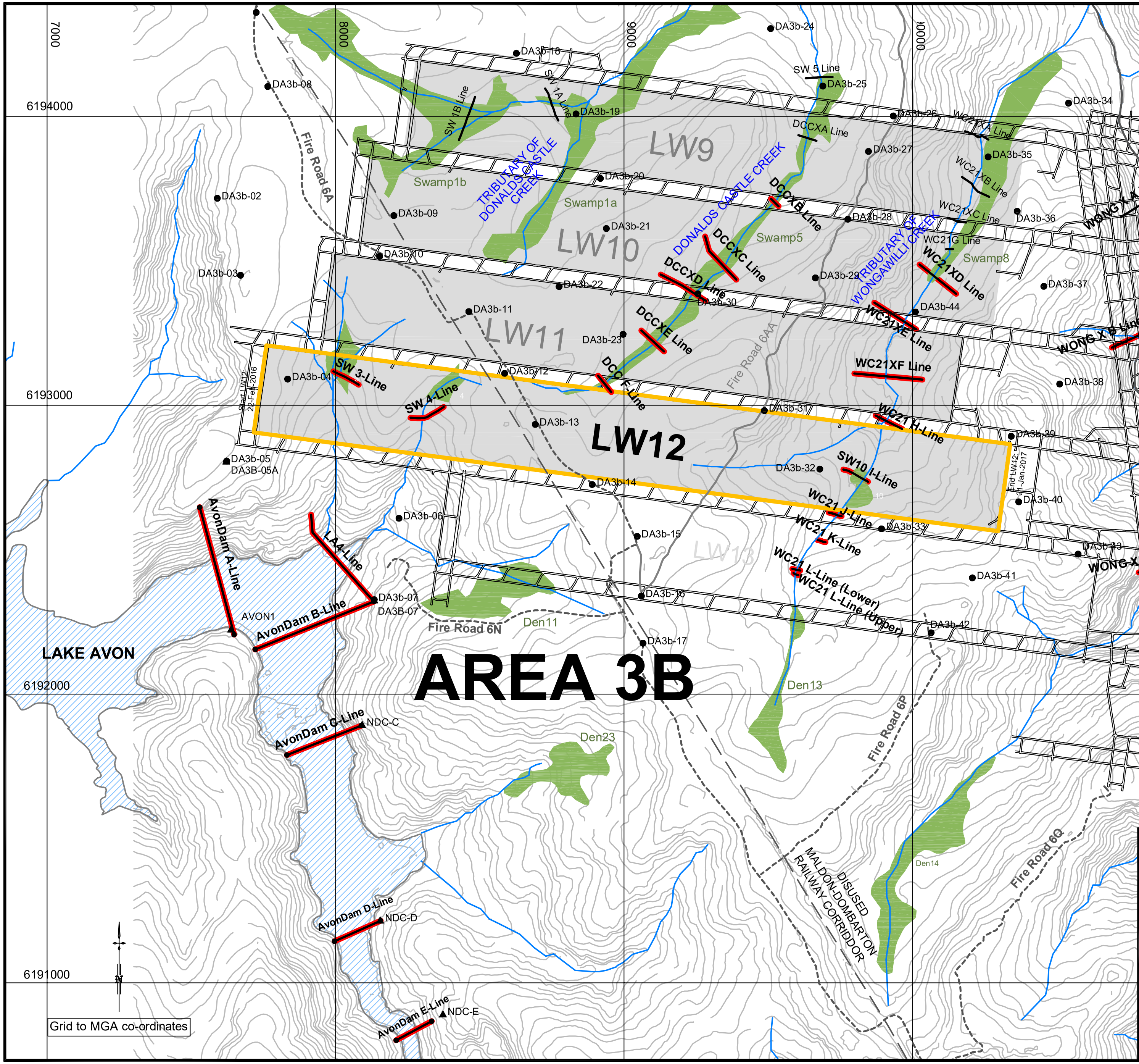


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**ILLAWARRA COAL**
DENDROBIUM COLLIERY - AREA 3B
LONGWALL 12 END OF PANEL REPORT
GENERAL LAYOUT &
MONITORING LINES

| DATE: | SCALE: | DRAWING No: | Rev No |
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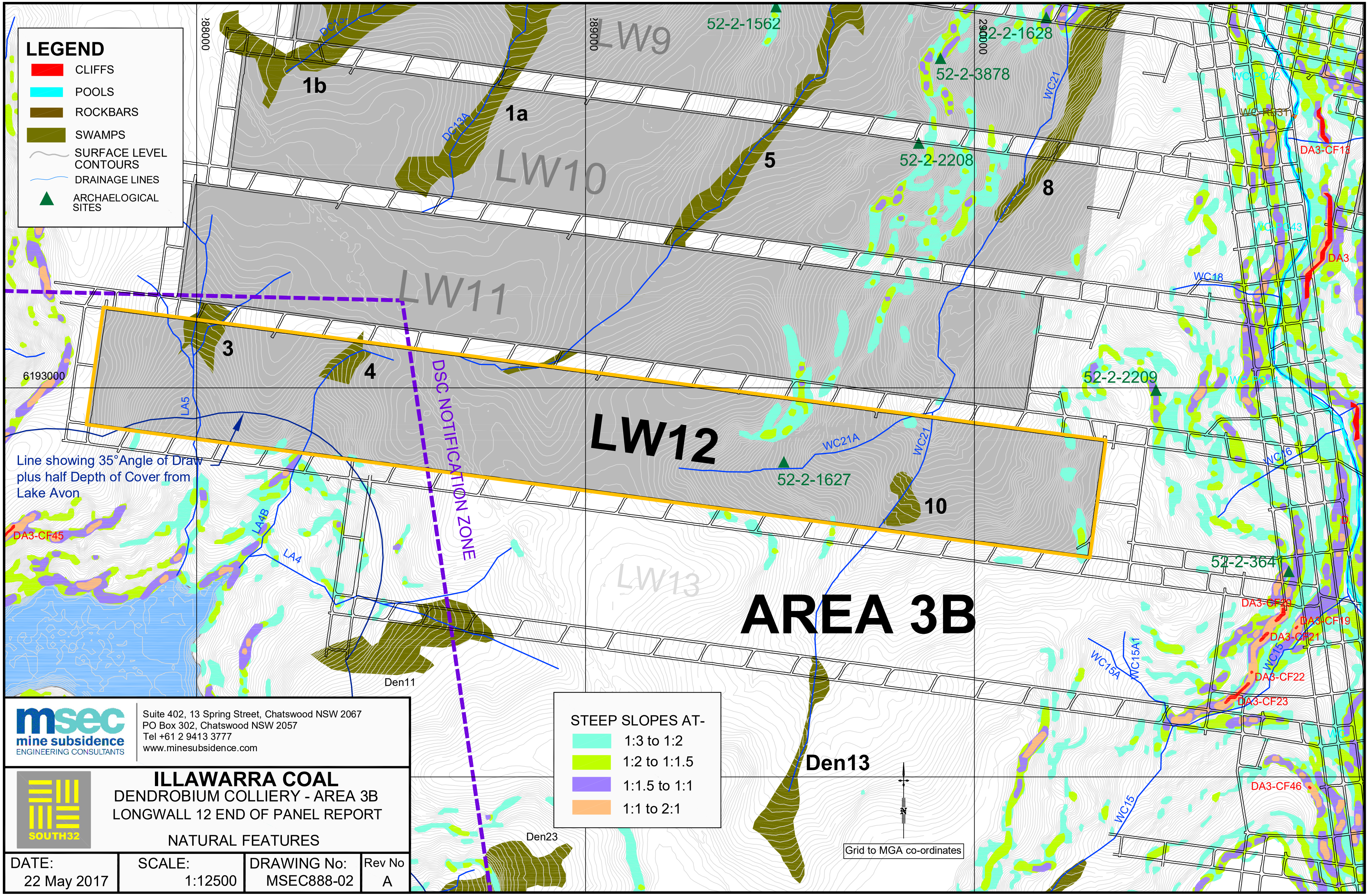


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LONGWALL 12 END OF PANEL REPORT

NATURAL FEATURES

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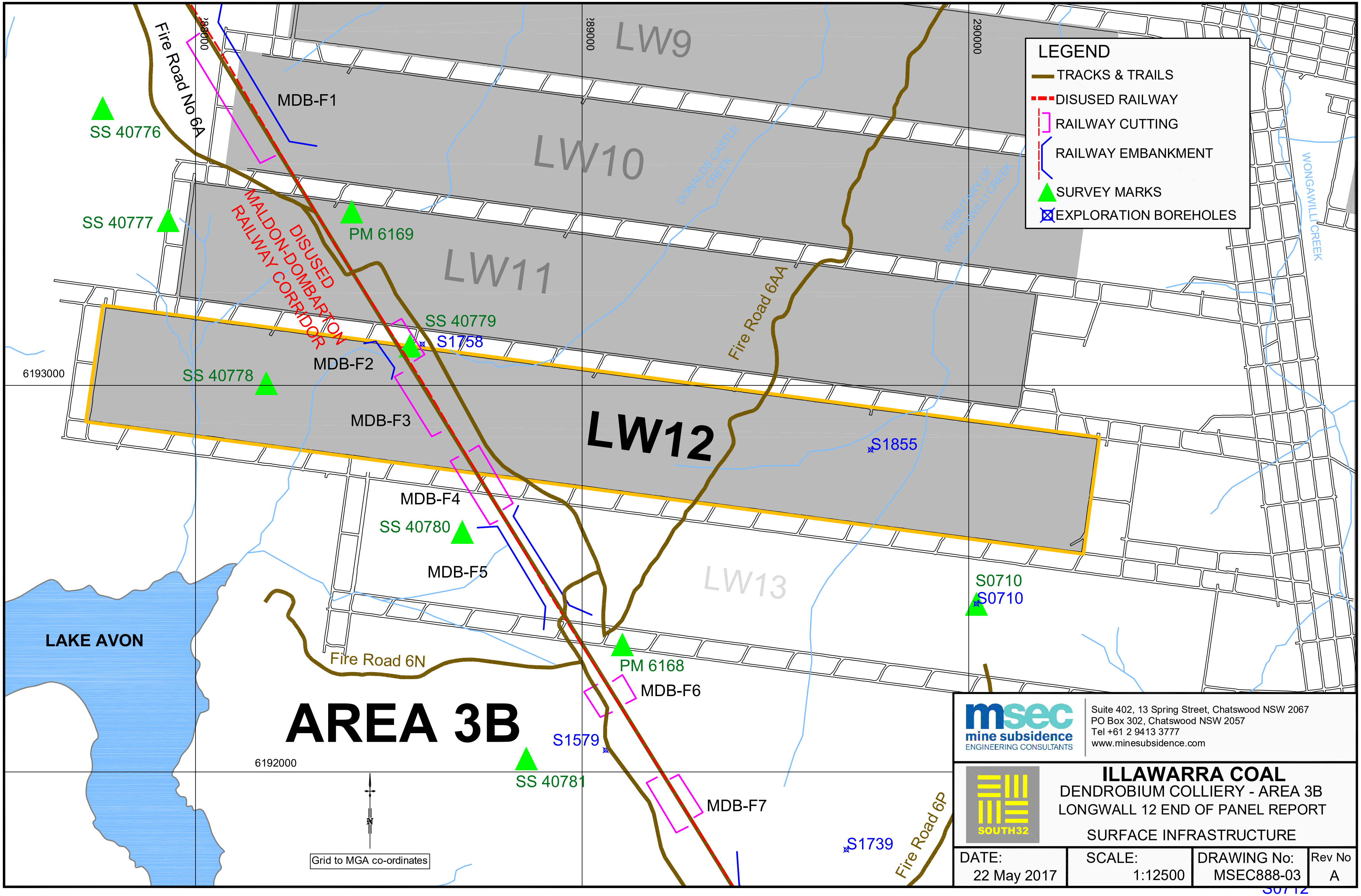


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LONGWALL 12 END OF PANEL REPORT
SURFACE INFRASTRUCTURE

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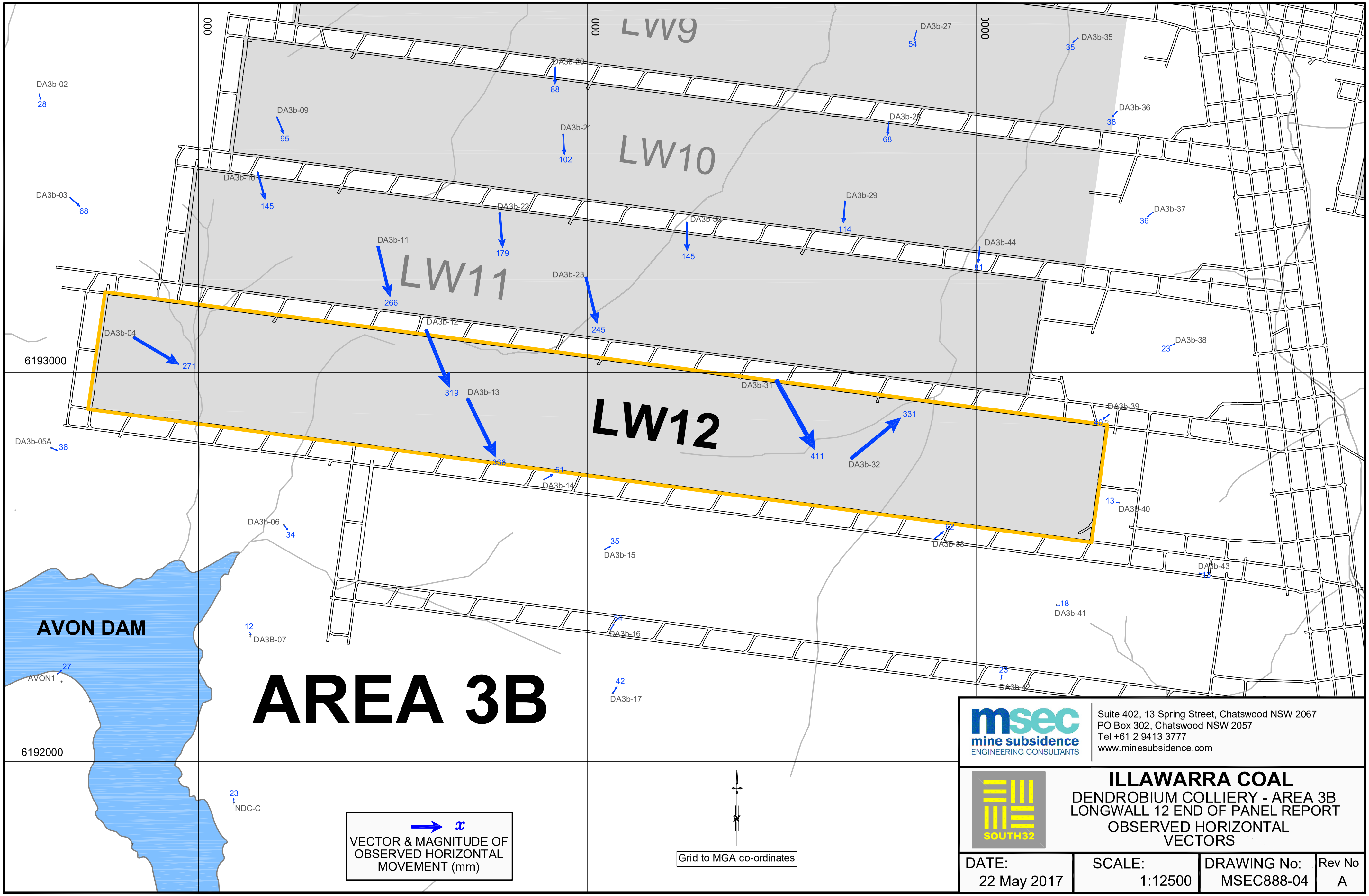


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LONGWALL 12 END OF PANEL REPORT
OBSERVED HORIZONTAL
VECTORS

| DATE: | SCALE: | DRAWING No: | Rev No |
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