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SIMEC Mining:

Tahmoor Coking Coal Operations - Longwall 31

End of Panel Subsidence Monitoring Report for Longwall 31

DOCUMENT REGISTER

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Associated reports:-

MSEC (2014). Tahmoor Colliery Longwalls 31 to 37 - Subsidence Predictions and Impact Assessments for Natural and Built Features in support of the SMP Application. (Report MSEC647, Revision A, December 2014), prepared by Mine Subsidence Engineering Consultants.

MSEC909-R01 to MSEC909-R34 – Subsidence Monitoring Reports, issued during the extraction of Longwall 31 between August 2017 and October 2018.

MSEC910-R02 to MSEC910-R67 – Main Southern Railway Monitoring Reports, issued during the extraction of Longwall 31 between July 2017 and October 2018.

GeoTerra (2019). Longwall 31 Surface Water, Dams & Groundwater End of Panel Monitoring Report, Tahmoor, NSW. Report No. TA31-R1, March 2019.

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Tables

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Figures

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

Drawings

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

1.0 INTRODUCTION

This report has been prepared by Mine Subsidence Engineering Consultants (MSEC) for Tahmoor Coking Coal Operations to comply with conditions of the SMP Approval for Tahmoor Colliery Longwall 31 dated 3 May 2017.

This report includes:-

- A summary of the subsidence and environmental monitoring results for Longwall 31,
- An analysis of these results against the relevant impact assessment criteria, monitoring results from previous panels and predictions provided in the SMP application,
- The identification of any trends in the monitoring results, and
- A description of actions that were taken to ensure adequate management of any potential subsidence impacts.

The location of Longwall 31 is shown in Drawing No. MSEC1001-01, which together with all other drawings, is attached in Appendix B at the back of this report.

This report also includes many of the movements and impacts observed during the extraction of Longwalls 22 to 30. Note that Longwall 24B was extracted prior to Longwall 24A. The dates of extraction for all longwalls are provided in Table 1.1.

Table 1.1 Start and Finish Dates for Longwalls 22 to 31

Longwall	Start Date	Completion Date
Longwall 22	31 May 2004	27 July 2005
Longwall 23A	13 September 2005	21 February 2006
Longwall 23B	22 March 2006	26 August 2006
Longwall 24B	14 October 2006	2 October 2007
Longwall 24A	15 November 2007	19 July 2008
Longwall 25	22 August 2008	21 February 2011
Longwall 26	30 March 2011	15 October 2012
Longwall 27	8 November 2012	10 April 2014
Longwall 28	24 April 2014	1 May 2015
Longwall 29	29 May 2015	18 April 2016
Longwall 30	20 June 2016	15 June 2017
Longwall 31	28 June 2017	17 August 2018

The predicted movements and impacts resulting from the extraction of Longwall 31 were provided in Report No. MSEC647 (2014, Revision A). The comparisons provided here are based on the subsidence predictions provided in this report.

Longwall 31 was approximately 2,450 metres long and 283 metres wide, rib to rib. The pillar width was approximately 39 metres, rib to rib. The depth of cover over the panel varied from 450 metres to 500 metres. The seam thickness over the panel was approximately 2.1 metres.

Chapter 2 of this report describes the locations of the ground monitoring lines and points which were surveyed during the extraction of Longwall 31. This chapter also provides comparisons between the observed and predicted movements resulting from the extraction of Longwall 31.

Chapter 3 of this report summarises the surveys and inspections undertaken during the mining of Longwall 31.

Chapter 4 of this report describes the reported impacts on surface features resulting from the extraction of Longwall 31 and compares these with the MSEC assessed impacts. The reported impacts on surface water are provided in other reports.

Appendices A and B include figures and drawings associated with this report.

2.1.1. Comparison between Observed and Predicted Maximum Subsidence Parameters

Maximum observed incremental and total subsidence parameters during or after the mining of Longwall 31 are shown in Table 2.1. The maximum values do not include parameters observed in creeks, which are discussed separately in this report.

Table 2.1 Summary of Maximum Incremental and Total Subsidence Parameters due to the mining of Longwall 31 (beyond creeks)

Monitoring Line	Maximum Observed Subs (mm)	Maximum Observed Tilt (mm/m)	Maximum Observed Tensile Strain (mm/m)	Maximum Observed Comp. Strain (mm/m)
Incremental due to LW31 only	803	8.2	1.8	-3.3
Total after LW31	1070	8.2	4.6	-4.5

The maximum observed incremental subsidence was greater than predicted maximum incremental subsidence for Longwall 31, which was 725 mm. The difference is within 15% of the prediction, which is within the typical range of accuracy.

Maximum observed incremental and total subsidence parameters for monitoring lines surveyed during Longwall 31 are summarised in Table 2.2. The maximum value for each parameter (not including creeks) is highlighted in yellow.

Table 2.2 Summary of Maximum Subsidence Parameters along Monitoring Lines

Monitoring Line		Maximum Observed Subs (mm)	Maximum Observed Tilt (mm/m)	Maximum Observed Tensile Strain (mm/m)	Maximum Observed Compressive Strain (mm/m)
Remembrance Drive	LW31 Inc	52	0.8	0.4	-0.6
Bollard Place	LW31 Inc	8	0.2	0.1	-0.3
Thirlmere Way	LW31 Inc	26	0.3	0.4	-0.5
Thirlmere Carrier (East)	LW31 Inc	11	0.3	0.4	-0.8
Optical Fibre Line	LW31 Inc	473	1.9	0.9	-0.7
	Total	1070	4.8	1.7	-4.5
Stilton Lane	LW31 Inc	803	8.2	1.8	-2.3
	Total	838	8.2	1.9	-2.4
Main Southern Railway (2D) (incl. creek)	LW31 Inc	791	7.1	1.3	-2.5
	Total	1051	6.9	2.4	-9.5
Bridge St	LW31 Inc	742	5.6	0.9	-3.3
	Total	970	6.3	4.6	-1.2
Redbank Place	LW31 Inc	94	0.7	0.3	-0.2
	Total	93	0.5	0.5	-0.4
Thirlmere Carrier	LW31 Inc	117	0.5	0.4	-0.3
	Total	823	3.2	1.1	-1.1

2.1.2. Observed Subsidence during the extraction of Longwall 31

Extensive ground monitoring within the urban areas of Tahmoor has allowed detailed comparisons to be made between predicted and observed subsidence, tilt, strain and curvature during the mining of Longwalls 22 to 31.

In summary, there is generally a reasonable correlation between observed and predicted subsidence, tilt and curvature over the majority of the mining area.

The extraction of longwalls at Tahmoor Coking Coal Operations has generally resulted in mine subsidence movements that were typical of those observed at other collieries in the Southern Coalfield of NSW at comparable depths of cover.

However, observed subsidence was greater than the predicted values over Longwalls 24A and the southern parts of Longwalls 25 to 27. Monitoring during the mining of Longwalls 28 to 31 has found that subsidence behaviour has returned to normal levels.

2.1.3. Analysis of Measured Strain

A distribution of the observed incremental tensile and compressive strains along monitoring lines from the extraction of Longwall 31, for survey bays located directly above goaf, is shown in Fig. 2.1. In the cases where the survey bays were measured a number of times during mining, the maximum tensile strain and the maximum compressive strain for each survey bay were used in these distributions.

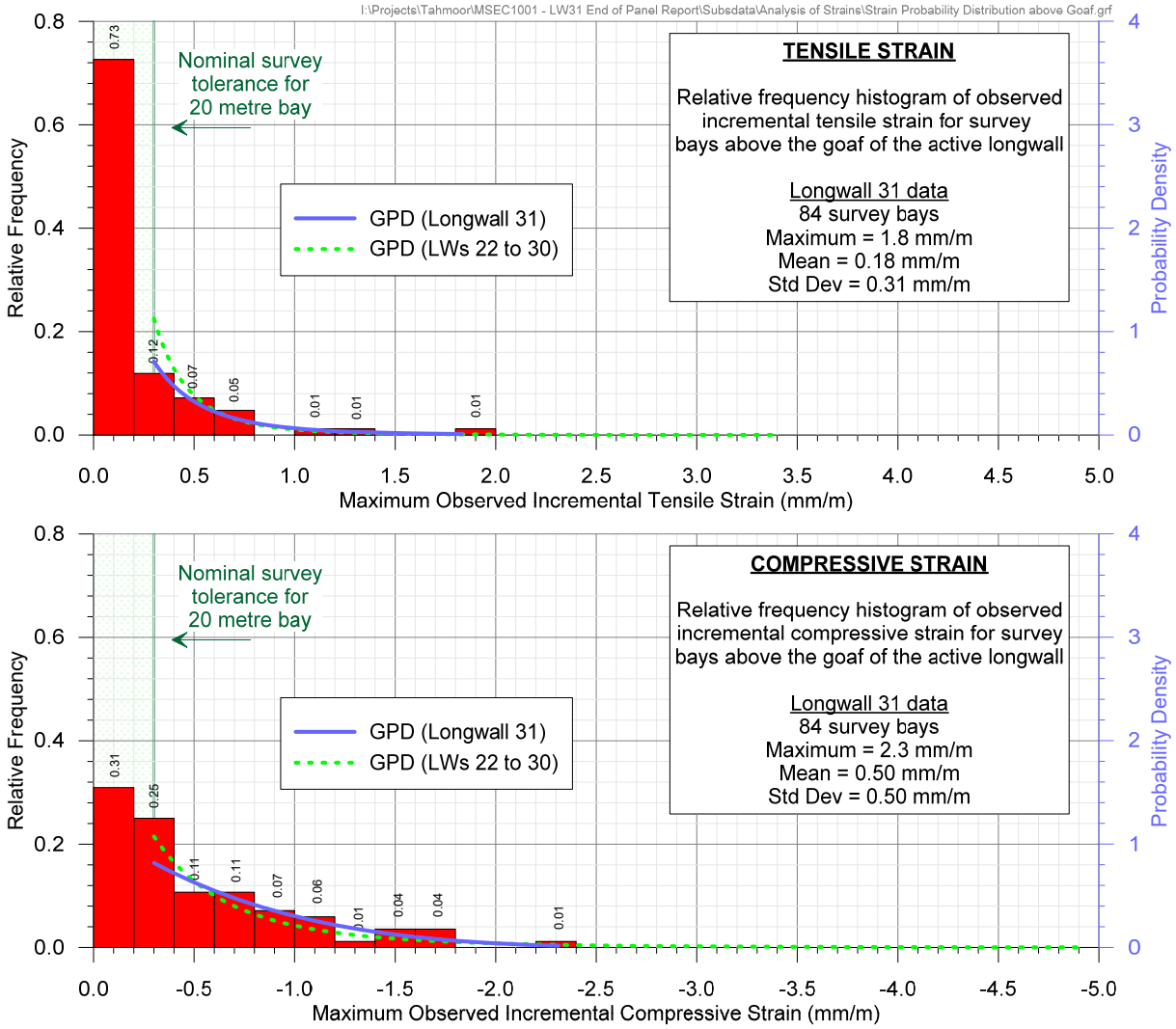


Fig. 2.1 Observed Incremental Strain for Survey Bays above Goaf resulting from the Extraction of Longwall 31

A *Generalised Pareto Distribution (GPD)* has been fitted to the raw strain data for Longwall 31, as shown in blue.

The probability distribution functions for previous monitoring during the mining of Longwalls 22 to 30 are also shown in this figure, as dashed green lines. It can be seen from these comparisons, that the overall distribution of tensile and compressive strain resulting from the extraction of Longwall 31 was similar to that observed during the mining of Longwalls 22 to 30.

2.2. Identification of Non-Systematic Subsidence Movements

A plan showing the locations of observed non-systematic movements at Tahmoor is shown in Fig. 2.2. The locations were selected based on ground monitoring results or observed impacts that appear to have been caused by non-systematic movement. A total of approximately 55 locations (not including valleys) have been identified over the extracted Longwalls 22 to 31, of which 1 new location was observed during the mining of Longwall 31.

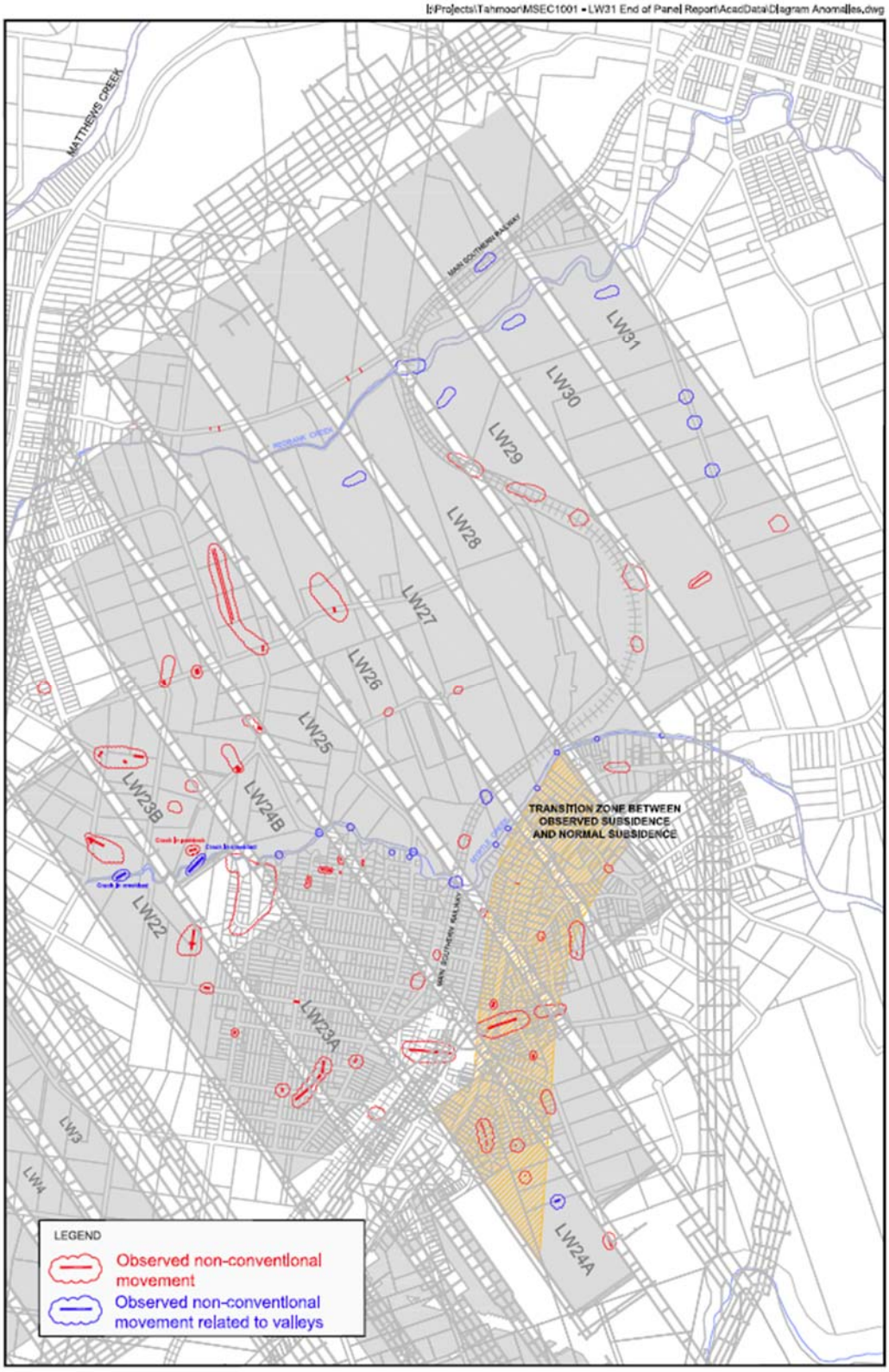


Fig. 2.2 Map of Locations of Potential Non-Systematic Movements

Monitoring lines were surveyed where non-systematic movement was identified. A summary of non-systematic movements at these locations is provided below in Table 2.3.

Table 2.3 Locations of New Identified Non-Systematic Movements during Longwall 31

Monitoring Line or Location	Maximum Change in Vertical Alignment during LW31 (mm)	Maximum Incremental Strain during LW31 (mm/m)	Type	Impacts on Surface Features
Main Southern Railway at 90.660 km to 90.680 km	13 mm over 40 m bay	-2.4	Valley closure	Increase in crack widths in brick arch culvert at outlet. The cracks were inspected by a structural engineer. Integrity of culvert was maintained.
Main Southern Railway at 90.680 km to 90.700 km	5 mm over 40 m bay	-2.5	Valley closure	
Stilton Lane No. 95 Stilton Lane	-	-	Non-conventional movement	Substantial impacts on northern part of house.
Stilton Lane Pegs ST8 to ST11	20 mm over 44 m bay	-1.7	Valley closure	No impacts
Stilton Lane Pegs ST18 to ST19	45 mm over 43 m bay	-1.7	Valley closure	No impacts
Stilton Lane Pegs ST23 to ST24	113 mm over 47 m bay	-2.3	Valley closure	Bump in road pavement near Peg ST25
Bridge Street Pegs BG105 to BG106	19 mm over 45 m bay	-3.3	Valley closure	Impacts observed to Sydney Water's Thirlmere Carrier Pipe and local road. Reversal of grade observed to Thirlmere Carrier Pipe over short, 23m bay length where upsidence observed. Joints observed closed with compressive cracks in pipework, with no leakage observed. Cracks and compressive humps observed along side of road pavement. Compressive hump across pavement at old joint line where sewer crosses the road, which was patched. Cracks in width and extent in the culvert pipes and joints and concrete headwall.

Valley closure movements were also observed across Redbank Creek and its tributaries, and the results of these surveys are discussed in following sections of this report.

Changes in vertical alignment have been calculated by measuring the difference in subsidence between each peg and average subsidence of the adjacent two pegs. The calculations quantify the small 'bumps' that are observed in the subsidence profiles.

2.3. Redbank Creek

Ground surveys were undertaken in relative 3D from Bridge Street to a monitoring line that is located in cleared pasture land along the top of the valley, as shown in Fig. 2.3. This has provided measurements of total valley closure. Some survey pegs have been installed along a fence line on the southern side to a point where surveyors can sight a survey peg on Bridge Street. Despite the best efforts of the survey team, the accuracy of the survey is challenged by the lack of cross lines across Redbank Creek. Baseline monitoring indicates that the valley closure measurements were accurate to approximately 20 to 30 mm.

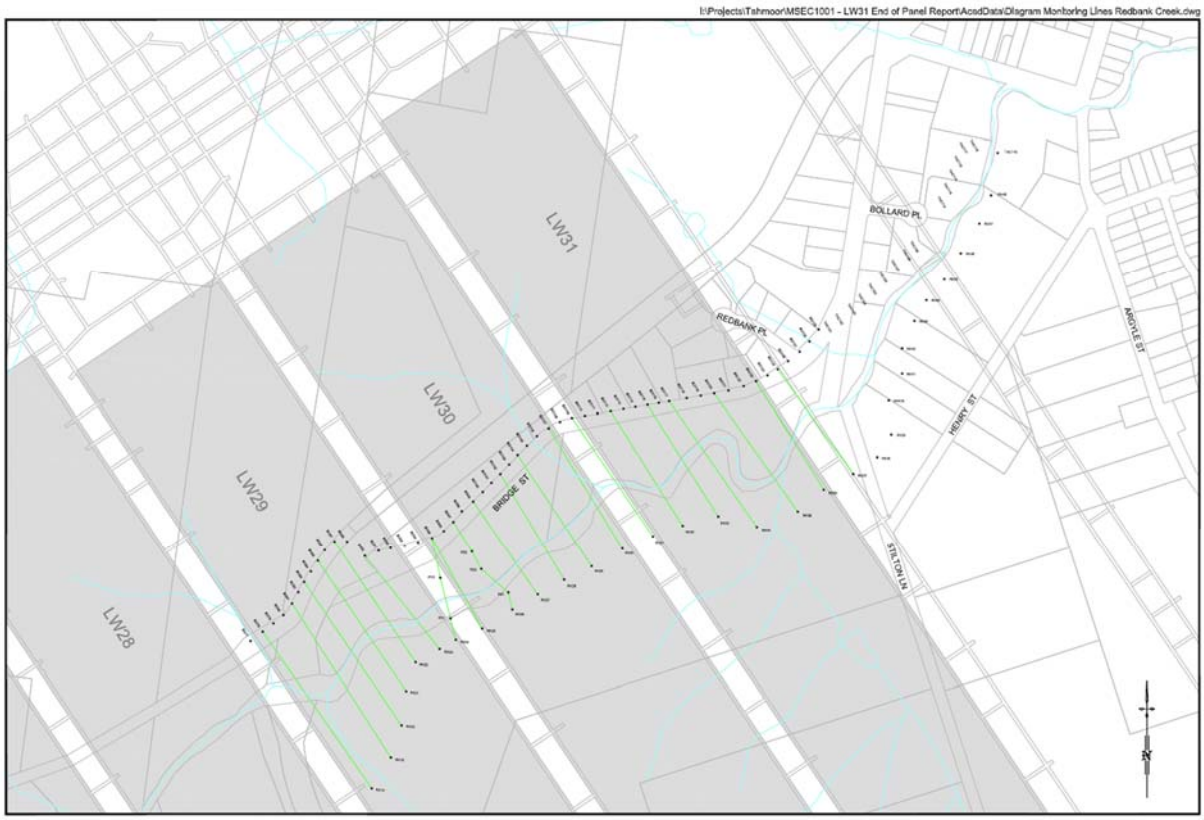


Fig. 2.3 Location of survey marks across Redbank Creek

Graphs showing observed subsidence, tilt and strain along each of the monitoring lines are provided in Figs. A.15 to A.20 and drawings showing incremental subsidence and relative horizontal movements are shown in Drawings Nos. MSEC1001-02 and MSEC1001-03.

The development of valley closure across Redbank Creek and its tributaries during the mining of Longwall 31 against time is shown in Fig. 2.4.

The closures are based on calculating changes in horizontal distance between pegs located across the valley in an orientation that is approximately parallel to the longwall panel. This orientation was chosen as Redbank Creek flows approximately at right angles across the panel.

Different results can be derived if the calculations were based on different pairs of pegs, though it is considered that if different pairs were chosen, such calculations would include an additional component of conventional and non-conventional ground shortening that occurs across the panel in both plateau areas or valleys. This is particularly the case if the pegs are located across the width of the longwall panel from each other. When comparing the results against predictions of valley closure, it was considered simpler to choose pegs that are approximately aligned with longwall direction so as not to make allowances for the additional effects of conventional lateral ground closure movements.

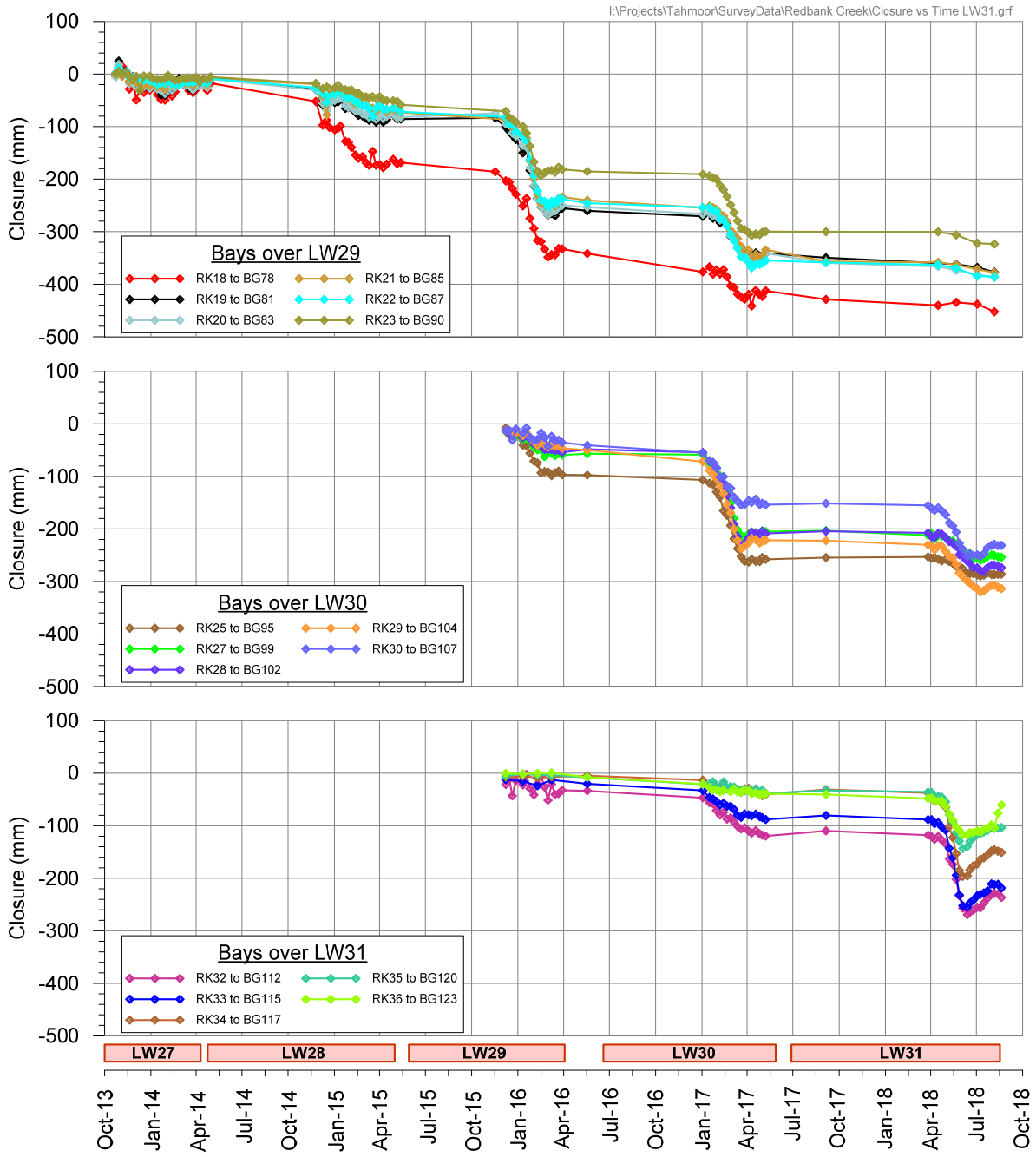


Fig. 2.4 Observed development of closure across Redbank Creek over time

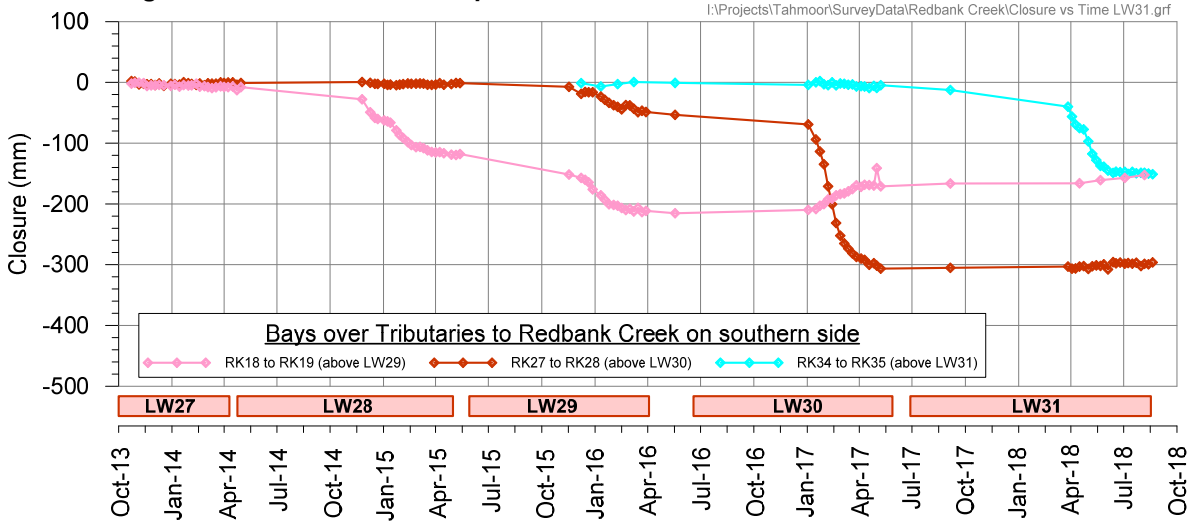


Fig. 2.5 Observed development of closure across tributaries to Redbank Creek over time

A number of observations are made from the monitoring data:

- It can be seen from Fig. 2.4 that valley closure was slightly greater for a temporary period of time, when the transient effects of the subsidence travelling wave passed through the valley.
- Maximum observed closure above Longwall 31 was similar to maximum observed closure above Longwall 30 and less than maximum observed closure above Longwall 29. This was predicted as the valley is deeper and more incised above Longwall 29.

A comparison between observed and predicted valley closure along Redbank Creek is shown in Fig. 2.6. A number of observations are made from the monitoring data:

- There has been a reasonable correlation between predicted and observed closure at the completion of Longwall 31.
- Observed total closure from the mining of Longwalls 26 to 31 is less than predicted.

Maximum predicted valley closure due to extraction of Longwall 31 was 152 mm. As shown in the bottom graph of Fig. 2.6, observed maximum incremental valley closure at the completion of Longwall 31 was 138 mm.

It can also be seen, from the top graph of Fig. 2.6 that observed total closure from the mining of Longwalls 26 to 31 is less than predicted along the length of Redbank Creek. Maximum observed total closure is 452 mm, which is less than the predicted total closure of 575 mm due to the mining of Longwalls 22 to 31, as reported in Report No. MSEC647.

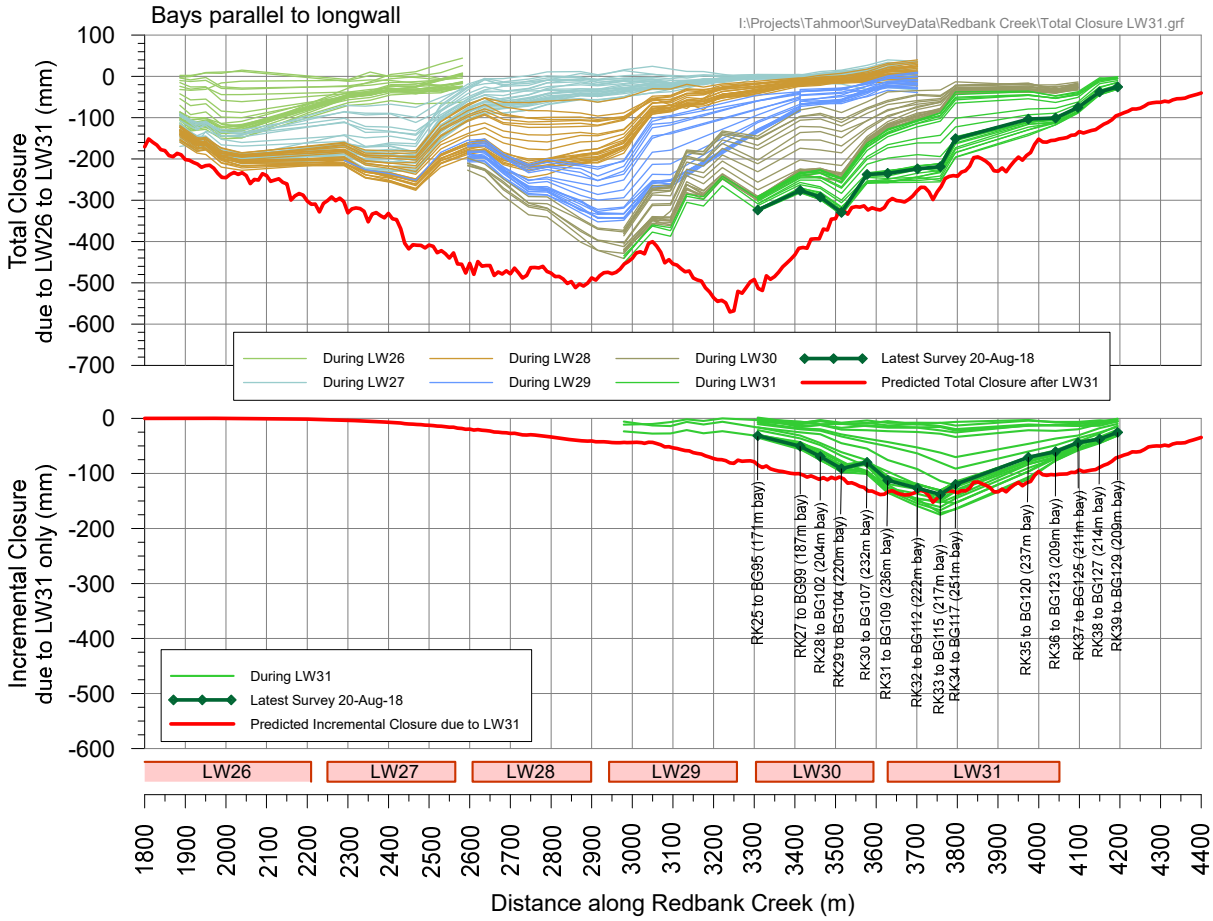


Fig. 2.6 Comparison between observed and predicted valley closure along Redbank Creek

2.4. Main Southern Railway

The Main Southern Railway was surveyed in either 2D or 3D for a total of 63 times on a weekly basis during the extraction of Longwall 31. Details of the monitoring undertaken are provided in the monitoring reports prepared by MSEC on behalf of Tahmoor Coking Coal Operations and these reports have been provided to ARTC throughout the mining period.

The Main Southern Railway experienced maximum incremental subsidence of 791 mm during the mining of Longwall 31.

When comparing predicted and observed subsidence, the following comments are provided:

- Observed maximum subsidence is greater than predicted maximum subsidence.
- There is a reasonable correlation between the shapes of the predicted and observed subsidence profiles. There is, therefore, a reasonable correlation between predicted and observed maximum tilt though observed maximum tilt is greater than predicted maximum tilt.
- Increased ground strain was observed between 92.660 km and 92.700 km, where the railway crosses a small tributary to Redbank Creek. A substantial change in vertical and horizontal alignment was previously observed at 90.660 km during the mining of Longwall 30. While further changes were observed at this location during the mining of Longwall 31, the impacts on track geometry were less noticeable. Impacts were observed in the brick arch culvert at the outlet end, with increases in crack widths observed. The cracks were inspected by a structural engineer, who advised that the integrity of culvert was maintained.
- Observed ground strains along the railway corridor have generally been relatively small in magnitude.

2.4.1. Automated Track Monitoring

Rail Stress Transducers

Rail stress transducers are located along all four rails of the railway track, spaced every 25 to 60 metres. They measured changes in rail strain every 5 minutes during the mining of Longwall 31. Rail stresses exceeded Blue trigger on one occasion during the mining of Longwall 31, due to high compressive stress at time of high rail temperature. The rail was unclipped and re-clipped to achieve a change in SFT.

Expansion switch displacement sensors

Displacement sensors have been installed at each expansion switch. Measurements were recorded every 5 minutes during the mining of Longwall 31. Mining-induced changes were observed, though larger temperature-induced changes were observed. Some low level (Blue) alarms were triggered as a result of subsidence in combination with low or high rail temperatures. The alarms were responded to in accordance with the Management Plan. Some of the responses had already been planned in anticipation of the alarm.

2.4.2. Redbank Creek Culvert and Embankment at 91.265 km

A total of 23 ground surveys, 24 extensometer surveys and 24 detailed visual inspections were undertaken for the Redbank Creek Culvert and Embankment on a weekly to monthly basis in accordance with the agreed management plans with ARTC.

The Culvert has subsided between approximately 340 mm and 610 mm in total during the mining of Longwalls 27 to 31.

Observed absolute horizontal movements along the Main Southern Railway are shown in Fig. 2.7. It can be seen that the rockmass on the southern of Country side of the Culvert has moved in a different direction to the northern or Sydney side of the Culvert.

Observed total subsidence and horizontal movement of survey marks in the immediate of the culvert and embankment are shown in Fig. 2.8. The results show that boundaries of the rockmass in the south-western quadrant intersect with the country side of the culvert. The corner of the rockmass is approximately aligned with midpoint of the culvert, which correlates well with observed detailed closure measurements inside the culvert itself.

The observed gradual development with time of differential horizontal movements between selected pegs at the culvert and embankment are shown in Fig. 2.9. Maximum observed closure was measured between the long bay survey pegs on the track at 91.220 km and 91.360 km, though a similar result was observed between Pegs RBCCU4 and RBCCU6, RBCU4 and RBCU6, and between RBCD2 and RBCD6, which are located in the base of the embankment across the upstream inlet. This suggests that closure across the valley of Redbank Creek and its tributary, were focussed at the culvert. This was confirmed at greater detail from additional detailed surveys in the culvert, which are discussed later.

Whilst the ends of the wingwall on the upstream end have closed by 274 mm, the culvert barrel at the inlet has opened by 20 mm. Measured closure at the ends of the wingwall on the downstream end is 59 mm, and the culvert barrel at the inlet has opened 21 mm.

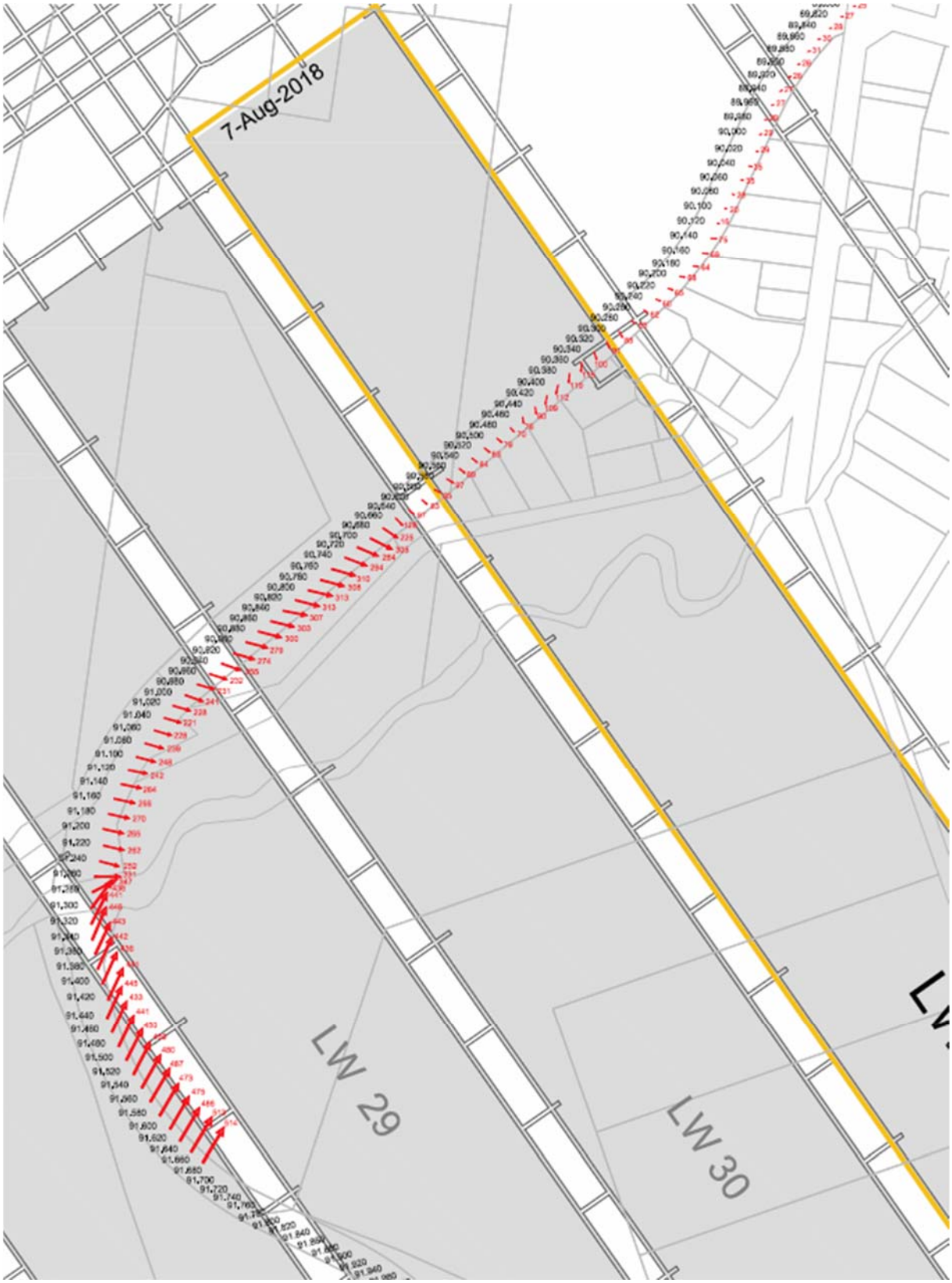


Fig. 2.7 Observed total horizontal movement along Main Southern Railway during the mining of Longwalls 27 to 31

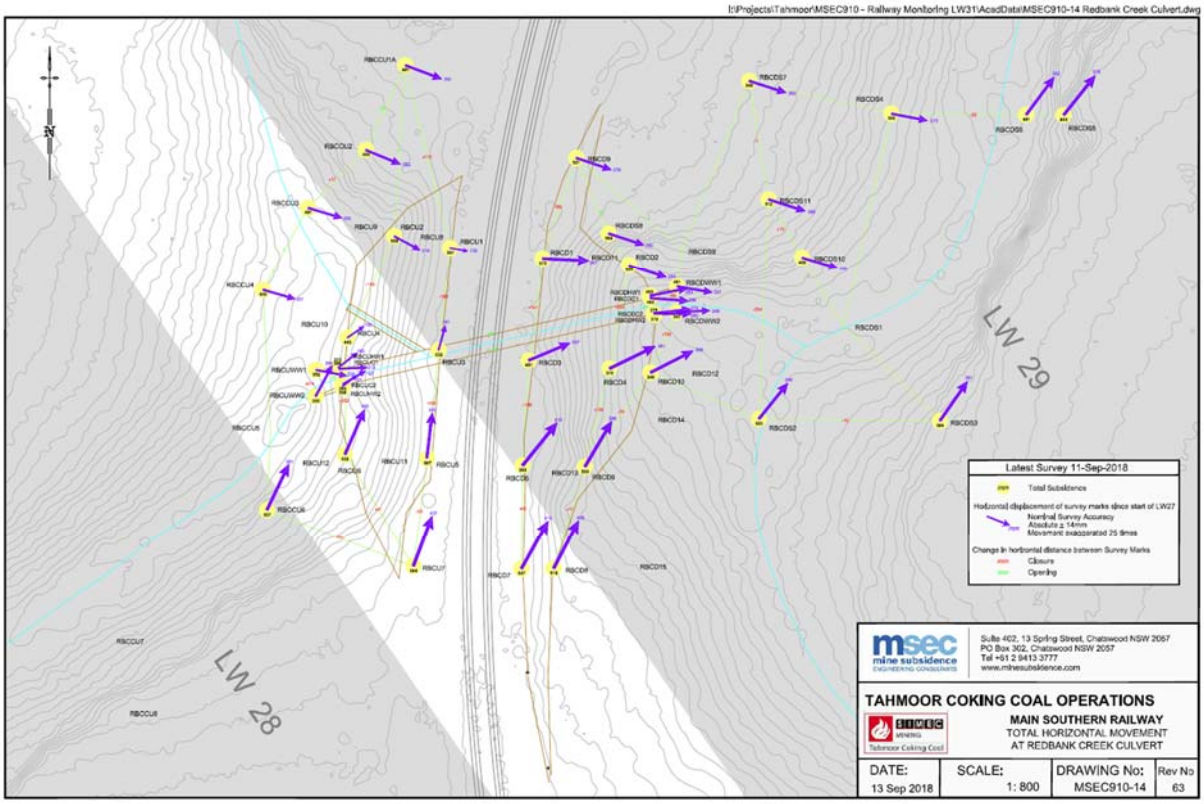


Fig. 2.8 Observed total horizontal movement at Redbank Creek Culvert and embankment during the mining of Longwalls 27 to31

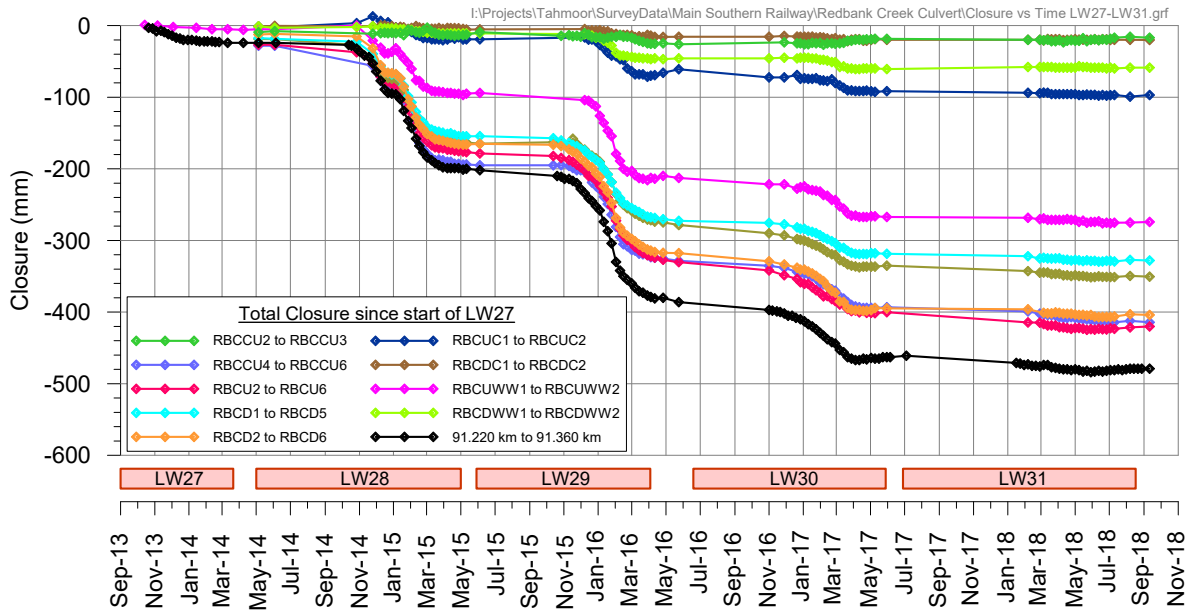


Fig. 2.9 Observed Total Valley Closure over time across Redbank Creek Culvert at Main Southern Railway during the mining of Longwall 31 (includes closure from Longwalls 27 to 30)

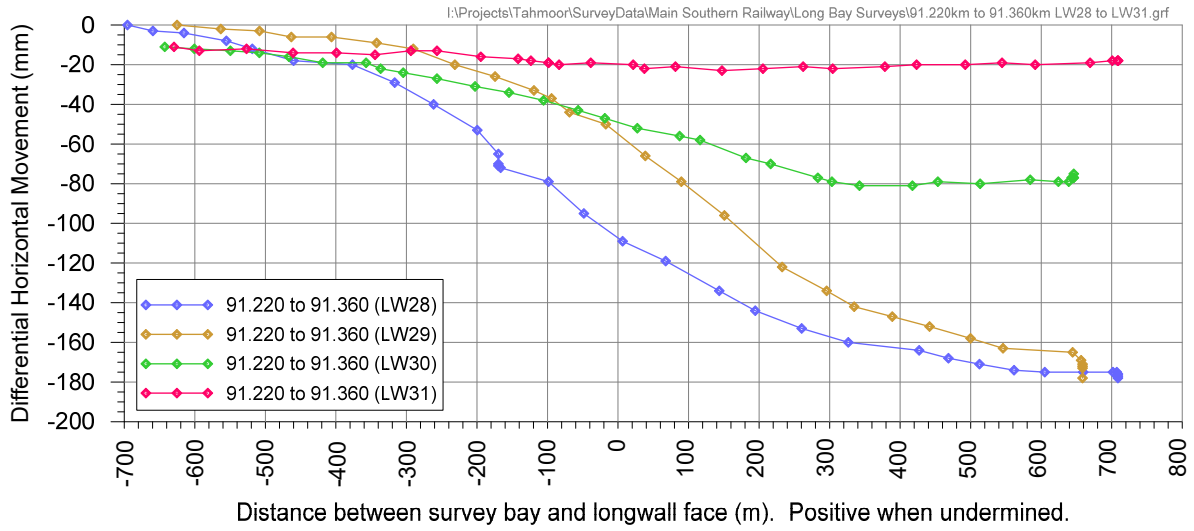


Fig. 2.10 Observed incremental valley closure as measured by long bay survey, relative to face distance, across Redbank Creek Culvert at Main Southern Railway during the mining of Longwalls 28 to 31

It can be seen from Fig. 2.10 that only minor valley closure movements occurred during Longwall 31. When compared to the development of valley closure during the mining of Longwalls 28 and 30, it can be seen that valley closure was substantially less than observed during previous longwalls. By the end, the increment of valley closure due to the extraction of Longwall 31 was a quarter of the increment observed due to the extraction of Longwall 30.

Observed subsidence along the base of the embankment on the upstream side is shown in Fig. 2.11. The results show valley closure focussing between Pegs RBCCU4 and RBCCU6, with upsidence observed at Peg RBCCU4. It can also be seen that very little change in ground strain was observed during the mining of Longwall 31.

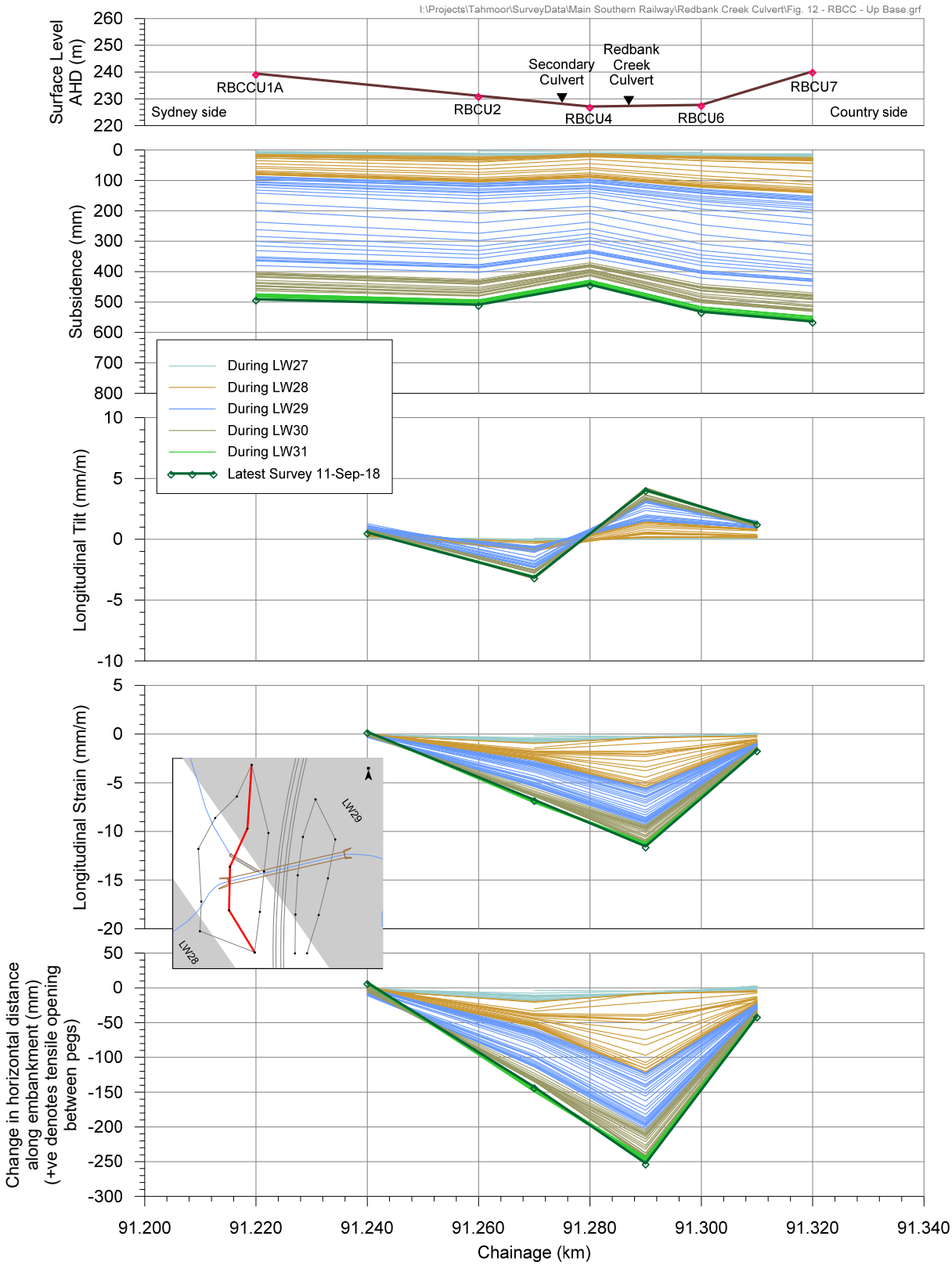


Fig. 2.11 Observed total subsidence, tilt and strain across the upstream base of Redbank Creek Culvert due to the mining of Longwalls 27 to 31

2.5. Sewer Infrastructure

2.5.1. Sewer grades

Subsidence monitoring was undertaken along the streets and along the Thirlmere Carrier pipe during the mining of Longwall 31.

The Thirlmere Carrier is the main branch servicing the majority of Thirlmere township. A total of 24 surveys were undertaken along the Thirlmere Carrier during the mining of Longwall 31. Small improvements in sewer grade were observed above the eastern edge of previously extracted Longwall 30 between Pegs BG106 and BG108, as expected. An improvement in grade was not observed between Pegs BG105 and BG106. An invert level survey was completed on 6 September to improve understanding of current levels along the pipe. The survey confirmed a reversal of grade at the Pits Nos. 3186019 and 3186018, which are located opposite Pegs BH105 and BH106, respectively. While good flows continue to be observed, the replacement pipe will be laid to re-establish a positive grade.

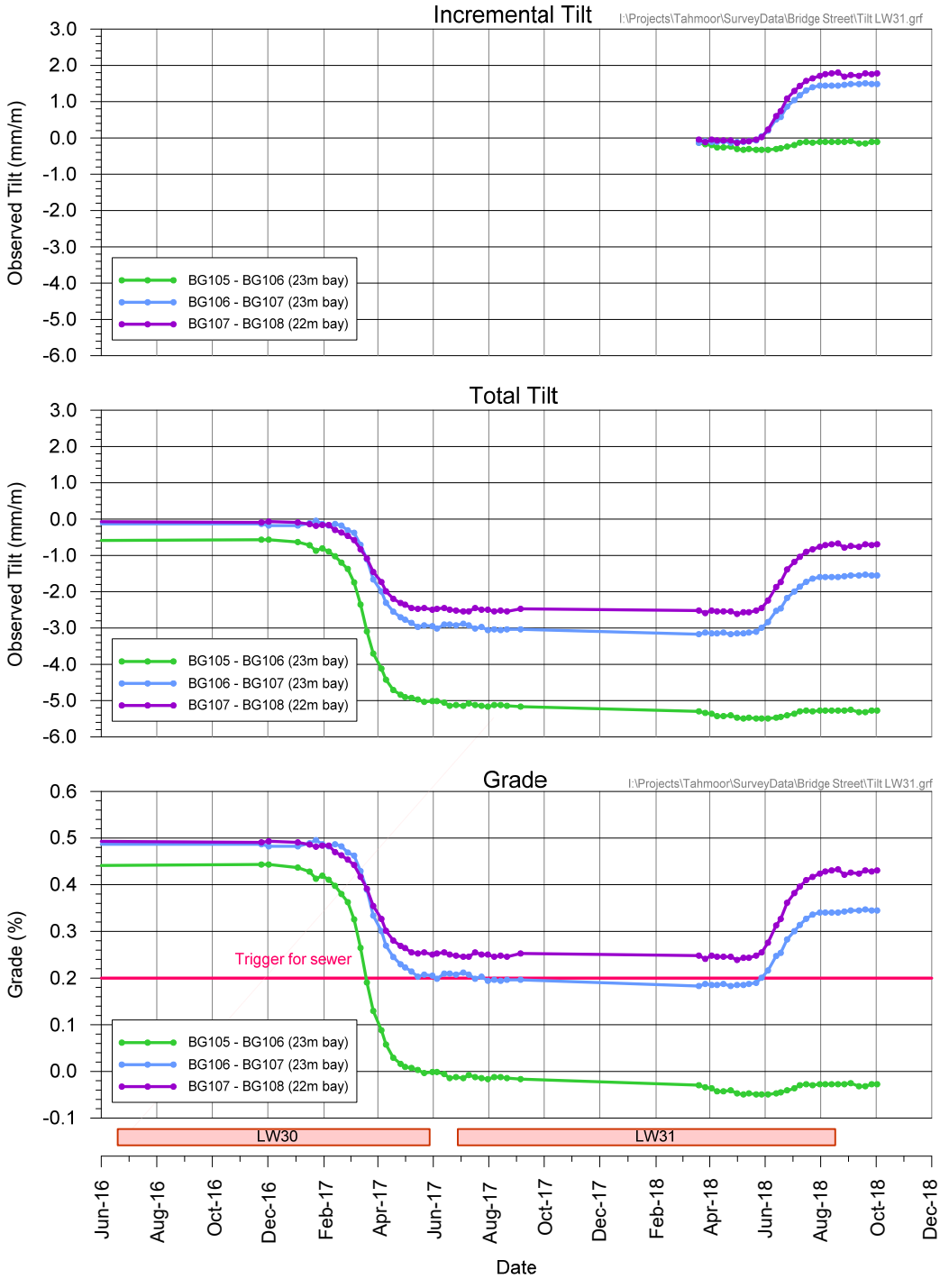


Fig. 2.12 Development of tilt on Bridge Street between pegs BG105 and BG108

2.6. Power Pole Surveys

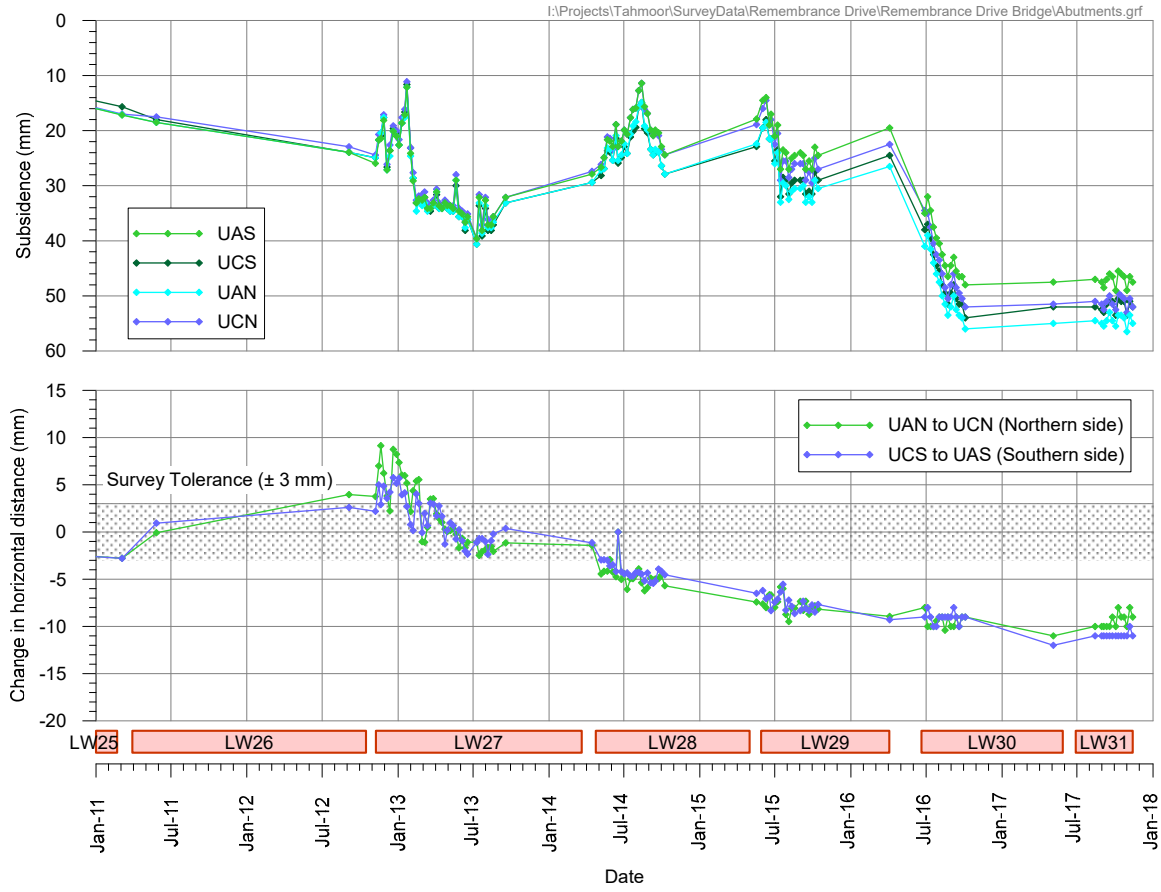
A total of 74 surveys of selected power poles were conducted in accordance with the agreed management plan with Endeavour Energy. No impacts were observed to any power pole or cables during the mining of Longwall 31, as expected.

Of the poles that were surveyed, maximum incremental subsidence of 618 mm was observed at Pole 623341 located on Bridge Street above Longwall 31.

2.7. Wollondilly Shire Council

2.7.1. Remembrance Drive Bridge

Survey marks were installed on the Remembrance Drive Road Bridge prior to the extraction of Longwall 24A. While the Bridge has experienced approximately 60 mm of subsidence, measured changes in horizontal distances between the abutments are small. Minor closure has been measured, as shown in Fig. 2.13. This includes the measured changes in horizontal distances across the gas pipe supports. Vertical subsidence is relatively consistent across all survey marks, indicating that no measurable upsidence has occurred to date.



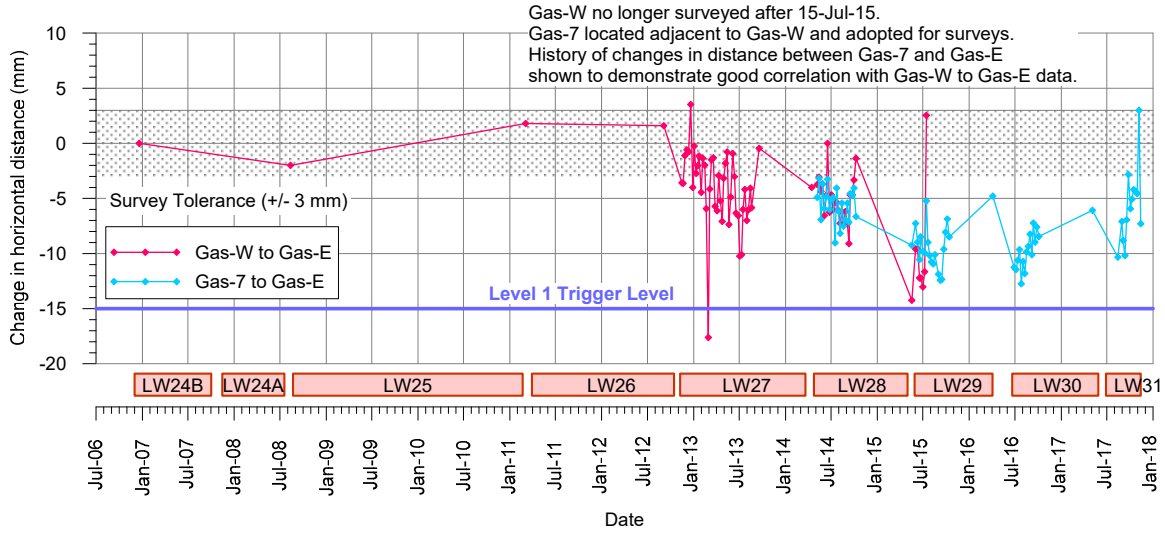


Fig. 2.13 Observed subsidence and changes in horizontal distances across the abutment and gas pipe supports at Remembrance Drive (Myrtle Creek) Road Bridge

3.0 SUMMARY OF SURVEYS AND INSPECTIONS

Many surveys and inspections were conducted to meet the requirements of the Surface, Safety and Serviceability Management Plans for Longwall 31. A timeline showing when each type of survey and inspection was conducted is shown in Fig. 3.1 below.

Fig. 3.1 Timeline of surveys and inspections during Longwall 31

A summary of surveys and inspections is provided in Table 3.1

Table 3.1 Surveys and inspections conducted during Longwall 31

Inspection / Survey	Responsibility	Number of Inspections / Surveys
Ground Monitoring Surveys		
	SMEC	125
Sub-Total		**125**
Natural Features		
Redbank Creek Survey Lines	SMEC	22
Redbank Creek Visual inspections	GeoTerra	28
Sub-Total		**50**
Main Southern Railway		
Ground Surveys	Southern Rail Surveys	63
Rail Creep Surveys	Southern Rail Surveys	63
Long Bay Surveys	Southern Rail Surveys	63
Track Geometry Surveys	BloorRail	63
Track Inspections	BloorRail	63
Cutting Surveys	Southern Rail Surveys	29
Embankment Surveys	Southern Rail Surveys	51
Noise Wall Surveys	Southern Rail Surveys	6
Deviation Overbridge Surveys	Southern Rail Surveys	25
Bridge St Overbridge Surveys	Southern Rail Surveys	19
Redbank Creek Culvert Surveys	Southern Rail Surveys	23
Far-field Surveys	Southern Rail Surveys	10
Sub-Total		**434**
Jemena - Gas		
Remembrance Drive Bridge Surveys	SMEC	13
Sub-Total		**13**
Sydney Water - Sewer		
Thirlmere Carrier Pipe Surveys	SMEC	24
Sub-Total		**24**
Endeavour Energy - Electrical		
Power Pole Surveys	SMEC	74
Sub-Total		**74**
Telstra - Telecommunications		
Optical Fibre Line Surveys	SMEC	22
Sub-Total		**22**
Commercial / Industrial		
Picton Industrial Area	SMEC	25
Sub-Total		**25**
Heritage		
Queen Victoria Memorial Home	Veris	14
Koorana	SMEC	7
Mill Hill	SMEC	12
Sub-Total		**33**
Wollondilly Shire Council		
Remembrance Drive Footbridge Surveys	SMEC	13
Sub-Total		**13**
Total		**813**

4.1. Summary of Impacts to Surface Features

A comparison between assessed and observed impacts to surface features is summarised in Table 4.1 below. The assessed and observed impacts to surface features compare reasonably well.

Table 4.1 Summary of Predicted and Observed Impacts during Longwall 31

Surface Feature	Predicted Impacts	Observed Impacts
Natural Features		
Redbank Creek	Potential cracking in creek bed. Potential surface flow diversion. Potential reduction in water quality during times of low flow. Potential increase in ponding.	Stream bed cracking and loss of pool holding capacity has been observed in numerous pools and stream reaches in Redbank Creek over LW's 25 to 31 and future LW 32. Changes observed in salinity levels downstream of Redbank Creek subsidence zone, along with elevated Total Nitrogen, Total Phosphorous, copper, nickel, zinc, iron and manganese. These observations have been reported in ferruginous pools since LW29. Refer report by GeoTerra and Section 4.2.
Aquifers or known groundwater resources	Temporary lowering of piezometric surface by up to 10m which may stay at that level until maximum subsidence develops. Groundwater levels should recover with no permanent post mining reduction in water levels in bores on the plateau unless a new outflow path develops Potential impacts to privately owned groundwater bores. Please refer report by GeoTerra.	Previously depressurised groundwater monitoring boreholes have gradually re-pressurised. No indication of any adverse interconnection between aquifers and aquitards within 20m of the surface. No impacts on privately owned bores in yield and serviceability. Please refer report by GeoTerra.
Steep slopes and cliffs	Potential soil slippage and cracking to slopes. Large scale slope failures or cliff instabilities unlikely.	No impacts observed during Longwall 31.
Natural vegetation	No impacts anticipated.	No impacts observed during Longwall 31.
Public Utilities		
Railway	Railway will remain safe and serviceable with management plans in place.	Railway maintained in safe and serviceable condition during mining. The railway infrastructure has experienced some impacts during mining. Refer to Section 4.3 for further details.
Roads and Bridges (all types)	Minor cracking and buckling may occur in isolated locations. Bridges will remain safe and serviceable with management plans in place.	Minor impacts to pavement and kerbs in isolated locations. Minor cracking and minor compression on Bridge Street. Refer Section 4.4 for further details.

Surface Feature	Predicted Impacts	Observed Impacts
Water pipelines	Minor impacts possible to pipelines, particularly older cast iron pipes with lead joints.	No impacts observed during Longwall 31. Refer Section 4.5 for further details.
Gas pipelines	Ground movements unlikely to adversely impact pipelines if systematic movement occurs.	No impacts observed during Longwall 31. Refer Section 4.6 for further details.
Sewer pipelines	Mining induced tilt unlikely to reduce grade less than that required for self-cleansing. Cracking to pipes and joints is unlikely if systematic movement occurs. Potential impacts where non-systematic movement occurs.	Short section of Thirlmere Carrier Pipe with slight reversal of grade. No impacts on flows observed. Cracks observed by CCTV inspection in Thirlmere Carrier Pipe approx. 50 m to the west of creek crossing, where increased compressive strains have been measured. Refer Section 4.7 for further details.
Electricity transmission lines or associated plants	Ground movements unlikely to adversely impact electrical infrastructure if systematic movement occurs.	No impacts observed during Longwall 31. Refer Section 4.8 for further details.
Telecommunication lines or associated plants	Ground movements unlikely to adversely impact telecommunications infrastructure if systematic movement occurs. Most vulnerable cables are older cables such as air pressurised lead sheathed cables. Strains may be higher where cables connect to support structures or where affected by tree roots.	No impacts observed during Longwall 31. Refer Section 4.9 for further details.
Public Amenities	No public amenities affected by Longwall 31.	No public amenities affected by Longwall 31
Queen Victoria Memorial Gardens	All structures expected to remain safe, serviceable and repairable provided that they are in sound condition prior to mining.	No impacts observed during Longwall 31.
Farmland and Facilities		
Farm buildings or sheds	Negligible to slight impacts predicted for all farm buildings and sheds if systematic movement occurs.	No impacts observed during Longwall 31.
Fences	Potential for impacts to fences and gates.	No impacts reported to fences on farm properties during Longwall 31.
Farm dams	Potential adverse effects on dam walls and storage capacity. Please refer report by GeoTerra.	No dam wall cracking and no adverse effects on dam wall integrity or dam water storage reduction have been observed from field investigations. Please refer report by GeoTerra.
Wells or bores	Potential impact on one NOW registered bore. Please refer report by GeoTerra.	No impacts observed during Longwall 31. Please refer report by GeoTerra
Industrial, Commercial or Business Establishments	All structures expected to remain safe, serviceable and repairable provided that they are in sound condition prior to mining. Potential impacts predicted to occur to structures, equipment and machinery.	Minor impacts on business and commercial establishments affected by Longwall 31. Establishments remained safe and serviceable during the mining of Longwall 31.
Areas of Archaeological Significance	Potential fracturing, rock falls or water seepage affecting artwork on rock shelter on Redbank Creek. Potential for fracturing and buckling of bedrock in the vicinity of the grinding groove site on Redbank Creek ,which is located above future Longwall 32. Low potential impacts on isolated artefact sites, which are located directly above Longwall 31.	No impacts on archaeological sites observed during Longwall 31.

Surface Feature	Predicted Impacts	Observed Impacts
Areas of Heritage Significance	Potential low level impacts at Queen Victoria Memorial Home, Mill Hill Homestead and Koorana Homestead, which are located adjacent to but not directly above Longwall 31.	No items of heritage significance affected by Longwall 31, including Queen Victoria Memorial Home, Mill Hill Homestead and Koorana Homestead.
Permanent Survey Control Marks	Ground movement predicted at identified survey marks.	Ground movement occurred.
Residential Establishments		
Houses, flats or units	All houses expected to remain safe, serviceable and repairable provided that they are in sound condition prior to mining. Impacts predicted to some houses. Refer Section 4.11 for details.	While impacts occurred, houses were safe, serviceable and repairable during Longwall 31. Refer Section 4.11 for details.
Swimming pools	While predicted tilts are not expected to cause a loss in capacity, tilts are more readily noticeable in pools as the height of the freeboard will vary along the length of the pool. While predicted strain impacts are low, many of the pools are inground, which are more susceptible.	Impact to 36 pools during the mining of Longwalls 22 to 31, with impact to no additional pools reported damaged during the mining of Longwall 31. Impact observed to one pool fence during the mining of Longwall 31.
Associated structures such as workshops, garages, on-site wastewater systems, water or gas tanks or tennis courts	Potential impact to pipes connected to inground septic tanks. Negligible impacts predicted for non-residential domestic structures, including sheds and tanks.	Impact to 1 pergola and associated garden walls was reported during Longwall 31.
External residential pavements	Cracking and buckling likely to occur, though majority minor.	Impacts to external pavements were reported by 1 property during Longwall 31.
Fences in urban areas	Some fences and gates could be slightly damaged. Most vulnerable are Colorbond fences.	No impacts to fences reported during Longwall 31.

4.2. Creeks

4.2.1. Redbank Creek

GeoTerra undertook an investigation into the effects of Longwall 31 on surface and ground waters in the area (GeoTerra, 2019).

During the mining of Longwall 31, new subsidence effects were observed at Sites RR29 (rock bar delamination and uplift and reduction in pool water levels), and Sites RR30, RR31, RB32 and RC4 (reduction in pool water levels with no obvious cracking). The new impact sites were observed above future Longwall 32. No new impact sites were observed directly above Longwall 31, though additional cracking was observed in pools that previously experienced impacts during the mining of Longwall 30.

Pools located directly above Longwall 31 and future Longwall 32 have experienced a reduction in pool water levels and low water flows compared to baseline monitoring. Approximately half of the pools have been observed dry during the mining of Longwall 31.

Re-emergence of the connected stream “through-flow” has been observed downstream of future Longwall 32, at site RR29 (refer to report by GeoTerra for locations of sites).

Increased salinity was observed directly above and downstream of the subsidence zone, particularly during periods of low flow. Elevated levels of Total Nitrogen, Total Phosphorous, copper, iron, manganese, zinc and nickel were observed during the mining of Longwall 31 and are observed in ferruginous pools.

A number of seeps were identified in Redbank Creek prior to mining. No new springs have been generated, or reduced, due to subsidence due to the mining of Longwalls 22 to 31, though increased ferruginous and salinity levels have been observed in the stream over Longwalls 29 to Longwall 31 and future Longwall 32.

4.2.2. Comparison against Triggers in Natural Features Management Plan

The observed impacts have been compared against the triggers stated in Section 3.1.1 of the *Environmental Management Plan for Longwall 31*, (Rev. 0, May 2017).

Table 4.2 Comparison against Triggers for Myrtle and Redbank Creeks during Longwall 31

Trigger	Redbank Creek
Redirection of surface water flows and pool level / flow decline of >20% during mining compared to baseline variability for > 2 months, considering rainfall / runoff variability	Trigger exceeded during mining of LW31 at 16 sites: Sites RW13, RB14 and RR15 above LW30, Site RR16 above the chain pillar between LW30 and LW31, Sites RB17, RR18, RR19, RB20 to RB27 incl Weir 26 above LW31, Site RR27 above the chain pillar between LW31 and LW32 Sites RR28 and RR29 east of LW31.

4.3. Main Southern Railway

4.3.1. Railway Track

While changes were observed, the Main Southern Railway remained serviceable at all times during the mining of Longwall 31. The track condition deteriorated slightly in isolated locations as a result of mining and the track was resurfaced.

During the mining of Longwall 31 some of the triggers associated with the *Tahmoor Colliery Longwall 31 Management Plan for Longwall Mining beneath the Main Southern Railway (Rev A, April 2017)* were exceeded.

Some low level (Blue) rail stress triggers and switch displacement triggers were exceeded during the mining of Longwall 31 as a result of subsidence in combination with low or high rail temperatures. The alarms were responded to in accordance with the Management Plan. Some of the responses had already been planned in anticipation of the alarm.

4.3.2. Redbank Creek Culvert and Embankment

Tahmoor Coking Coal Operations has successfully managed Redbank Creek Culvert during the extraction of Longwall 31. Substantial ground shortening of approximately 480 mm was observed along the length of the embankment, and ground extension of approximately 260 mm was observed in the transverse direction across the base of the embankment.

A detailed Subsidence Management Plan was developed to manage potential impacts on the Redbank Creek Culvert and Embankment during the mining of Longwall 31.

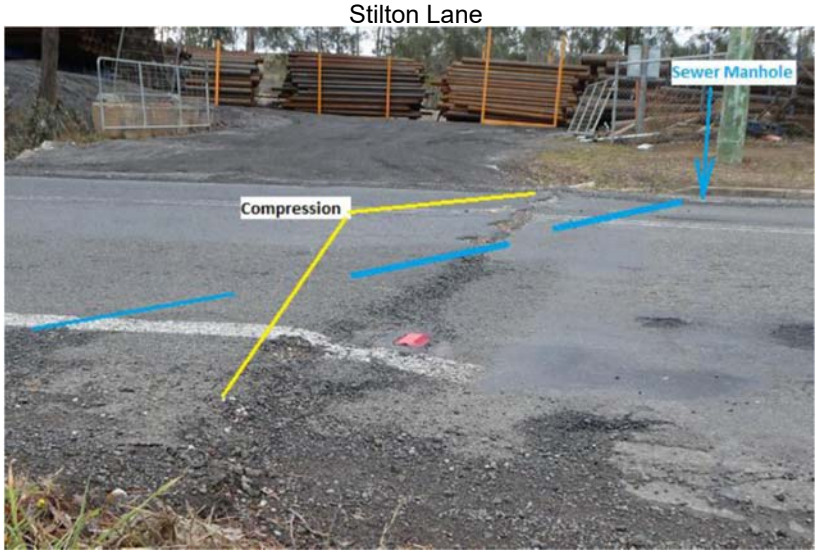
The Redbank Creek Culvert and Embankment has remained safe and serviceable during the mining of Longwall 31.

4.4. Roads and Bridges

4.4.1. Roads

Approximately 28 kilometres of asphaltic pavement lie directly above the extracted longwalls and a total of 54 impact sites have been observed. The observed rate of impact equates to an average of one impact for every 520 metres of pavement. The impacts were minor and did not present a public safety risk. A collection of photographs of impacts is provided in Fig. 4.1.

Stilton Lane



Bridge Street

Photographs courtesy of Colin Dove

Fig. 4.1 Photographs of Impacts to Road Pavements during Longwall 31

4.5. Potable Water Infrastructure

Longwalls 22 to 31 have directly mined beneath approximately 5.4 kilometres of ductile iron concrete lined (DICL) pipe and 19 kilometres of cast iron concrete lined (CICL) pipe, with only minor impacts recorded. No impacts were observed during the mining of Longwall 31.

4.6. Gas Infrastructure

Longwalls 22 to 31 have directly mined beneath approximately 18 kilometres of gas pipes and no impacts have been recorded so far. The local nylon and 160 mm polyethylene main along Remembrance Drive are very flexible and have demonstrated that they are able to withstand the full range of subsidence experienced at Tahmoor to date.

4.7. Sewer Infrastructure

Longwalls 22 to 31 have directly mined beneath approximately 29.4 kilometres of sewer pipes. The observed impacts to date have been within expectations. The following observations have been made:

- *Changes to grades of self-cleansing gravity sewers*
  While changes in sewer grades have occurred as a result of mine subsidence, no blockages have been observed. This includes observations at locations above Longwalls 24A to 30 where specific ground surveys were undertaken to confirm that mining-induced tilts did not exceed pre-mining grades.
  For the first time during the mining of Longwalls 22 to 31, a sewer pipe has experienced a permanent reversal of grade. An improvement in grade was not observed between Pegs BG105 and BG106 after it was observed to reduce during the mining of Longwall 30. An invert level survey was completed on 6 September to improve understanding of current levels along the pipe. The survey confirmed a reversal of grade at the Pits Nos. 3186019 and 3186018, which are located opposite Pegs BH105 and BH106, respectively. While good flows continue to be observed, the replacement pipe will be laid to re-establish a positive grade

- *Physical damage to pipes*
  There were no observations of damage during the mining of Longwalls 22 to 24 and Longwalls 27 to 30. Physical damage was observed at three locations during the mining of Longwall 25. In each case the pipes remained serviceable, though repairs were required at each location.

    - Crushing and vertical bending of 150 mm diameter pipe at Abelia Street. The impacts coincide with a large measured ground strain of 4.6 mm/m (over a 22 metre bay length) between Pegs A12 and A13, a measured vertical bump in the subsidence profile and an observed hump in the road pavement. The pipe was repaired prior to the influence of Longwall 26 and no impacts were observed to the repaired pipe during the mining of this longwall.
    - Crushing and vertical bending of 150 mm diameter pipe at Remembrance Drive. The impacts coincide with a large measured ground strain of 2.8 mm/m (over a 37 metre bay length) between Pegs R1 and RE1, a measured vertical bump in the subsidence profile and an observed hump in the road pavement and roundabout. The pipe was repaired prior to the influence of Longwall 26 and no impacts were observed to the repaired pipe during the mining of this longwall.
    - Crushing and vertical bending of the 225 mm diameter horizontal bore between Amblecote Place and Myrtle Creek. There is no monitoring line above this bore.

  Physical damage was observed at two locations during the mining of Longwall 26. In each case the pipes remained serviceable, though repairs were required at each location.

    - Deformation and cracking of 100 mm diameter pipe at Tahmoor Road. The pipe was repaired.
    - Deformation of 150 mm diameter pipe between Abelia Street and Oxley Grove where non-systematic subsidence movements were observed (this may have occurred during the mining of Longwall 25). The pipe was repaired.
    - Continued deformation of the 225 mm diameter horizontal bore between Amblecote Place and Myrtle Creek from Castlereagh Street to Brundah Road.

  Physical damage was observed at one location during the mining of Longwall 31.

    - Longitudinal (axial) compression and cracking of the Thirlmere Carrier Pipe approximately 50 metres of the creek crossing. Further details are provided below.

Compressive strain was observed to increase between Pegs BG105 and BG106. CCTV inspections were undertaken on multiple locations and Sydney Water conducted pit lid inspections during mining to check for any signs of backing up of wastewater.

Whilst no impacts were observed between Pegs BG105 and BG106, cracks were found approximately 50 metres to the west between Pegs BG102 and BG103. The locations of the impact sites are shown in Fig. 4.2.

Fig. 4.2 Locations of cracks observed by CCTV inspection in Thirlmere Carrier Pipe on 25 July 2018

The damage is consistent with a mechanism of longitudinal (axial) compression, where the joint has closed and the end of the pipe has been pushed into the adjacent pipe. The location is approximately 50 to 55 metres to the west of the concrete encased creek crossing, where compressive strains have been observed between Pegs BG105 and BG106. Actual ground strains at the damage location are relatively small, in the order of -0.6mm/m compressive, and 0.2mm/m tensile. The small red values in Fig. 4.2 are measured changes in horizontal distance between the pegs, where negative values represent closure and positive values represent ground extension. It is considered that the pipes have been pushed in response to compression and the pipe joints have progressively closed up in a concertina fashion. Sydney Water has viewed the attached photographs and advise that there are no immediate concerns, but the damage will have to be repaired.

4.8. Electrical Infrastructure

Longwalls 22 to 31 have directly mined beneath approximately 41 kilometres of electrical cables and 1050 power poles and no significant impacts have been recorded so far. However, minor changes in tension of some aerial cables has been observed.

4.9. Telecommunications Infrastructure

Longwalls 22 to 31 have directly mined beneath approximately 43.1 kilometres of buried copper cable and 3.2 kilometres of buried optical fibre cable and 6.5 kilometres of aerial cable and no impacts have been recorded to telecommunications services so far.

Adjustments to tension of aerial telecommunications cables were required during the mining of Longwall 26 on Tahmoor Road and Krista Place. Damage was also observed to a conduit on the north-western abutment of the Castlereagh St Bridge. No issues were detected during the mining of Longwalls 27 to31.

4.10. Picton Industrial Area

Tahmoor Coking Coal Operations undertook intensive surveys and visual inspections of structures, equipment and machinery of commercial, industrial and business establishments within the Picton Industrial Area during the mining of Longwall 31.

All structures within the Picton Industrial Area remained safe and serviceable during the mining of Longwall 31. Minor impacts were observed to structures, equipment and machinery.

4.11. Residential Establishments

All structures remained safe and serviceable during the mining of Longwall 31.

Information on impacts is based on claims received from the Subsidence Advisory NSW (formerly Mine Subsidence Board). Information on the nature of the impacts was provided by the Subsidence Advisory NSW (Mine Subsidence Board.

A summary of reported impacts following the completion of Longwall 31 is provided in Table 4.3. The count of residential structures and public amenities includes only those structures that were predicted to experience more than 20 mm of subsidence due to the extraction of Longwalls 22 to 31.

Table 4.3 Summary of Observed Impacts to Structures

	Total after LWs 22 to 30	Increment during Longwall 31
Number of structures within zone of influence (predicted subsidence > 20 mm)	1961	22
Number of properties with reported impacts (not including refused claims)	555	8
Number of properties with reported impacts that relate to main structures (e.g. house or shop)	494	5
Number of properties with reported impacts that only relate to associated structures	61	3

4.11.1. Discussion of Results

Prior to the mining of Longwall 27, the probabilities of impacts for each house within the SMP Area for Longwalls 27 to 30 were assessed using the method developed as part of ACARP Research Project C12015, based on observations of impacts during the mining of Longwalls 22 to 24A. Additional statistical information was collected in 2016 after the mining of Longwall 29. The timing of the data is such that it accounts for much of the time lag effect that occurs between the time of impact, when damage is claimed by residents and when the nature and level of the damage requiring repairs is assessed in detail by SA NSW.

A summary of the observed distribution of impacts for all houses within a 35° angle of draw of previously extracted Longwalls 22 to 29 as at 2016 is provided in Table 4.4.

Table 4.4 Observed Frequency of Impacts for Building Structures Resulting from the Extraction of Tahmoor Longwalls 22 to 29

Group	Repair Category			
	No Claim or R0	R1 or R2	R3 or R4	R5
All houses within 35 degree angle of draw of LWs 22 to 29 (total of 1890)	1430 (76 %)	329 (17 %)	111 (6 %)	20 (1%)

It is noted that a comparison cannot easily be made based on the total number of affected houses. It is very difficult to separate effects on houses due to the mining of Longwall 31 only due to the time lag effect discussed previously. All properties that reported impacts during the mining of Longwall 31 were associated with the mining of previous Longwalls 22 to 29.

It is recommended, therefore, that comparisons be made based on total percentages of claims, where a reasonable correlation can be seen.

The primary risk associated with mining beneath houses is public safety. Residents have not been exposed to immediate and sudden safety hazards during the mining of Longwall 31. One house experienced substantial damage and measured were undertaken during mining to maintain safety and serviceability.

4.11.2. Swimming Pools

No pools were reported damaged during the mining of Longwall 31, though one pool gate was damaged.

4.11.3. Associated Structures

One pergola and associated garden walls was reported damaged during Longwall 31.

4.11.4. Fences

The potential for impacts to fences was raised in the SMP Report, however, no properties have claimed impacts to gates and fences during the mining of Longwall 31, with the exception of one pool gate.

5.0 SUMMARY OF RESULTS

In summary, there is generally a reasonable correlation between observed and predicted subsidence, tilt and curvature over the majority of the mining area.

As anticipated prior to mining, little to no increased subsidence was observed during the first stages of mining Longwall 31. The maximum observed incremental subsidence due to the mining of Longwall 31 was 803 mm, which is slightly more than the maximum predicted incremental subsidence for Longwall 31, with the difference being within the accuracy of the subsidence prediction methods.

There is a reasonable correlation between observed and predicted impacts, particularly in relation to public infrastructure such as the Main Southern Railway, sewer mains, water mains, gas mains, and electrical and telecommunications infrastructure.

All structures remained safe and serviceable during the mining of Longwall 31.

In relation to Redbank Creek, there was a reasonable correlation between predicted and observed incremental valley closure movements due to the mining of Longwall 31.

Cracking was observed in Redbank Creek and pools were observed to drain at times of low flow, with sub-surface flow diversion observed to re-emerge downstream of Longwall 32. Some adverse changes in water quality were observed at times of low flow. The observed impacts are within predictions.

APPENDIX A. FIGURES

Tahmoor Coking Coal Operations - Longwall 31
Incremental Subsidence Profiles along Remembrance Drive

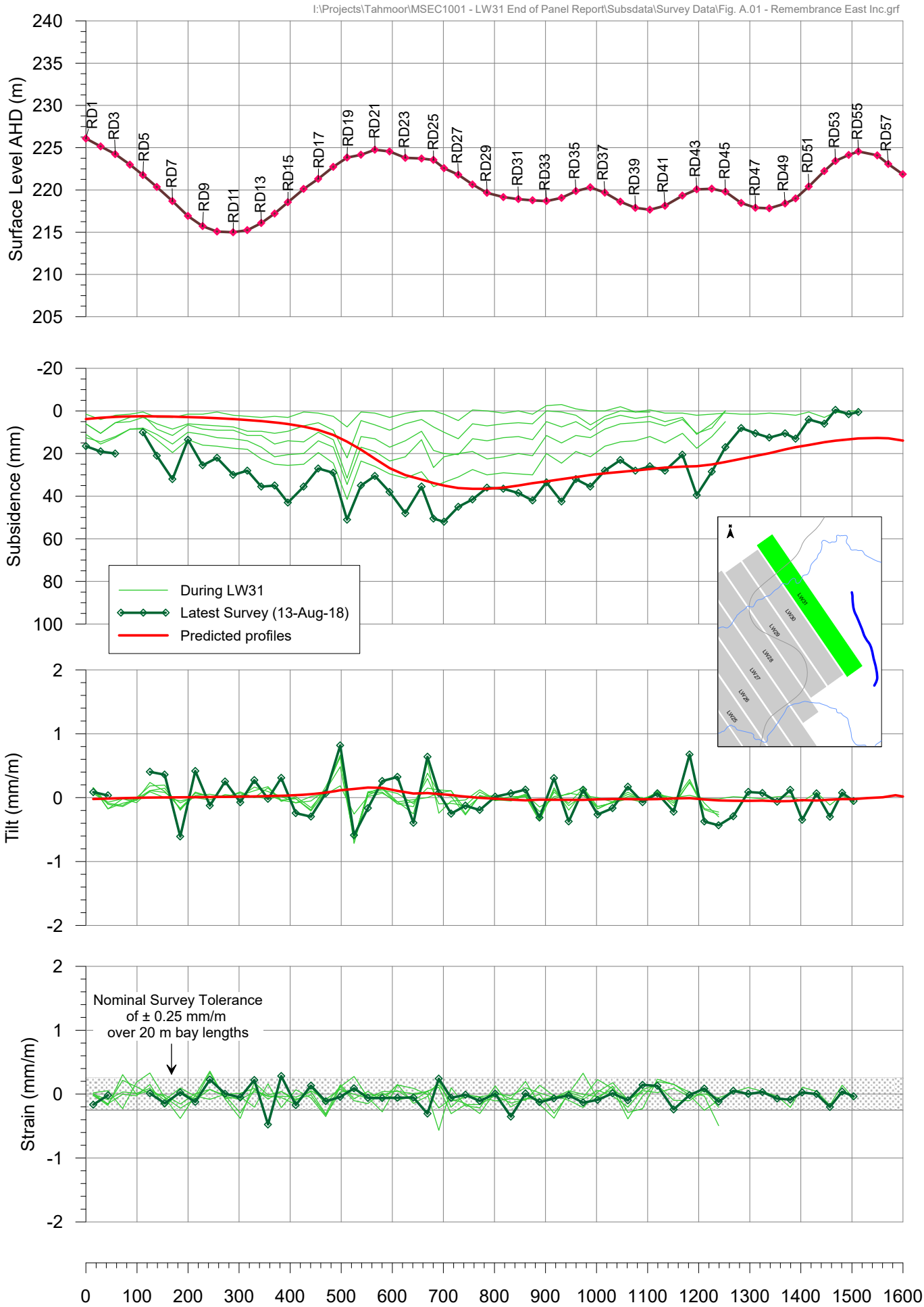


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Fig. A.01

Tahmoor Coking Coal Operations - Longwall 31
Incremental Subsidence Profiles along Bollard Place

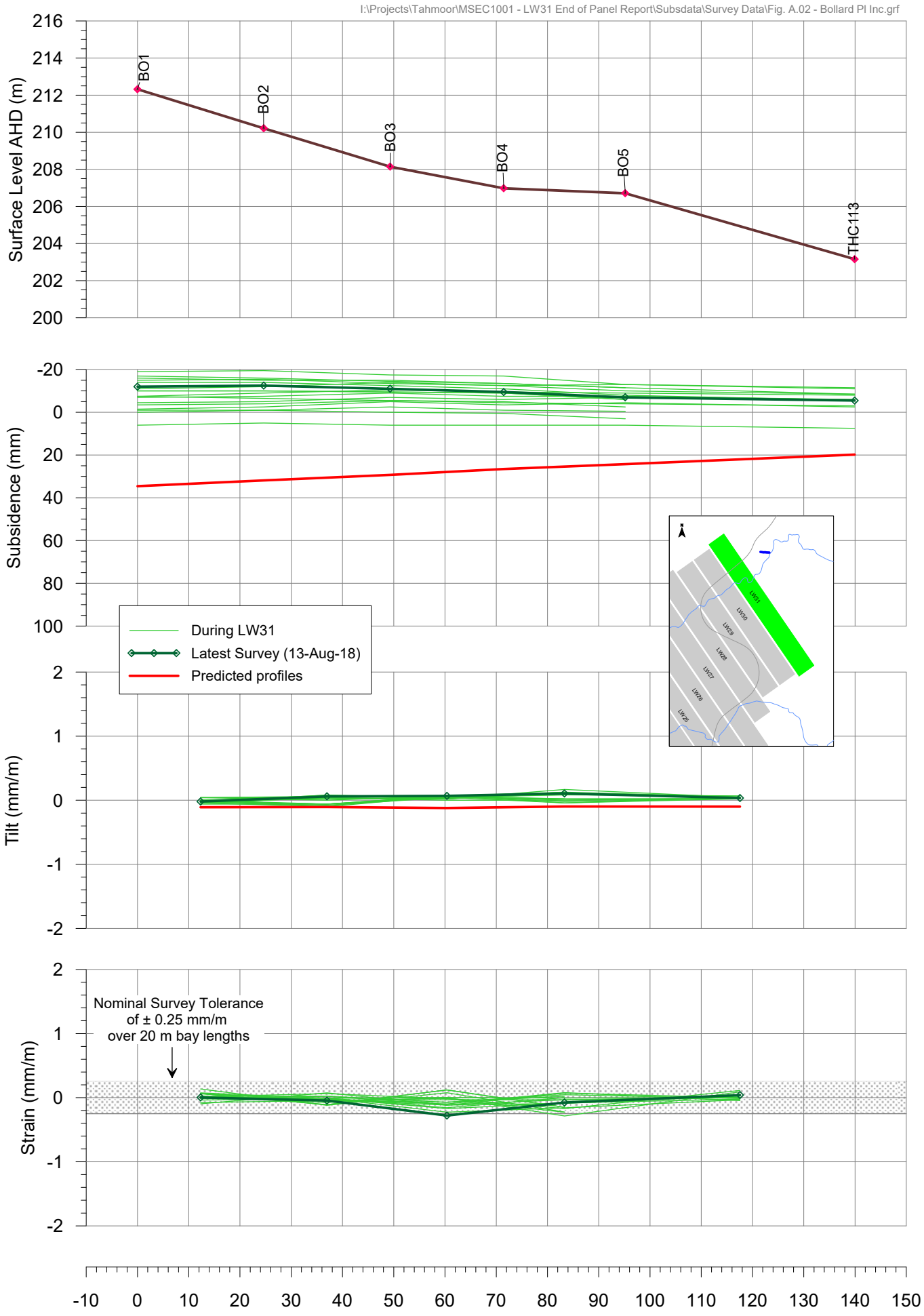

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Fig. A.02

Tahmoor Coking Coal Operations - Longwall 31
Incremental Subsidence Profiles along Thirlmere Way

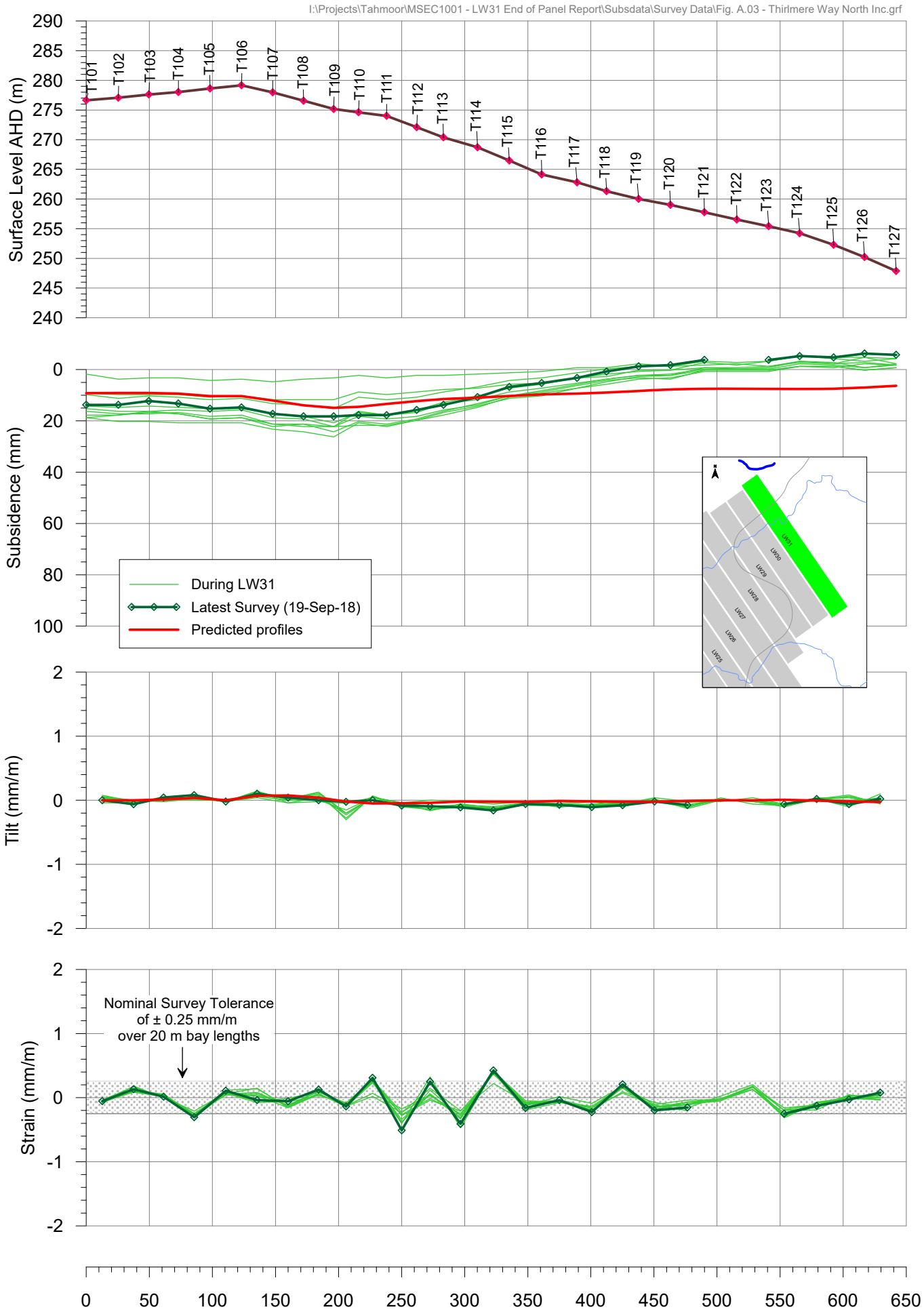

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Fig. A.03

Tahmoor Coking Coal Operations - Longwall 31
Incremental Subsidence Profiles along Thirlmere Carrier (east)

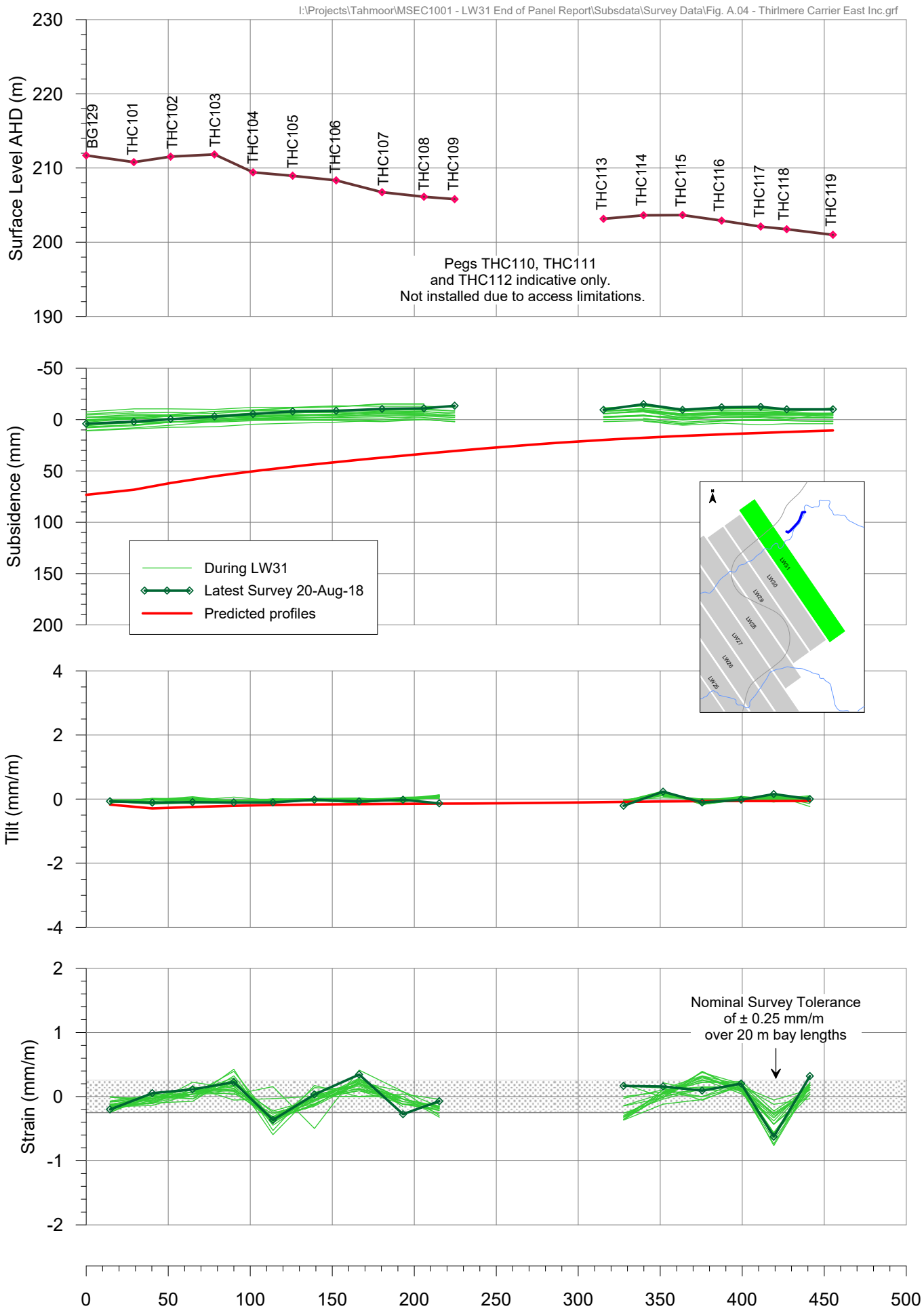

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Fig. A.04

Tahmoor Coking Coal Operations - Longwall 31
Total Subsidence Profiles along the Optical Fibre Line

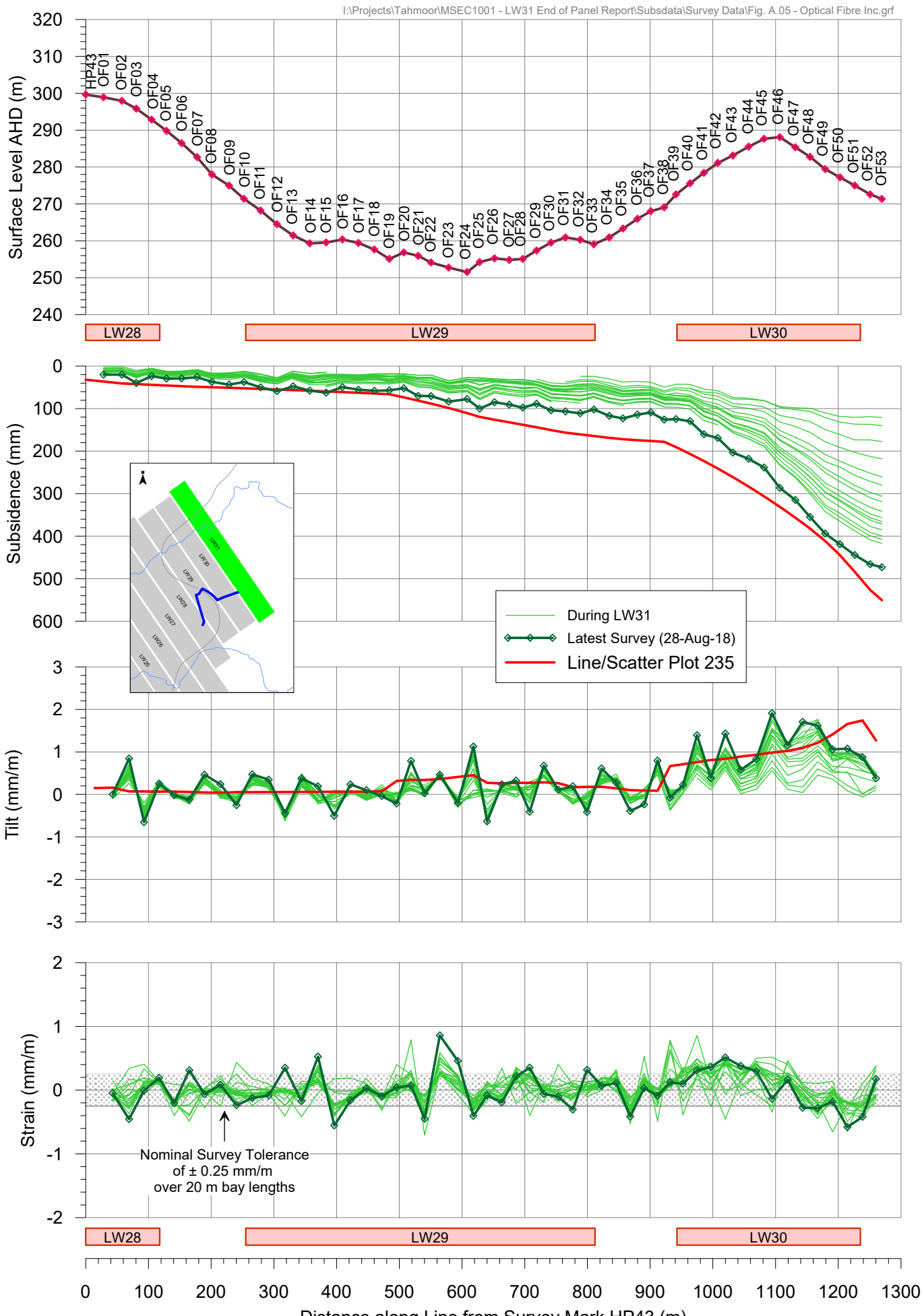

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Fig. A.05

Tahmoor Coking Coal Operations - Longwall 31
Total Subsidence Profiles along the Optical Fibre Line

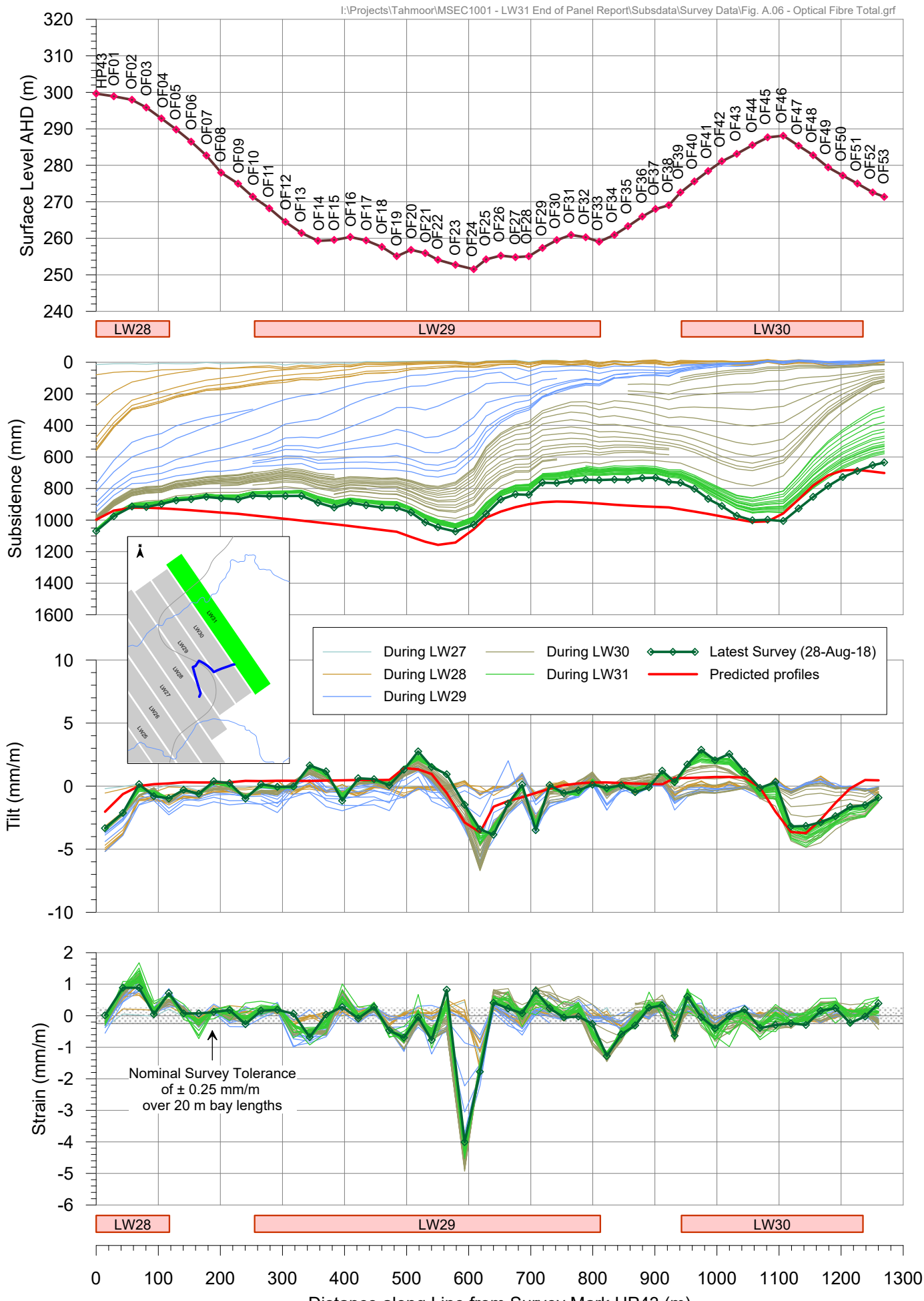

Fig. A.06

Tahmoor Coking Coal Operations - Longwall 31
Incremental Subsidence Profiles along Stilton Lane

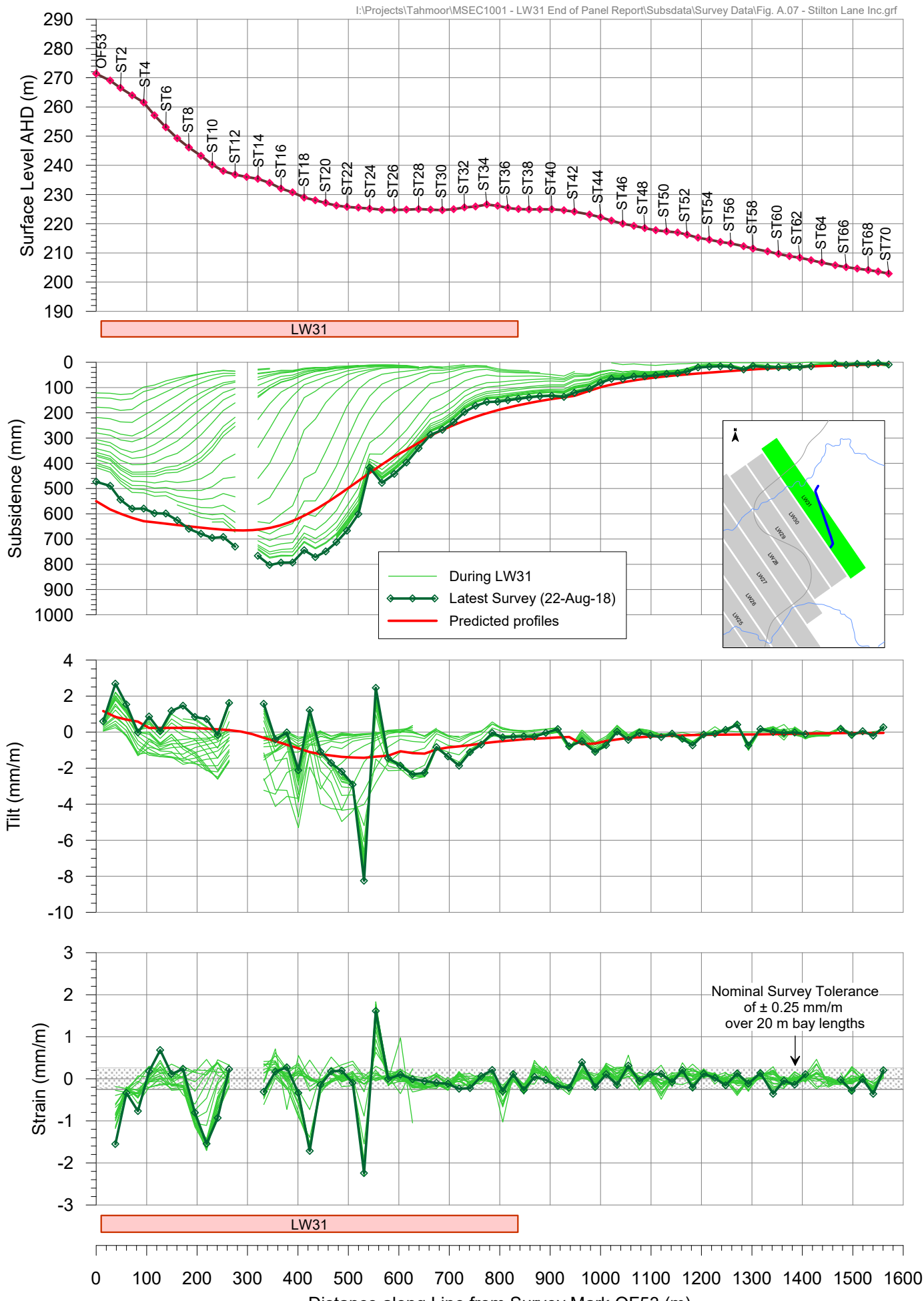

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Fig. A.07

Tahmoor Coking Coal Operations - Longwall 31
Total Subsidence Profiles along Stilton Lane

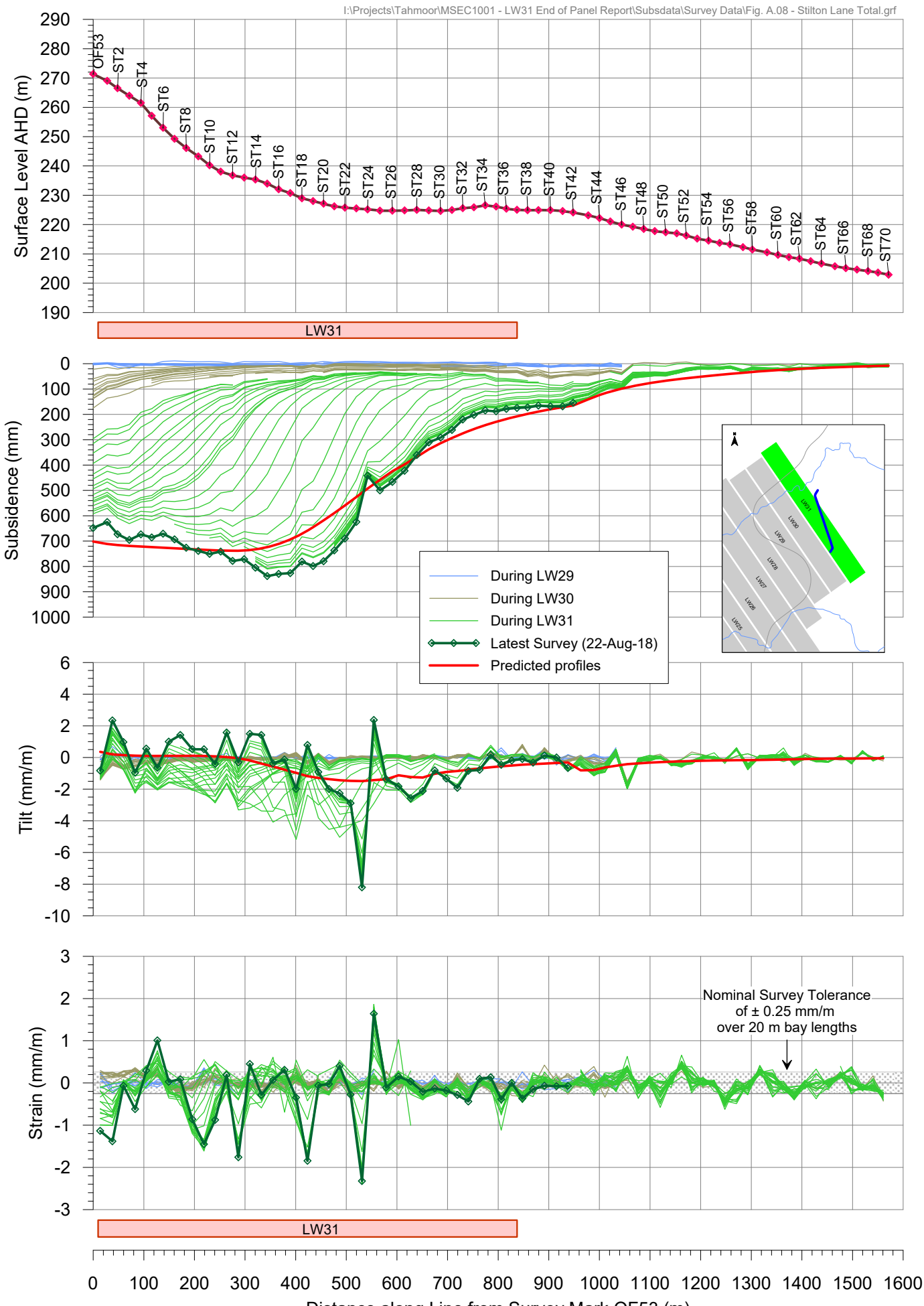

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Fig. A.08

Tahmoor Coking Coal Operations - Longwall 31
Incremental Subsidence Profiles along Bridge Street

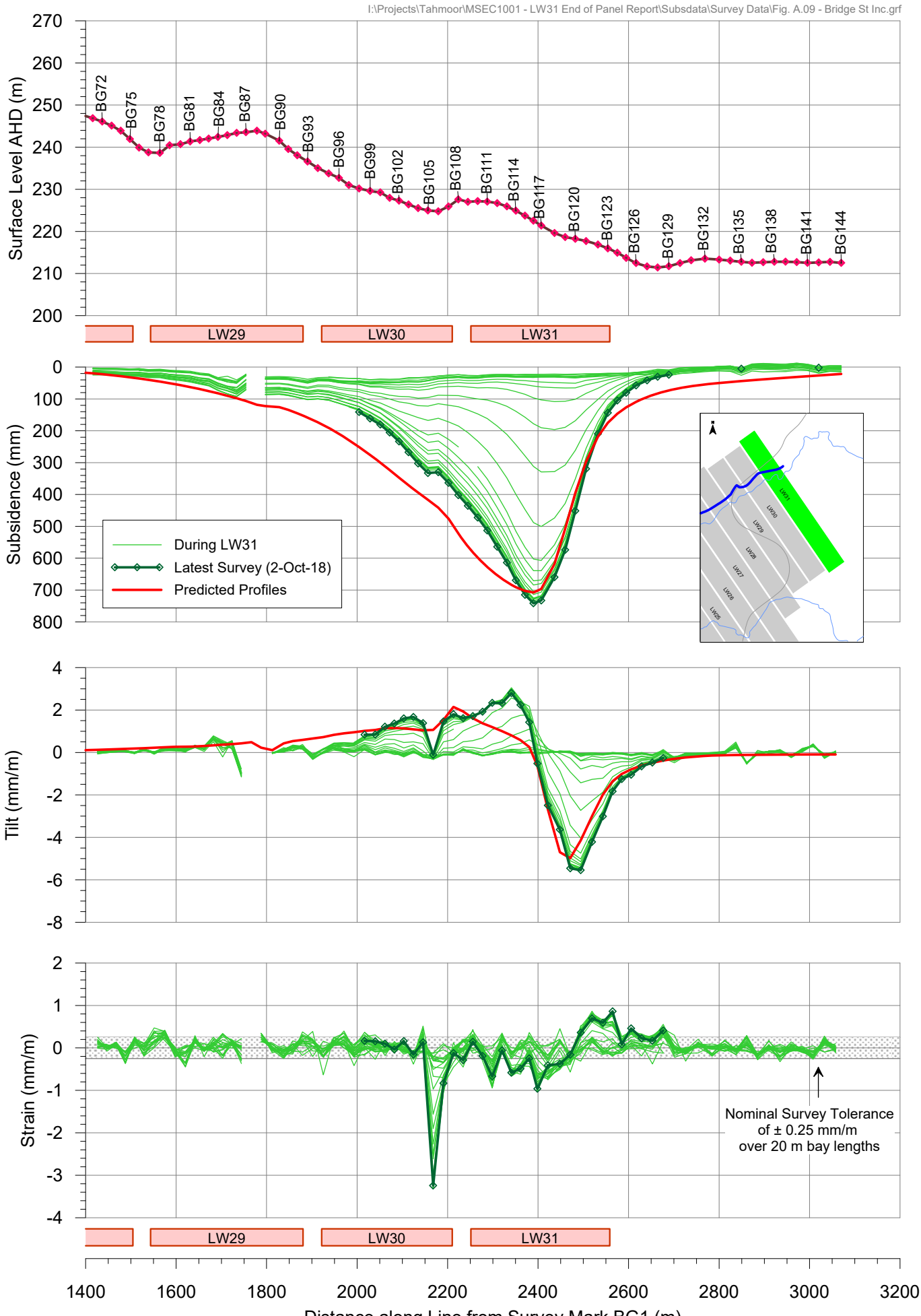

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Fig. A.09

Tahmoor Coking Coal Operations - Longwall 31
Total Subsidence Profiles along Bridge Street

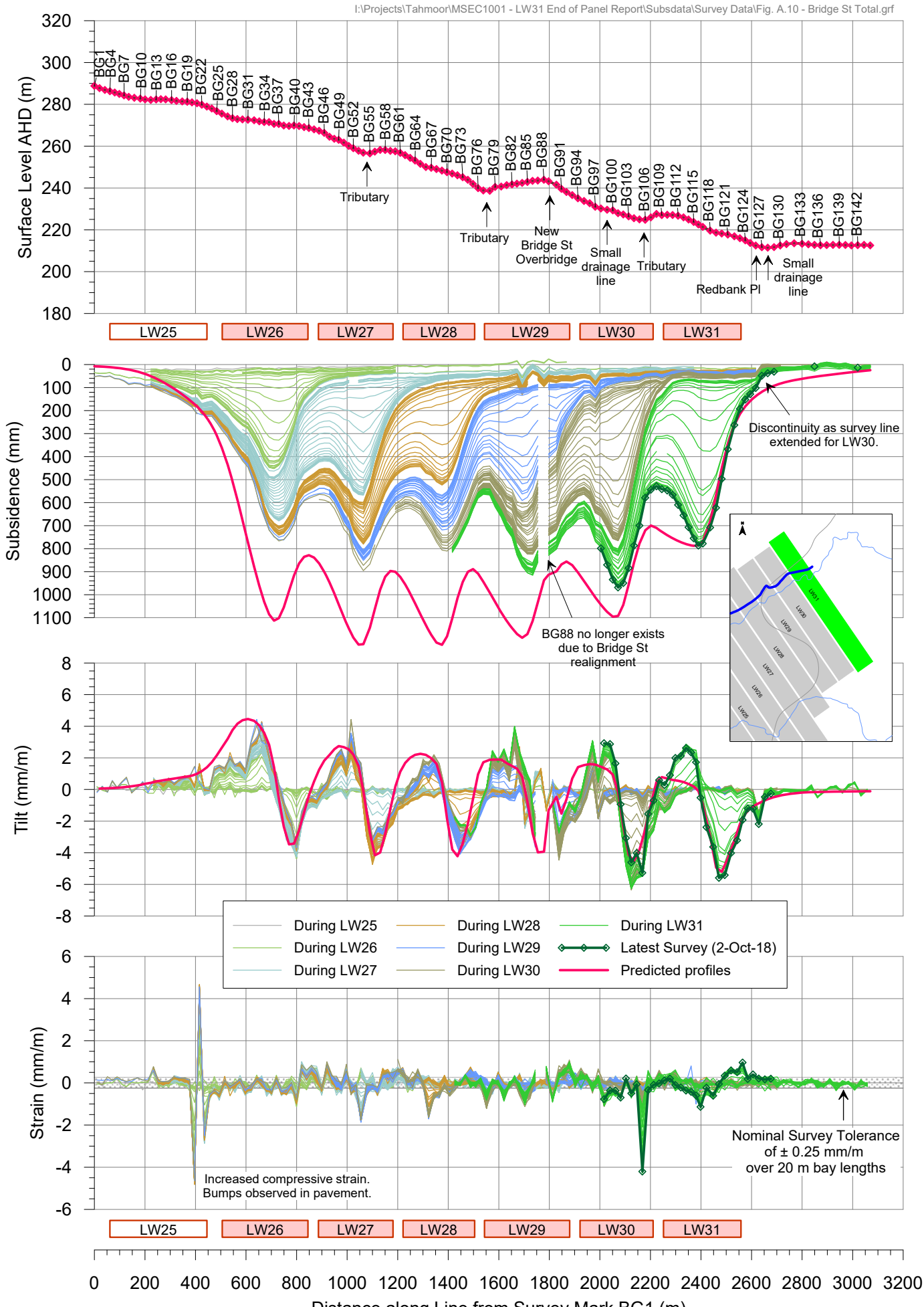

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Fig. A.10

Tahmoor Coking Coal Operations - Longwall 31
Incremental Subsidence Profiles along Redbank Place

I:\Projects\Tahmoor\MSEC1001 - LW31 End of Panel Report\Subsdata\Survey Data\Fig. A.11 - Redbank Pl Inc.grf

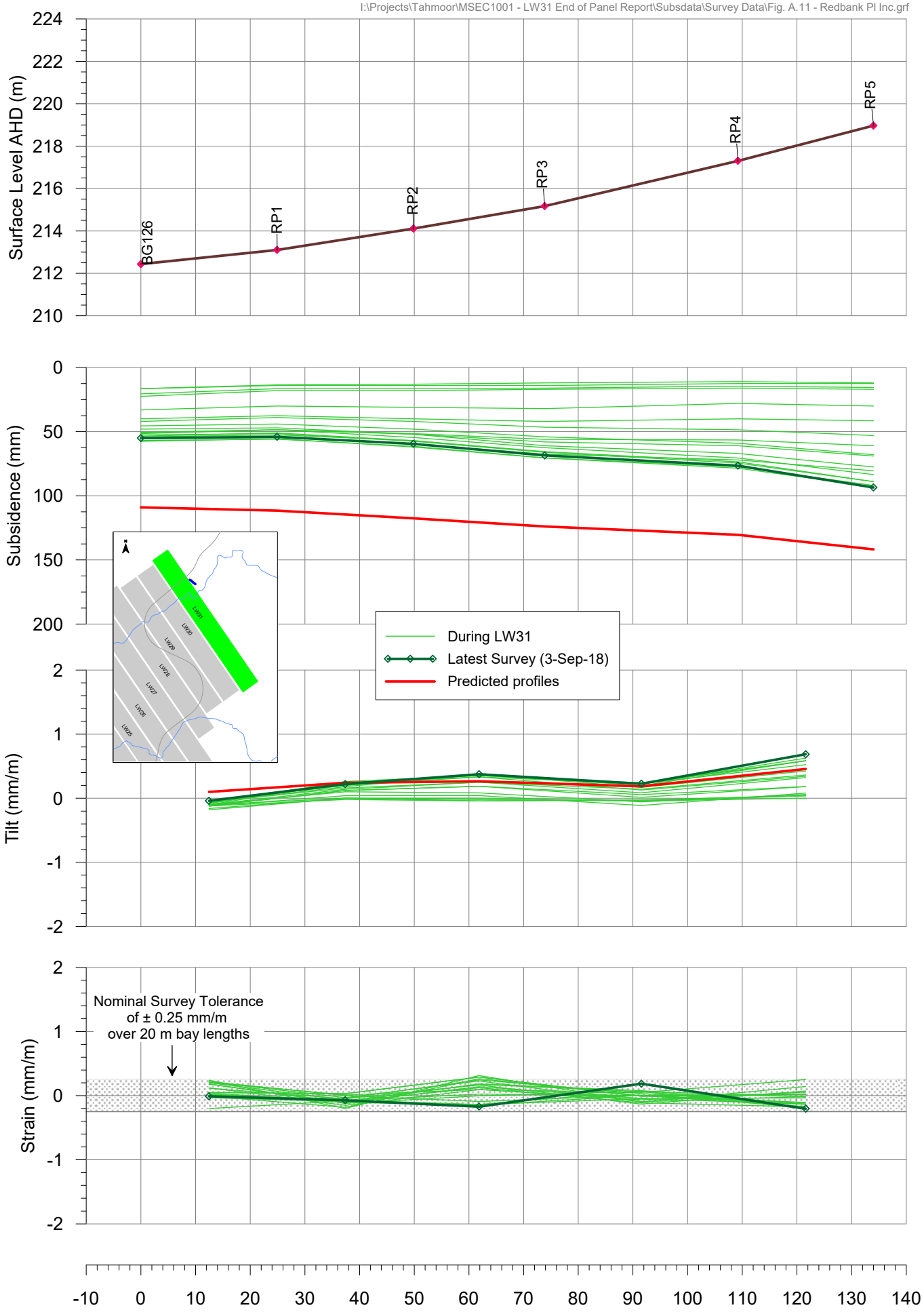

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Fig. A.11

Tahmoor Coking Coal Operations - Longwall 31
Total Subsidence Profiles along Redbank Place

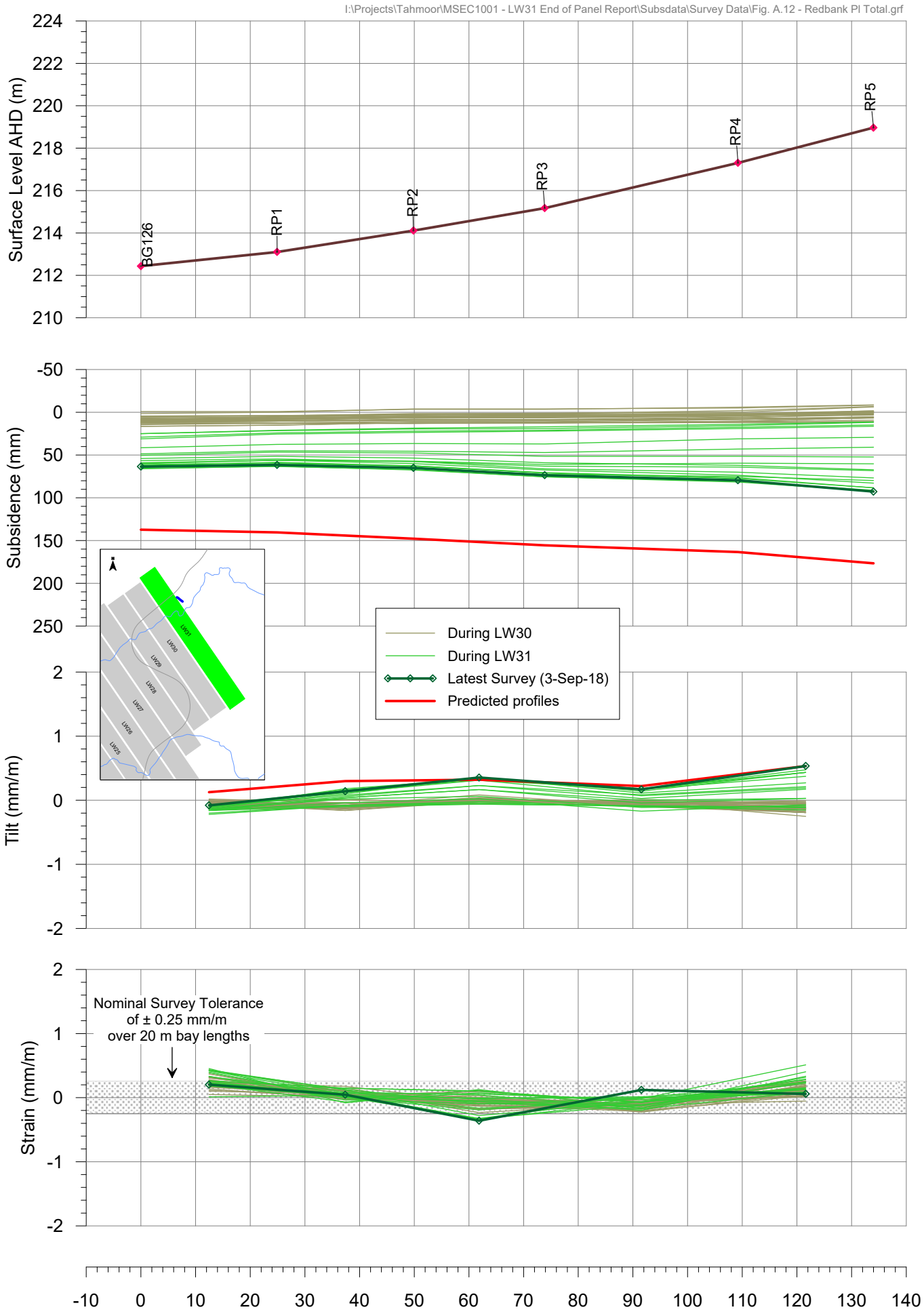

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Fig. A.12

Tahmoor Coking Coal Operations - Longwall 31
Incremental Subsidence Profiles along Thirlmere Carrier Pipe

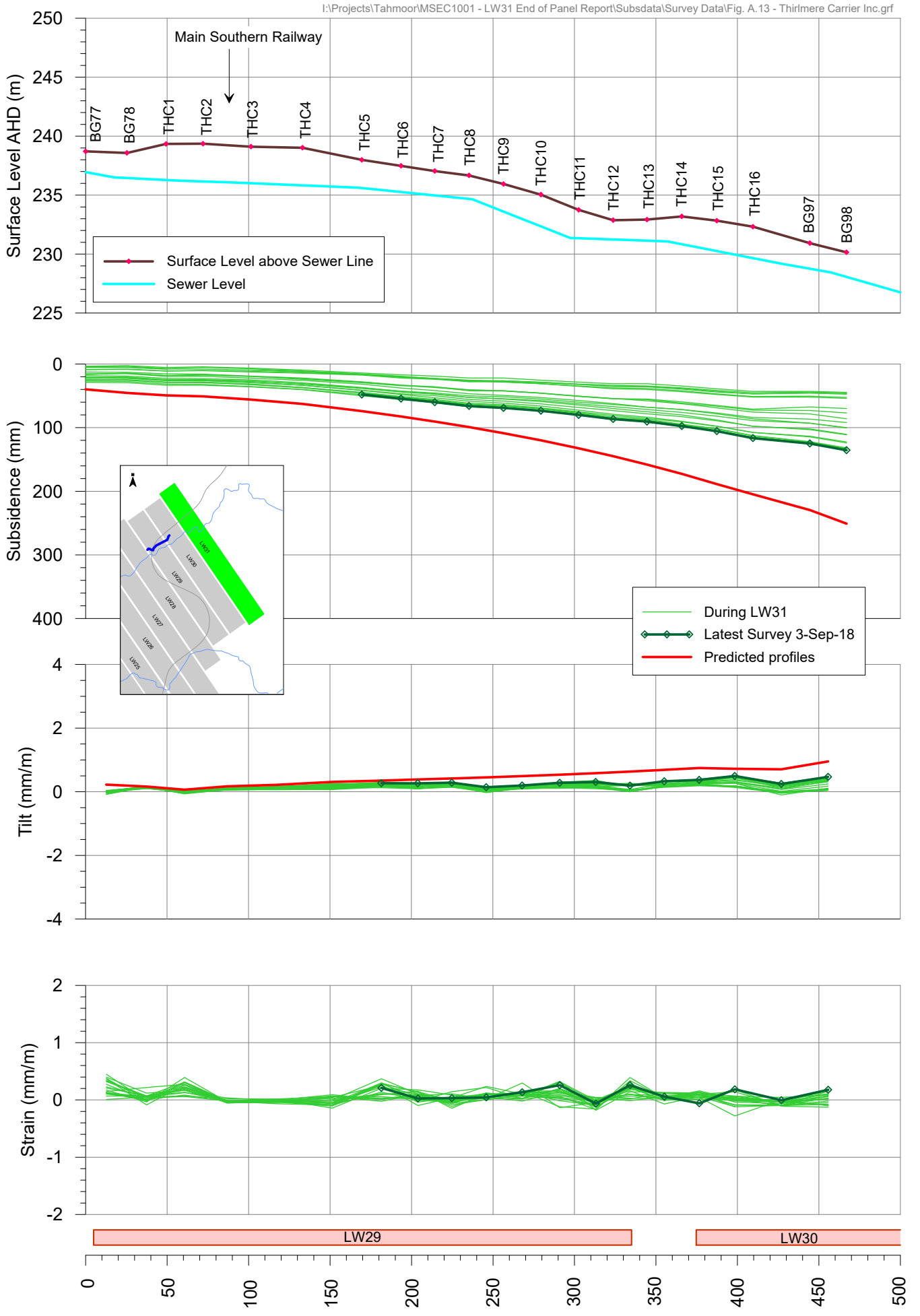

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Fig. A.13

Tahmoor Coking Coal Operations - Longwall 31
Total Subsidence Profiles along Thirlmere Carrier Pipe

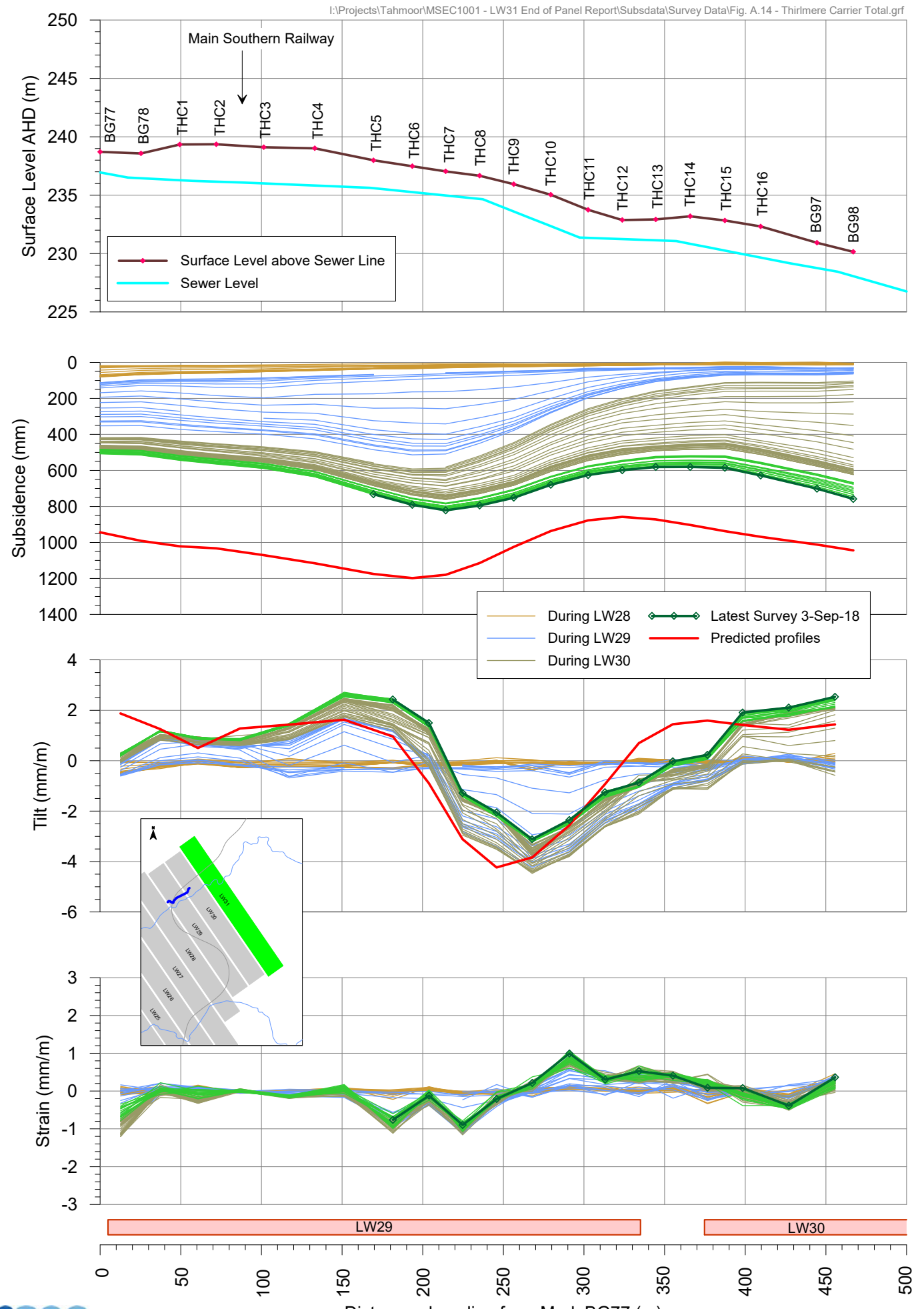

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Fig. A.14

Tahmoor Coking Coal Operations - Longwall 31
Relative 3D surveys along Redbank Creek RK Line (incremental)

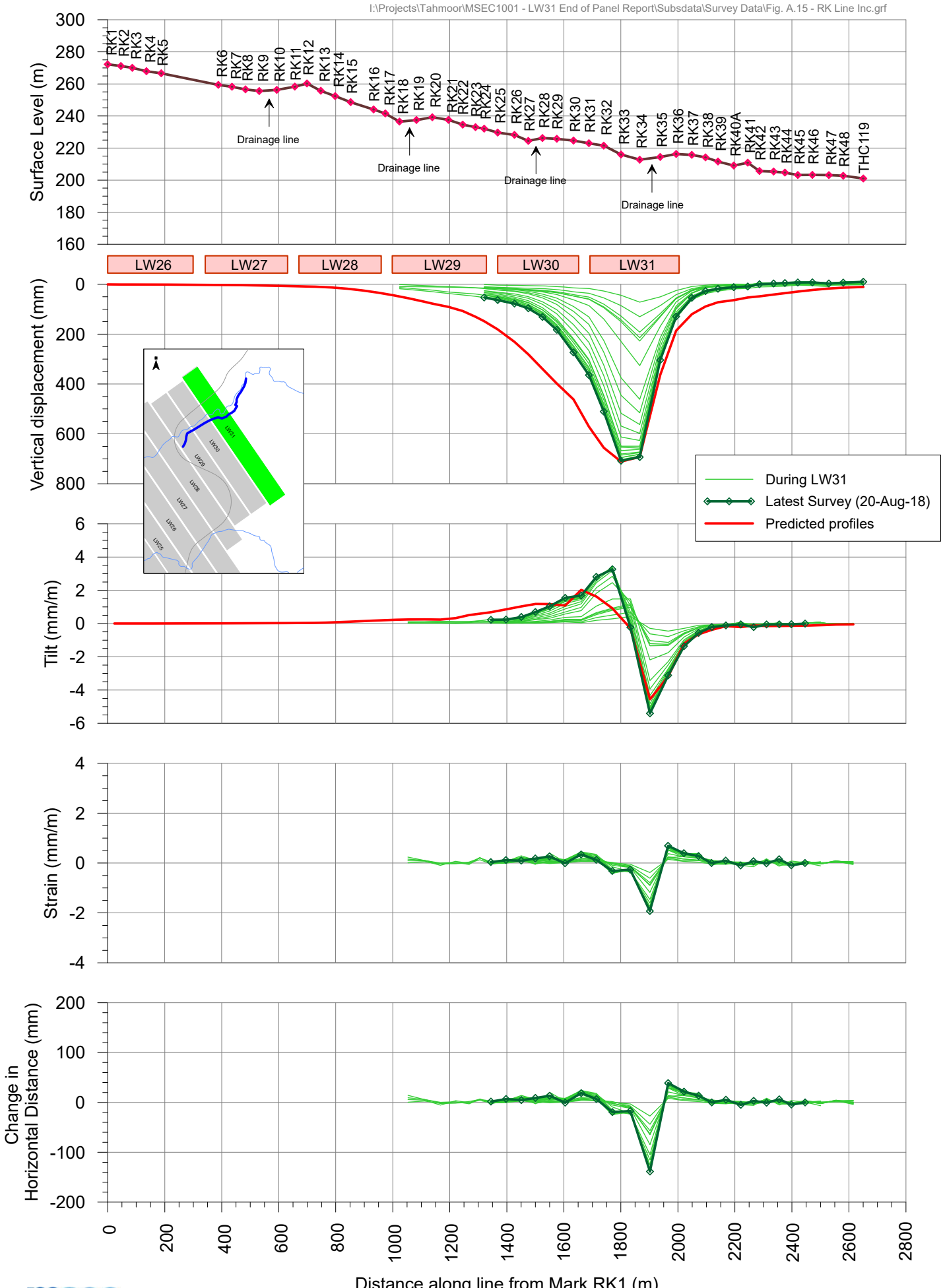

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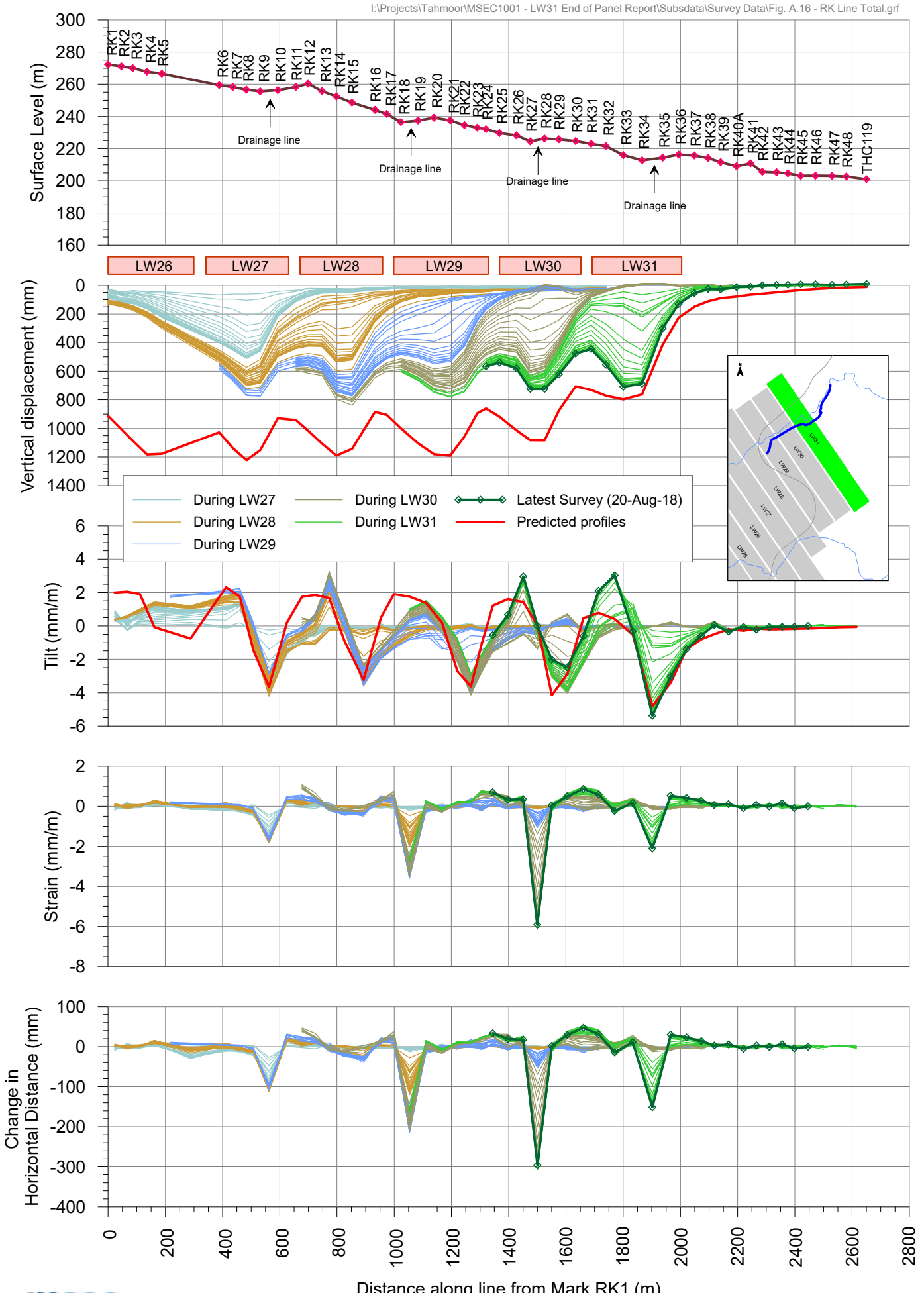
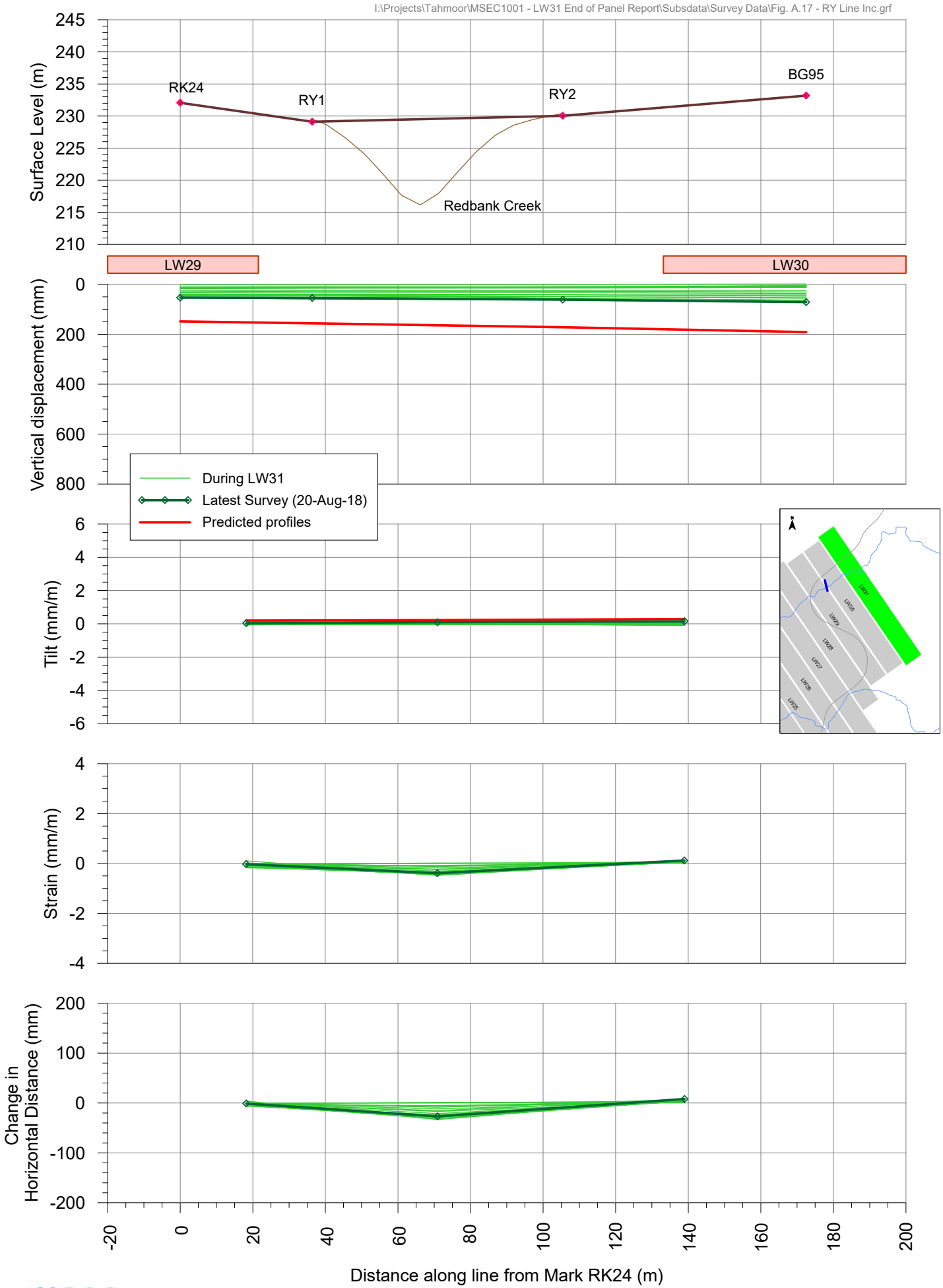
Fig. A.15

Tahmoor Coking Coal Operations - Longwall 31
Relative 3D surveys along Redbank Creek RK Line (total)



Tahmoor Coking Coal Operations - Longwall 31
Relative 3D Surveys along Redbank Creek RY Line (incremental)



msec

Fig. A.17

Tahmoor Coking Coal Operations - Longwall 31
Relative 3D Surveys along Redbank Creek RY Line (total)

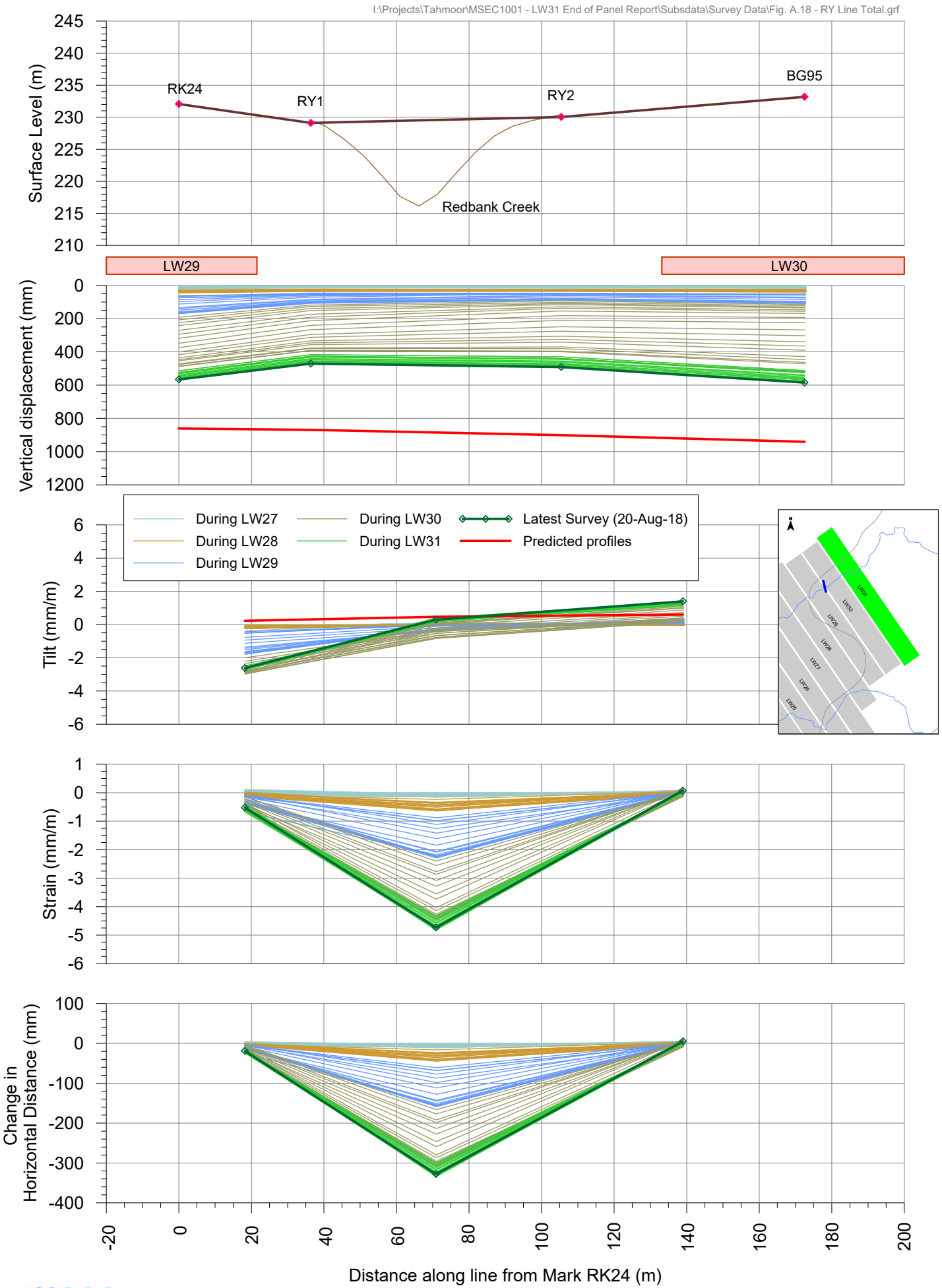
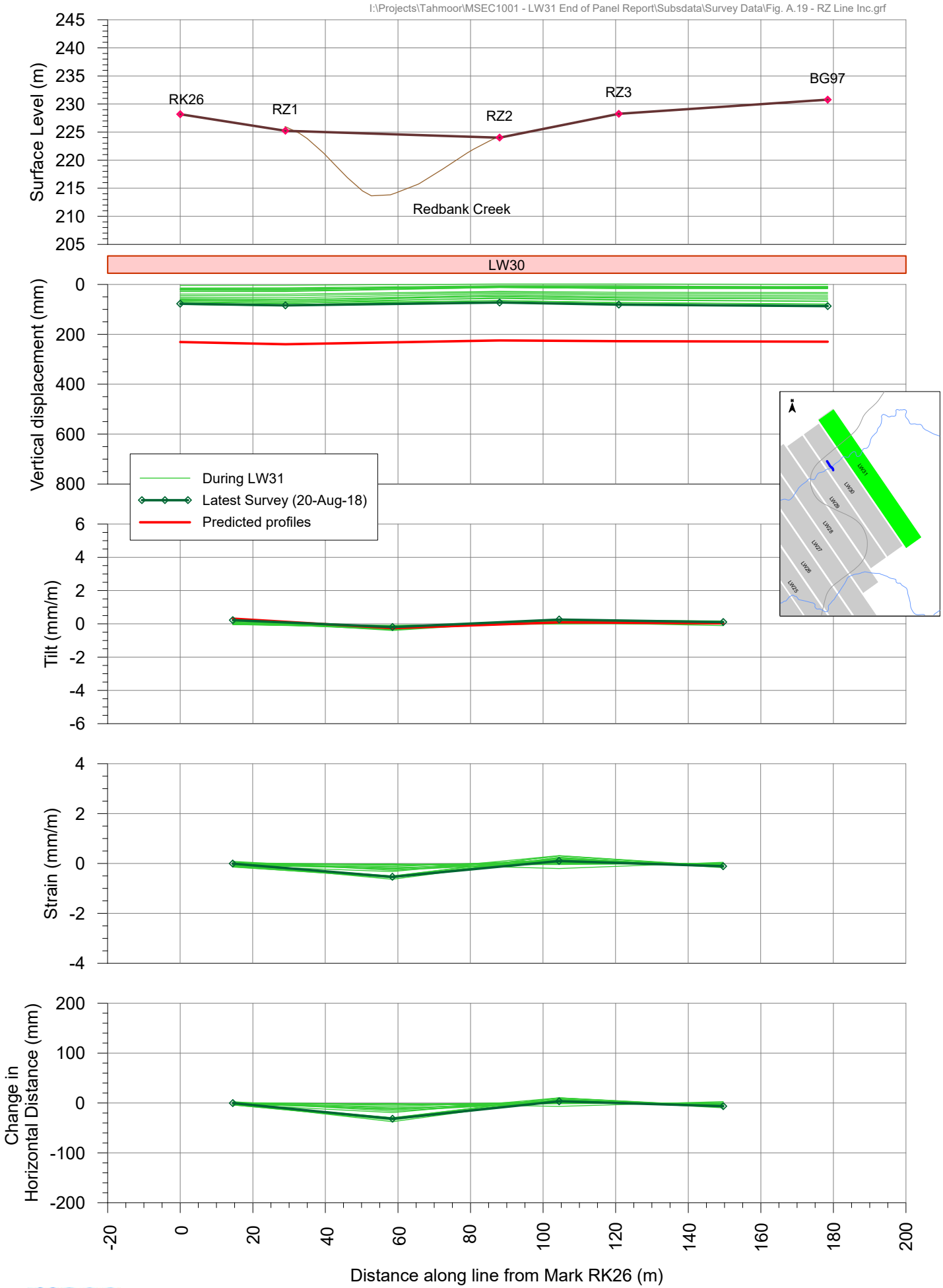


Fig. A.18

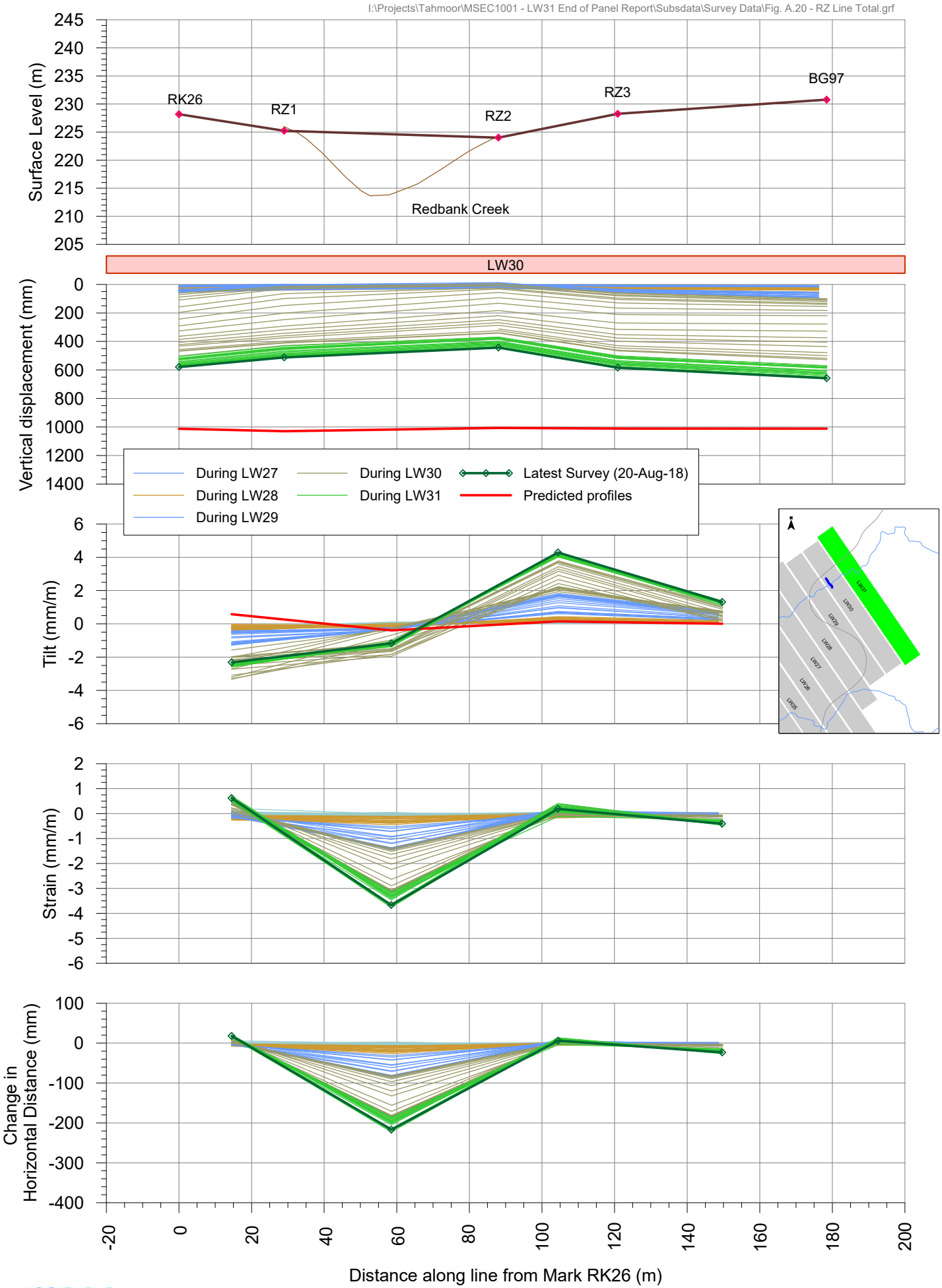
Tahmoor Coking Coal Operations - Longwall 31
Relative 3D Surveys along Redbank Creek RZ Line (incremental)



msec

Fig. A.19

Tahmoor Coking Coal Operations - Longwall 31
Relative 3D Surveys along Redbank Creek RZ Line (total)



msec

Fig. A.20

Tahmoor Coking Coal Operations - Longwall 31
Incremental Subsidence Profiles along Main Southern Railway

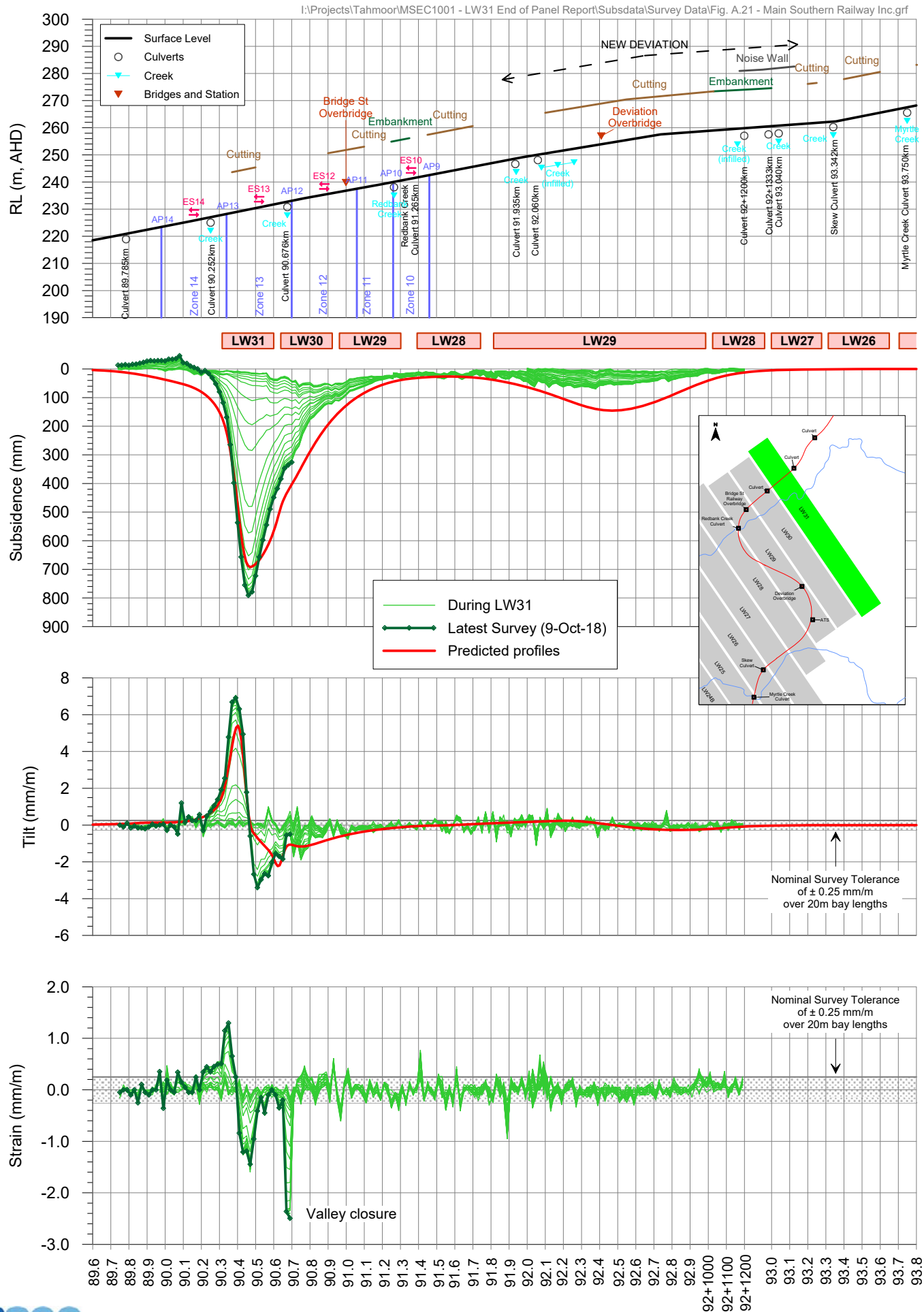


Fig. A.21

Tahmoor Coking Coal Operations - Longwall 31
Total Subsidence Profiles Main Southern Railway

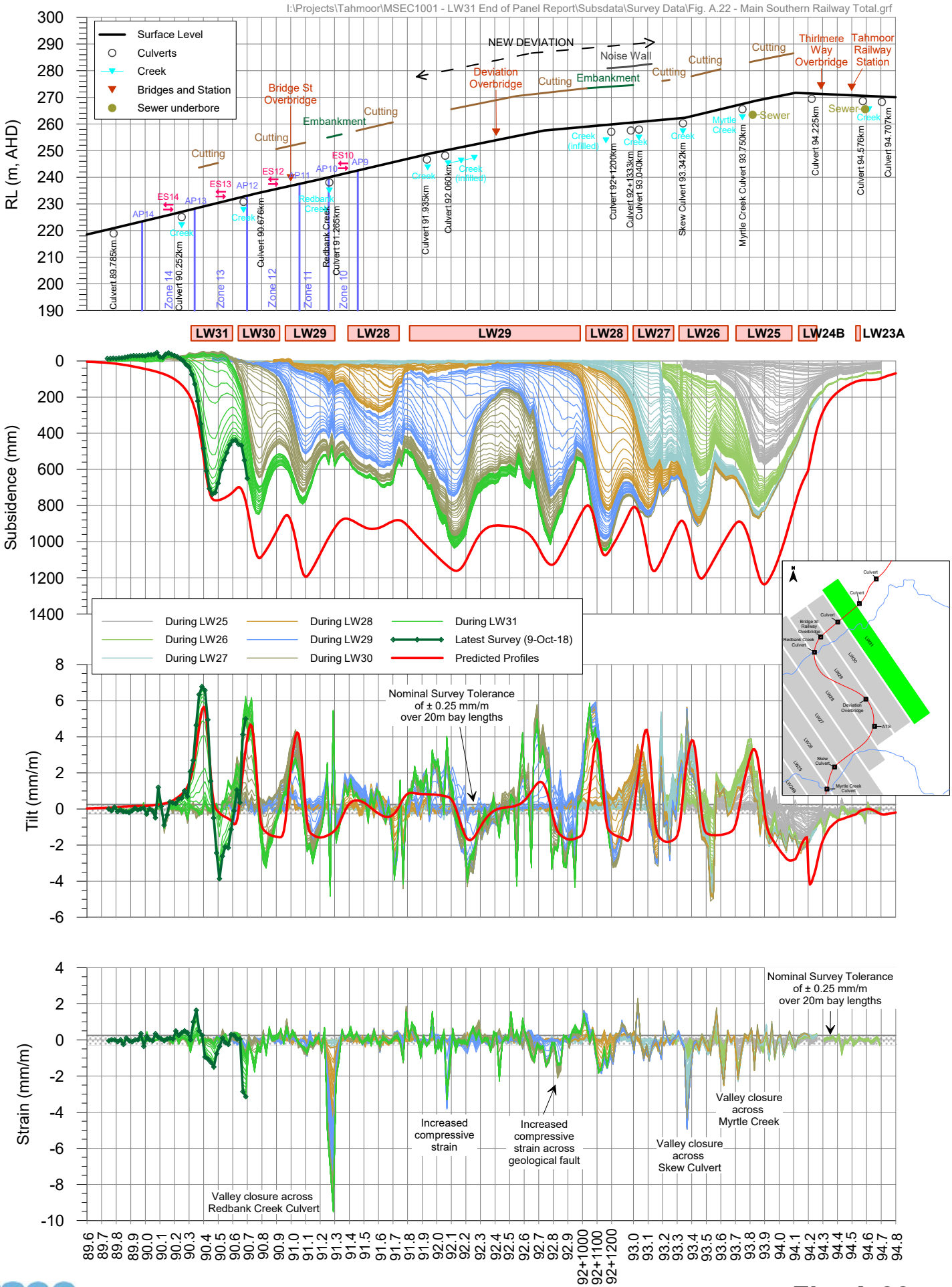


Fig. A.22

APPENDIX B. DRAWINGS

I:\Projects\Tahmoor\MSEC1001 - LW31 End of Panel Report\AcadData\MSEC1001-01 Monitoring LW31.dwg

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

TAHMOOR COKING COAL OPERATIONS

SIMEC MINING Tahmoor Coking Coal

TAHMOOR NORTH - LW31
MONITORING OVER LW31

DATE:	SCALE:	DRAWING No:	Rev No
26 Mar 2019	1:15000	MSEC1001-01	A

277 500 278 000 278 500 279 000

Grid to MGA co-ordinates

6 214 500 6 214 000 6 213 500 6 213 000 6 212 500 6 212 000 6 211 500 6 211 000

THIRLMERE WAY
RUMKER ST
ARGYLE ST
BRIDGE ST
BOLLARD PL
REDBANK PL
REDBANK CREEK
HENRY ST
STILTON LN
REMEMBRANCE DRIVEWAY
MAIN SOUTHERN RAILWAY
MYRTLE CREEK

LW 31
LW 28
LW 30
LW 29
LW 27
LW 26

PREDICTED 20mm SUBSIDENCE CONTOUR DUE TO LW31
35° ANGLE OF DRAW LW31

623338 623348 623344 623346 628465 628632 628573 805777 805778 628027 628623 628482 628485

Refer Railway diagram for details (MSEC863-03)

Dam removed 2016

Myrtle Creek Bridge

LEGEND
- Existing Monitoring Lines
- Future Monitoring Lines
- Surveys During LW31
- Critical Power Poles
- Specific Structure Inspections

Refer to Management Plans for Timing & Frequencies

I:\Projects\Tahmoor\MSEC1001 - LW31 End of Panel Report\AcadData\MSEC1001-02 Redbank Creek Subsidence.dwg

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TAHMOOR COKING COAL OPERATIONS

SIMEC MINING Tahmoor Coking Coal

REDBANK CREEK LINES
OBSERVED INCREMENTAL SUBSIDENCE
AND CHANGES IN HORIZONTAL DISTANCE
DURING LONGWALL 31

DATE:	SCALE:	DRAWING No:	Rev No
11 Mar 2019	Not to Scale	MSEC1001-02	A

Subsidence
72 mm (colour scale as shown)
Change in horizontal distance between survey marks
mm Closure
mm Opening

0 20 50 100 200 300 400 500 600 700 800 900 1000 1200 1400

LW31
LW30
LW29
LW28
BOLLARD PL
REDBANK PL
BRIDGE ST
HENRY ST
STILTON LN
N

I:\Projects\Tahmoor\MSEC1001 - LW31 End of Panel Report\AcadData\MSEC1001-03 Redbank Creek Horizontal Movement.dwg

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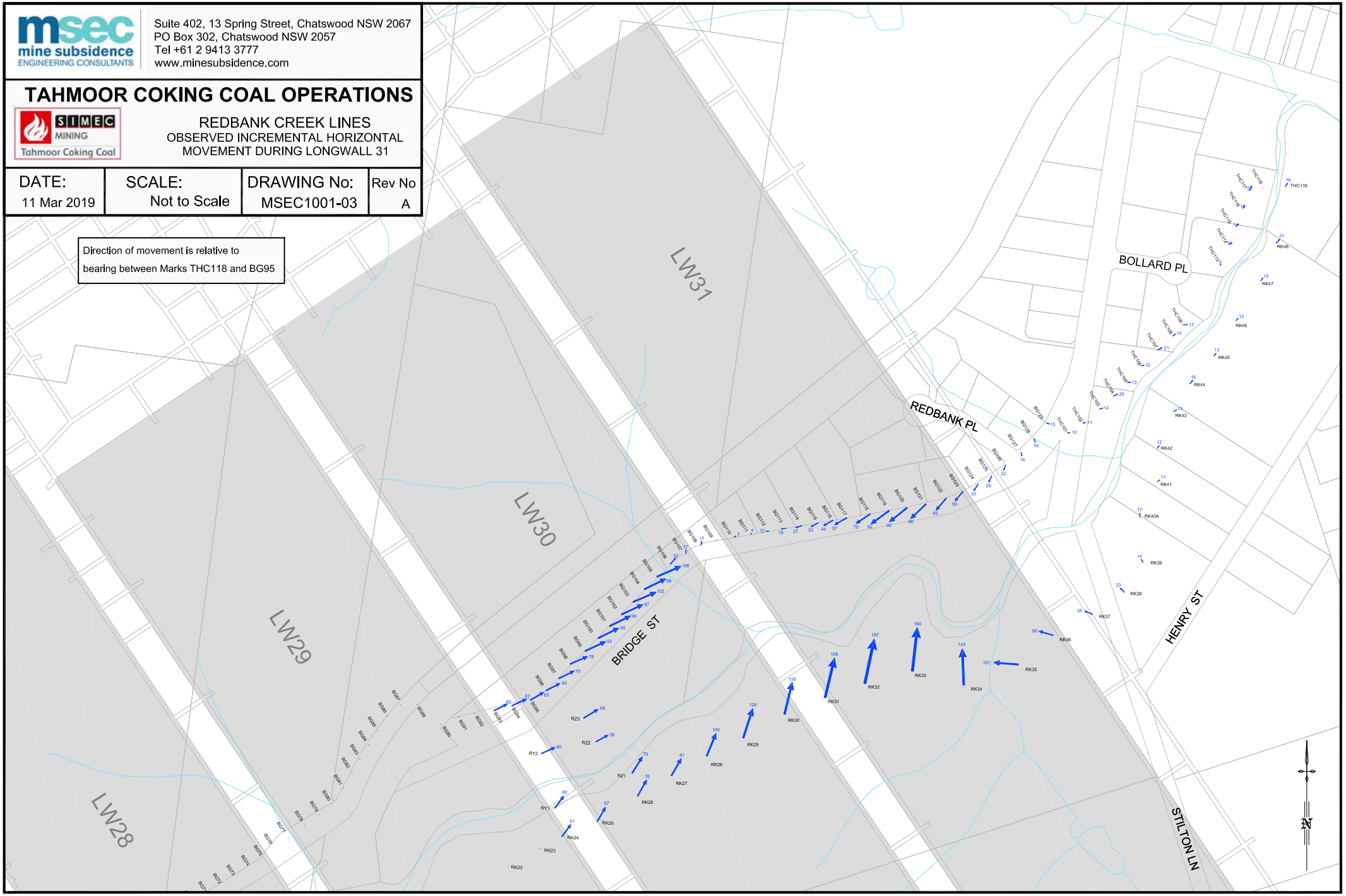
TAHMOOR COKING COAL OPERATIONS

SIMEC MINING
Tahmoor Coking Coal

REDBANK CREEK LINES
OBSERVED INCREMENTAL HORIZONTAL MOVEMENT DURING LONGWALL 31

DATE:	SCALE:	DRAWING No:	Rev No
11 Mar 2019	Not to Scale	MSEC1001-03	A

Direction of movement is relative to bearing between Marks THC118 and BG95



GeoTerra

Tahmoor Colliery

Longwall 31
Surface Water, Dams and Groundwater
End of Panel Monitoring Report

TA31-R1A

21 March, 2019

GeoTerra Pty Ltd ABN 82 117 674 941

PO Box 530 Newtown NSW 2042

Phone: 02 9519 2190 Mobile 0417 003 502 Email: geoterra@iinet.net.au

GeoTerra

Tahmoor Coal Pty Ltd
Tahmoor Underground
PO Box 100
TAHMOOR NSW 2573

Attention: Ron Bush

Ron,

RE: Tahmoor Coking Coal Operations End of Longwall 31 Surface Water, Dams and Groundwater Monitoring Report

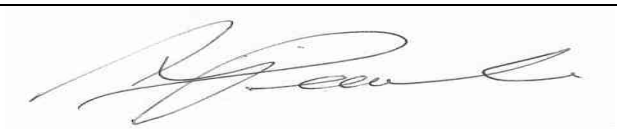
Please find enclosed a copy of the above mentioned report.

Yours faithfully

GeoTerra Pty Ltd

Andrew Dawkins (AuSIMM CP-Env)
Principal Hydrogeologist / Geochemist

Distribution:	Original	GeoTerra Pty Ltd
	1 electronic copy	Tahmoor Colliery
	1 electronic copy	MSEC Pty Ltd

Authorised on behalf of GeoTerra Pty Ltd:	
Name	Andrew Dawkins
Signature	
Position	Principal Hydrogeologist / Geochemist

Date	Rev	Comments
20/03/2019		Initial draft
21/03/2019	A	Incorporate Review Comments

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Executive Summary

The following table summarises the potential and observed effects on Redbank Creek as well as the Tahmoor North dams and groundwater systems within the Longwall 31, 20mm subsidence zone, and the observed effects due to subsidence related to extraction of the subject longwall and previous longwalls.

Potential Impacts	Observed Impacts Due to Extraction of Longwall 31
Surface Water	
Bedrock cracking and loss of plateau stream flow not anticipated in Redbank Creek or smaller gullies over Longwalls 22 to 30 due to mitigating effects of stream sediment cover	Stream bed cracking and loss of pool holding capacity has been observed in pools and stream reaches in Redbank Creek over LW's 25 to 32
No adverse ecological changes to plateau streams due to subsidence	No adverse effect on plateau stream ecology has been reported
Possible localised ponding may occur in plateau streams	No localised stream ponding due to subsidence has been observed
No adverse effects on plateau stream water quality anticipated	Increased salinity OVER AND downstream of the Redbank Creek subsidence zone, particularly at Sites RC3 and RC4, along with elevated iron, Total Nitrogen, Total Phosphorous, copper, zinc, nickel and manganese.
Plateau stream bed incision may occur	No plateau stream bed incision has been observed
Dams	
Subsidence, strain or tilting may cause adverse effects on dam walls or may affect dam storage capability	No dam wall cracking and no adverse effects on dam wall integrity or dam water storage reduction has been reported.
Groundwater	
Adverse interconnection of aquifers and aquitards is not anticipated within 20m of the surface	No adverse interconnection between aquifers and aquitards observed within 20m of the surface
Potential increased rate of recharge into the plateau	No increased rate of recharge into the plateau
Temporary lowering of regional phreatic water levels by up to 10m which may stay at that level until maximum subsidence develops	No lowering of shallow or phreatic open standpipe piezometer water levels greater than 10m due to Longwall 31
Groundwater levels should recover over a few months and no permanent post mining reduction in water levels in bores on the plateau unless a new outflow path develops	Previously depressurised open standpipe piezometers have gradually re-pressurised to similar, albeit lower pre-mining levels
The yield and serviceability in 1 NOW registered bore (P4) may be affected by subsidence	No private bores have been reportedly adversely affected by subsidence associated with Longwall 31
Horizontal displacement may make the private bore inaccessible	No private bores were reported to have been horizontally displaced in the Longwall 22 to 31 subsidence zone

Potential Impacts	Observed Impacts Due to Extraction of Longwall 31
Strata dilation and subsequent re-filling of secondary voids may temporarily lower standing water levels and increase the potential private bore yields	No private bores were reported to have been adversely affected by subsidence impacts associated with extraction of Longwall 31
Private bore groundwater may experience increased iron / manganese hydroxide precipitation and / or lowering of pH	No private bores were reported to have been adversely affected by Fe / Mn precipitates associated with extraction of Longwall 31
Interface drainage, ferruginous, brackish seeps may be generated in streams on the plateau	Increased ferruginous and salinity levels have been observed over Longwall 29 - 32 in Redbank Creek
Increased groundwater seepage inflow into the Bulli Seam workings should not occur	No increase in groundwater inflow to the mine
Strata gas discharge into private bores may occur	No strata gas discharge into private bores has occurred

1. INTRODUCTION

Tahmoor Coking Coal Operations (TCCO) has extracted the Bulli Seam in Longwalls 22, 23A, 23B, 24A, 24B and 25 to 31 by retreat mining within the Tahmoor North Lease Area since June 2004.

The previous and current longwall (Longwall 32) are located underneath Tahmoor and Thirlmere villages, as well as surrounding urban and semi-rural areas as shown in **Drawing 1,** which are approximately 4 kilometres (km) south of Picton in the Southern Coalfield of NSW.

This report provides a compilation of physical and geochemical groundwater, as well as Redbank Creek and catchment dam monitoring that has been conducted, and observation of any subsidence related changes that have occurred since August 2004, up to and including the extraction of Longwall 31.

Surface water and groundwater features within the Longwall 31, 20mm subsidence zone include:

- the main channel and tributaries of Redbank Creek, which flows ENE into Stonequarry Creek and subsequently, the Nepean River;
- the northern headwater tributaries of Matthews Creek, which flows to the northeast and joins with Cedar Creek and Stonequarry Creek, then into Racecourse Creek and subsequently the Nepean River;
- 15 generally small and 2 large earthen wall dams that directly overly Longwall 31, and;
- Four vibrating wire piezometer arrays (VWP) in bores TNC28 and TNC29 (now decommissioned) as well as TNC43 and P9(VWP), one open standpipe piezometer (P9) and one licensed private bores (GW105813 - Koorana).

Redbank Creek is a Category 2 stream with a 3rd order or higher channel, whilst its tributaries are Category 1 streams, being 1st or 2nd order channels.

Monitoring has been conducted since June 2004 by assessing the;

- ephemeral or perennial nature and flow in streams over the panels;
- creek bed and bank erosion and channel bedload;
- stream and dam water quality;
- stream bed and bank vegetation;
- nature of alluvial land along stream banks;
- presence, size and integrity of dams and their water levels,
- presence and use of groundwater bores, and;
- assessment of standing water levels and water quality.

2. PREVIOUS STUDIES

An assessment of potential subsidence levels and impacts for Longwalls 27 to 30 was studied by MSEC (2009).

Assessment of the baseline characteristics and prediction of possible subsidence related effects on the surface water and groundwater system were assessed for Longwalls 27 to 30 by GeoTerra (2009).

Surface water and groundwater monitoring End of Panel reports have been prepared for Longwalls 22, 23A, 23B, 24A, 24B and 25 to 30 by GeoTerra Pty Ltd.

Ongoing monitoring of water levels, flows and water quality in the plateau streams and groundwater bores is being conducted throughout extraction of Panel 32 by colliery staff, GeoTerra Pty Ltd and Hydrometric Consulting Systems Pty Ltd (HCS) in accordance with procedures outlined in GeoTerra (2013).

3. GENERAL DESCRIPTION

3.1 Mine Layout and Progression

Tahmoor Colliery has extracted coal by longwall mining Panels 1 to 31 to the south, southwest and northwest of the current panel (Longwall 32).

Longwall 31 commenced on 28 June 2017 and was completed on 17th August, 2018 as outlined in **Table 1**, with Longwall 32 extraction continuing updip in the Bulli Seam from south to north.

Table 1 Panel Extraction Details

Panel	Start	Finish	Length (m)	Depth of Cover (mbgl)
22	02/06/04	11/07/05	1877	420 – 432
23A	07/09/05	20/02/06	776	430 – 450
23B	15/03/06	21/08/06	771	430 – 440
24B	15/10/06	26/08/07	2072	430 – 440
24A	15/11/07	190/7/08	983	420 - 448
25	22/08/08	27/02/11	3730	440 - 460
26	30/03/11	11/10/12	3480	440 - 470
27	10/11/12	22/03/14	3030	420 - 495
28	20/04/14	01/05/15	2629	420 - 500
29	29/05/15	03/04/16	2322	425 - 490
30	20/6/16	15/05/17	2322	425 - 490
31	28/06/17	17/08/2018	2450	450 - 500
32	1/11/18	currently mining	2500	450 - 500

Extraction of Panel 31 occurred from 450 - 500m below surface with a seam thickness of approximately 2.1m.

Longwall 31 was 283m wide rib to rib, with a 39m wide chain pillar and approximately 2450m long as shown in **Drawing 1**.

3.2 Topography and Drainage

The plateau is generally flat to undulating and incised by the Bargo River gorge which is up to 104m deep in the Longwalls 22 to 28 (20mm subsidence area) with steep to vertical sandstone cliff faces and vegetated scree slopes, whilst the gorge and river bed comprise a series of exposed sandstone shelves interspersed with sandstone boulder fields and pools.

The Longwall 22 to 31, 20mm subsidence area also contains the main channel and tributaries of Myrtle and Redbank Creeks, which flow both to the Nepean River, with the Bargo River being approximately 2,490m to the south, whilst the Nepean River is approximately 1,340m south east of Longwall 31.

Both Myrtle and Redbank Creeks drain the residential areas of Tahmoor and Thirlmere, as well as semi-rural fallow, orchard and grazing areas outside of the villages.

3.2.1 Bargo River

The Bargo River is present in the south-eastern part of the Longwall 22 to 28 monitoring area, which covers approximately 1,130m of the river bed, with the closest panel (24A) being at least 289m from the edge of the gorge and 354m from the centre of the river.

The Bargo River over Longwalls 12 and 13 has previously sustained up to 550mm of subsidence, 2mm/m of tensile and 3mm/m of compressive strain in the “potholes” area and Rockford Road Bridge (GeoTerra, 2006) where the gorge was directly undermined.

The Bargo River and its associated gorge is outside the Longwall 31, 20mm subsidence zone, and is not discussed further in this report.

3.2.2 Myrtle Creek

Myrtle Creek is approximately 550m south of Longwall 31.

Its headwaters are located upstream of Longwall 22 and generally consist of small grass covered channels that become larger and more incised downstream of Longwalls 23 to 30.

Myrtle Creek has been undermined by Longwalls 4, 22, 23B, 24B and 25 to 28, whilst Longwalls 29 to 31 did not undermine the creek.

The riparian flanks have been significantly altered by residential development in Tahmoor, whilst the channel has not been significantly affected except where general rubbish or solid waste has been dumped in the creek or it is overgrown by invasive weeds. Some isolated weeding and stream bank regeneration works have been conducted, however many of the areas are re-infested with weeds.

The stream bed and banks are generally well vegetated, and do not show significant erosion or bank instability.

No Water NSW registered water extraction is listed within the creek, however an unlicensed pump was present over the middle of Longwall 25, off Castlereagh Street.

Myrtle Creek is outside the Longwall 31, 20mm subsidence zone, and is not discussed further in this report.

3.2.3 Redbank Creek

Redbank Creek drains into Stonequarry Creek, which subsequently flows to the Nepean River approximately 1.2km downstream of the monitoring area.

Redbank Creek has been undermined by Longwalls 25 to 31.

Within the monitoring area the creek has a reasonably incised, narrow (<10m wide) channel with a wetland upstream of Longwall 23.

The creek overlies the western end of Longwall 25 as a small channel with an incised bed 1m to 2m deep which evolves into a channel up to 3m deep and 10m wide downstream of Longwall 26.

The Redbank Creek channel becomes sequentially deeper and wider over Longwall 27, and subsequently is additionally wider and deeper over Longwalls 28 to 31.

The headwaters of Redbank Creek, outside of the monitoring area, lie within the residential development area of Thirlmere, with housing and road development significantly affecting the banks of the creek.

In the vicinity of Longwalls 25 to 31, the creek flows out of the Thirlmere residential area, into the downstream urban fringe and through the Thirlmere Industrial Estate.

The creek does not exhibit significant bed and bank erosion and is not significantly eroded due to the high vegetative and weed cover as well as exposed sandstone rock bars and shelves along the creek.

Areas of iron hydroxide precipitation that pre-existed mining related subsidence in Redbank Creek were observed in the reach between Redbank Creek Sites 24 and 25, as well as sites 30 to 37 (a.k.a. RC2 and R6) and downstream to RR29 over Longwall 32.

3.2.4 Dams

Surface runoff into the local streams and subsequently, the Bargo or Nepean Rivers is regulated by 17 dams that directly overly Longwall 31 or its chain pillars as shown in **Drawing 1**.

The dams are constructed of earthen walls that collect and store surface runoff that would otherwise drain directly into Redbank or Myrtle Creeks.

3.2.5 Geology

The Bargo River gorge is underlain by the fine to medium to coarse grained Hawkesbury Sandstone, with Wianamatta Shale outcrop present in the headwaters and mid-stream of Myrtle Creek and Redbank Creek, which transgresses to Hawkesbury Sandstone further downstream as shown in **Figure 1**.

Further details on the area's geology structure and stratigraphy are outlined in (GeoTerra, 2006).

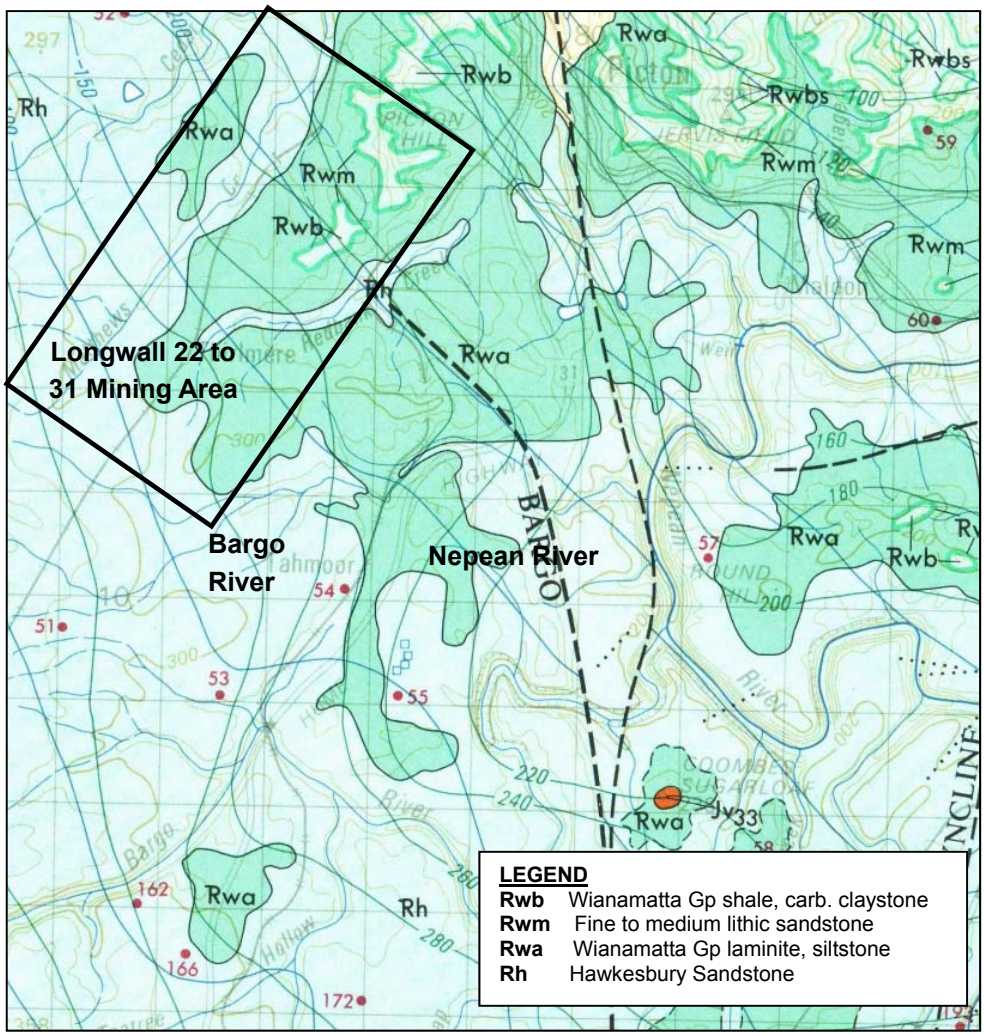


Figure 1 Surficial Geology

3.3 Hydrogeology

The Bargo River is a 'gaining' system, where groundwater flows from the plateau under a regional hydraulic gradient to the river, with groundwater flow being dominantly horizontal within confined flow along discrete layers that are underlain by fine grained or relatively impermeable strata.

The Hawkesbury Sandstone sequence exposed in the gorge is characteristic of sedimentary deposition and erosion in a braided stream with individual facies representing local sedimentary processes that generally do not persist across the area.

The Hawkesbury Sandstone within the Sydney Basin generally provides low yielding aquifers with low hydraulic conductivities.

Eight Water NSW registered private bores, two uncased coal exploration bores and fifteen registered piezometers are located within the Longwall 22 to 31 monitoring area as shown in **Drawing 1** and **Table 2**.

Open standpipe piezometers P9A, P9B and P9C are installed adjacent to Redbank Creek and overly Longwall 31 and the Longwall 31 / 32 chain pillar, whilst P10A, B and P10C are also located adjacent to Redbank Creek, immediately to the north of Longwall 32.

P9B and P9C were installed in November 2018 to replace the VWP intakes that failed at the same depths when the P9 VWP array was undermined by Longwall 31.

Piezometer P11 was installed in November 2018 adjacent to Redbank Creek approximately 330m downstream of the Longwall 32 tailgate edge.

Table 2 Monitoring Bores and Open Standpipe Piezometers

GW	Drilled	Depth (m)	SWL (m)	Aquifer (mbgl)	YIELD (L/s)	Purpose
SMP Area						
P1 (GW106281)	2004	48	Fig 7	18 - 20	0.75	monitoring
P2	-	150	Fig 7	-	n/a	coal exploration
P3	-	100	Fig 7	-	n/a	coal exploration
P4 (GW67570)	1988	85	Fig 7	-	0.22	domestic
P5 (GW63525)	1954 / 1990	76 / 91	Fig 7	60-66 & 70-91	1.0	stock domestic irrigation
P6 (GW42788)	1976	148	Fig 7	105 - 135	1.52	agriculture
P7 (GW110435)	2008	100	Fig 7	95 - 100	0.76	monitoring
P8 (GW110436)	2008	105	Fig 7	90 - 105	V low	monitoring
P9A	2017	23	Fig 7	18 - 23	+20L/sec	monitoring
P9B	2018	28	Fig 7	18 - 28	n/a	monitoring
P9C	2018	40	Fig 7	18 - 40	n/a	monitoring
P10A	2018	29	Fig 7	24 - 74	n/a	monitoring
P10B	2018	44	Fig 7	24 - 74	n/a	monitoring
P10C	2018	74	Fig 7	24 - 74	n/a	monitoring
P11	2018	29	Fig 7	22 - 29	n/a	monitoring
McPhee (GW105254)	2002	163	80.0	113 - 156	0.67	domestic
Koorana (GW105813)	2003	168	28	114 – 115 146 - 147 160 - 161	6.6	stock / domestic
Pescud (GW109010)	2008	169	89	n.a.	0.8	stock domestic
Boissery (GW109224)	2008	132	60	n.a.	1.0	domestic
Machin (GW107918)	2007	60	42.49	40 - 48	2.2	domestic

Note: All bore water supply is from Hawkesbury Sandstone.
redrill depth for bore replaced by Tahmoor Colliery
- no data available

Groundwater has been obtained from sandstone aquifers with yields ranging from 0.2L/sec to 5.0L/sec between 18m and 138m below surface.

Water NSW bore data indicates it is likely that significant aquifers are intersected below depths of approximately 18m to 60m, depending on whether the bore is spudded on top of a hill or in a valley. Shallower, low yielding groundwater may be present above that depth range as perched ephemeral aquifers.

Alluvial sediments within the plateau gullies and river bed are too shallow to be used as aquifers for groundwater supply.

3.3.1 Vibrating Wire Piezometer Arrays

One cement / bentonite sealed exploration bore (TNC29) was installed with vibrating wire piezometer (VWP) arrays over Longwall 30, whilst TNC28 was installed over Longwall 29.

Both of these arrays have now been decommissioned as they have been undermined and cracked and due to VWP arrays being a potential electrical hazard to the underground workings

Three VWP arrays (TNC36, 40 and 43) are located to the east and north of Longwall 31 as shown in **Drawing 1** and **Table 3**.

Readings from the VWP intakes at P9B (28mbgl) and P9C (38mbgl) were discontinued on 19th May 2018 due to shearing of the bore following undermining by Longwall 31, whilst P9D (68mbgl) monitoring has continued.

Table 3 Tahmoor North Vibrating Wire Piezometer Installation

Piezometer	Intake Depth (mbgl)	Formation	Piezometer	Intake Depth (mbgl)	Formation
TNC36	65	Hawkesbury Sandstone	TNC40	27	Wianamatta Shale
	97	Hawkesbury Sandstone		65	Hawkesbury Sandstone
	169	Colo Vale Sandstone		131	Hawkesbury Sandstone
	214	Colo Vale Sandstone		225	Hawkesbury Sandstone
	298.5	Colo Vale Sandstone		352	Bulgo Sandstone
	412.5	Colo Vale Sandstone		452	Bulgo Sandstone
	463.5	Bulli Seam		501.9	Bulli Seam
TNC43	65	Hawkesbury Sandstone	P9 (VWP)	(B) 28	Hawkesbury Sandstone
	111.5	Hawkesbury Sandstone		(C) 38	Hawkesbury Sandstone
	213	Hawkesbury Sandstone		(D) 68	Hawkesbury Sandstone
	240	Bulgo Sandstone			
	332.6	Bulgo Sandstone			
	425.2	Bulgo Sandstone			
	476.3	Bulli Seam			

3.4 Subsidence

The maximum monitored subsidence, tilt and strain following the completion of extraction of Longwall 31 is shown in **Table 4**.

Table 4 Maximum Subsidence at the Completion of Longwall 31

Component	Observed Total Movement
Vertical subsidence	1070 mm
Tilt	8.2 mm/m
Tensile / Compressive Strain	4.6 / -4.5 mm/m

3.4.1 Redbank Creek

The ability to survey valley closure across the creek has been constrained due to refusal by landowners to provide access, with no available access on the northern bank and limited access on the southern bank (MSEC, 2019), with the available survey data (accurate to approximately 20 – 30mm) shown in **Table 5**.

Valley closure was slightly greater for a temporary period of time when the transient effects of the subsidence travelling wave passed through the valley, with the maximum incremental valley closure due to Longwall 31 equalling 152mm.

Table 5 Maximum Redbank Creek Valley Closure up to Completion of LW31 (mm)

	After LW26	After LW27	After LW28	After LW29	After LW30	After LW31
Valley Closure (mm)	151	233	276	350	420	450

Source (MSEC, 2019)

3.5 Redbank Creek Monitoring

3.5.1 Water Level and Chemistry Monitoring Site Descriptions

Stream water level, and subsequently stream flow monitoring, as well as field chemistry and laboratory analysis of water samples has been conducted in Redbank Creek since April 2005 at the sites summarised in **Table 6** and shown in **Drawing 1**.

Table 6 Redbank Creek Water Level and / or Chemistry Monitoring Locations

Site	Description	Monitored Parameters
RC1	Off the end of Windeyer Street	field and laboratory chem, bedrock cracking / pool depth
RC2	Downstream of Railway bridge	field and laboratory chem, bedrock cracking / pool depth
RC3	Cement works weir	field and laboratory chem, bedrock cracking / pool depth
RC4	End of Bollard Place	field and laboratory chem, bedrock cracking / pool depth
RC5	Remembrance Drive culvert	field and laboratory chem, bedrock cracking / pool depth
RC6	Downstream of Council swimming pool	field and laboratory chem, bedrock cracking / pool depth
R1	Downstream of Turner Street bridge	Weir plate
R2	End of Windeya Street	Rock bar pool depth and flow
R3	350m downstream of R2	Rock bar pool depth and flow
R4	Upstream of railway culvert	Rock bar pool depth and flow
R5	Downstream of railway culvert	Rock bar pool depth and flow
R6	Downstream of R5 near RC2	Rock / gravel pool depth and flow
R7	Adjacent to Bridge Street	Rock bar pool depth and flow
R8	Downstream of R6	Rock bar pool depth and flow
R9	Access from old Highway thru Picton	Weir plate
R10	Between Nepean Conveyors and Site 9	Rock bar pool depth and flow
R11	Behind Nepean Conveyors	Rock bar pool depth and flow

Weekly monitoring of Redbank Creek over Longwalls 30, 31 and 32 commenced on 14th March 2018 and continued until 29th August 2018 at the observation sites shown in **Tables 7** and **8**.

Bi-monthly monitoring of the creek was conducted before and after this period.

Redbank Creek was first undermined by Longwall 31 on approximately the 3rd April, 2018.

Table 7 LW31 Redbank Creek Weekly Monitoring Sites

Site	Description	Additional Sites
RR7	long sandstone race with ferruginous rock shelf pools	R7
RR8	shallow sandstone race with ferruginous rock shelf pools	
RR9	shallow sandstone race with ferruginous rock shelf pools	
RR10	shallow sandstone race with ferruginous rock shelf pools	
RR11	shallow sandstone race with ferruginous rock shelf pools	
RRS12	extended sandstone rock shelf with ferruginous overflow	
RW13	<0.5m high sandstone rock step / waterfall constrained pool	
RB14	boulder constrained shallow ferruginous rock pool	
RR15	shallow sandstone race with ferruginous rock shelf pools	
RR16	shallow sandstone race with ferruginous rock shelf pools	
RB17	boulder constrained shallow ferruginous rock pool	
RR18	shallow sandstone race with ferruginous rock shelf pools	
RR19	shallow sandstone race with ferruginous rock shelf pools	R8
RR20	shallow sandstone race with ferruginous rock shelf pools	
RR21	shallow sandstone race with ferruginous rock shelf pools	
RR22	shallow sandstone race with ferruginous rock shelf pools	
RR23	shallow sandstone race with ferruginous rock shelf pools	
RR24	shallow sandstone race with ferruginous rock shelf pools	
RR25	rock bar constrained ferruginous pool	
Weir26	Long ferruginous pool regulated by a 1.5m high concrete weir	RC3 / R9
RR27	rock bar constrained ferruginous pool	
RB28	rock bar constrained ferruginous pool	
RR29	rock bar constrained ferruginous pool	
RR30	rock bar constrained ferruginous pool	R10
RR31	rock bar constrained ferruginous pool	
RB32	rock bar constrained ferruginous pool	

RB33	Boulder / rock bar constrained ferruginous pool	RC4

NOTE: RR= Redbank Ck rock bar constrained pool RB = boulder pool RRS = rock shelf RW = waterfall

3.5.2 Pre Longwall 31 Creek Subsidence Observations

Subsidence effects observed due to extraction of Longwall 31 (i.e. prior to early April 2018, when Longwall 31 first undermined Redbank Creek) at the following sites included;

Over Longwall 25

- 4 to 9 – pool desiccation in a clay incised section of the creek with cobbles and limited exposed sandstone rockbars.

Over Longwall 26

- 12 to 13 – sandstone stream bed cracking, with no obvious effect on pool holding capacity;
- 14 to 14a - pool desiccation in a cobble / sandstone based section;
- 15 to 17 - pool desiccation in sandstone based pools; and
- 17a to 19 - pool desiccation in cobble / sandstone based pools.

Over Longwall 27

- 21 to 21a - pool desiccation in sandstone based pools;
- 22 - pool desiccation in a cobble / sandstone based section;
- 22a to 23 – significant cracking and pool desiccation in sandstone based pools;
- 24 to 25 – pool desiccation with significant iron hydroxide in cobble / sandstone based pools;
- 25a to 26 - significant cracking and pool desiccation in sandstone based pools;

Over Longwall 28

- 26a to 28 - pool desiccation in sandstone based pools, and
- 29 – reduced flow over sandstone rock shelf.
- 30 to 34 – drying up of previously ferruginous pools in boulder and rock bar pools.

Over Longwall 29

- 35 to 37 and RB3 to RB5 – reduced pool level or drying up of previously ferruginous pools in boulder and rock bar pools.

Over Longwall 30

- Sites RB6 to RR11 – with additional cracking of rock shelves and total drying up of the pools outside of storm flow periods;
- partial drying up (without obvious cracking) at RRS12;
- partial drying up of the RW13 pool;

Over Longwall 31

- new cracking, without flow impacts at RR23, RR24;
- new cracking and reduced flow impacts at RB25;
- new cracking downstream of the Weir 26 concrete weir, without flow impacts, and;
- new cracking, without flow impacts at RR27 and RB28 over the Longwall 31 / 32 chain pillar

3.5.3 Post Longwall 31 Creek Subsidence Observations

After undermining by Longwall 31 in April 2018, Redbank Creek was observed to have undergone subsidence effects as summarised in **Table 8**.

In addition to the sites over Longwall 31 that had previously been affected by Longwall 30, subsidence (or additional subsidence) effects were observed:

Over Longwall 31

- no new sites

Over Longwall 32

- rock bar delamination and uplift at RR29, with pool level reduction, and;
- pool level reduction, without obvious cracking at RR30, RR31, RB32 and RC4.

Table 8 Redbank Creek Subsidence Effects During and After LW31 Extraction

Site	Relative Location	Effect	Date Initially Observed	TARP First Triggered
Over Longwall 30				
RR8	tailgate	cracking and drying up of long shallow sandstone race with ferrug. rock shelf pools without cracks	cracks 30/12/15 pool dry 28/1/16	31/5/16
RR9	tailgate	cracking / delamination and drying up of rock shelf / race with ferruginous pools	cracks 17/12/15 pool dry 13/1/16	18/2/16
R7 / RR10	tailgate / centre	cracking and drying up of rock shelf / race with ferruginous pools	cracks 7/1/16 pool dry 28/1/16	31/5/16 (R10) 27/3/17 (R7,8,9)
RR11	centre	drying up (without obvious cracking) of rock shelf / race with ferruginous pools	cracks 7/1/16 pool dry 28/1/16	27/3/17
RRS12	centre	partial drying (without obvious cracking) of extended rock shelf with overland ferruginous flow	pool dry 1/2/17	27/3/17
RW13	centre	reduction of pool level downstream of <0.5m high rock face / waterfall	pool reduced 1/2/17	15/6/18
RB14	centre - maingate	cracking and partial drying up of ferruginous pool	pool reduced 1/2/17	24/5/18
RR15	maingate	cracking and partial drying up of extended rock based ferruginous pool	cracks / pool reduced, 9/3/17	28/6/18
RR16	chain pillar	rock bar dry, pool very low, no obvious cracks	rock bar dry, pool very low, no obvious cracks 18/4/18	21/6/18
Over Longwall 31				
RB17	tailgate	pool very low to dry, cracked	pool very low to dry, no obvious cracks 18/4/18	5/7/18
RR18	tailgate	pool dry, cracked	pool dry, no obvious cracks 18/4/18	28/6/18
RR19	tailgate	pool dry, cracked	pool dry, no obvious cracks 18/4/18	28/6/18
RR20	tailgate / centre	pool dry, cracked	pool dry, no obvious cracks 18/4/18	24/5/18

Site	Relative Location	Effect	Date Initially Observed	TARP First Triggered
RR21	tailgate / centre	pool dry, cracked	pool dry, no obvious cracks 18/4/18	24/5/18
RR22	tailgate / centre	pool dry, cracked	pool dry, no obvious cracks 18/4/18	24/5/18
RR23	centre	cracking and partial drying up of extended rock based ferruginous pool	cracks / pool reduced 9/3/17	15/6/18
RR24	centre	cracking and partial drying up of extended rock based ferruginous pool	cracks / pool reduced 9/3/17	21/6/18
RR25	centre	cracking and partial drying up of rock bar constrained ferruginous pool	cracks / pool reduced 9/3/17	21/6/18
Weir26 / RC3	centre - maingate	Partial level reduction of ferruginous weir constrained pool	cracks / pool reduced 9/3/17	24/5/18
RR27	maingate	cracking without flow impacts in ferruginous pool	cracks 9/3/17	15/6/18
Over Longwall 32				
RR28	LW31 / 32 chain pillar	cracking without flow impacts in ferruginous pool	cracks 02/03/17	28/6/18
RR29	Tailgate LW32	Pool low, cracking, significant strata delamination	Pool v low, strata delam, 18/4/18	7/6/18
RR30	centre	Reduced pool level , no cracking	Pool medium depth, no cracks 18/4/18	–
RR31	Centre / maingate	Reduced pool level , no cracking	pool dry, no obvious cracks 27/4/18	–
RB32	Chain pillar	Reduced pool level , no cracking	pool dry, no obvious cracks 18/4/18	–
RB33 / RC4	Dwnstm of chain pillar	Reduced pool level , no cracking	pool dry, no obvious cracks 18/4/18	–

NOTE: RR= rock bar constrained pool RB = boulder pool RRS = rock shelf RW = waterfall

Photos of selected pools and stream reaches after the extraction of Longwall 31 are shown in **Appendix A**.

As shown in **Table 8**, the "*re-direction of surface water flows and pool level / flow decline of >20% during mining compared to baseline variability for > 2 months, considering rainfall / runoff variability*" TARP was triggered on the following dates;

- 24/5/18 RB14 (LW30), RR20, 21, 22, Weir 26/RC3 (LW31)
- 07/6/18 RR29 (LW32)
- 15/6/18 RW13 (LW30), RR23 and RR27(LW31)
- 21/6/18 RR16 (LW30), RR24, 25 (LW31)
- 28/6/18 RR15 (LW30), RR18, 19 (LW31), RR28 (LW32), and
- 05/7/18 RB17 (LW31)

3.5.4 Redbank Creek Pool Depth and Creek Flow Monitoring

GeoTerra commenced monitoring water levels in Redbank Creek in April 2005 (GeoTerra, 2011). HCS took over stream flow monitoring and decommissioned the original RC1-3 sites in January 2010.

Pool levels and creek flow at monitoring locations R1 – R3, as monitored by Hydrometric Consulting Services (HCS), are shown in **Figure 3**.

HCS are converting selected site stream depths to flow as sufficient manual stream flow data is collected, however insufficient readings are available for the conversion at all sites.

Reversal of flow in the creek has not occurred due to subsidence as the creek gradient exceeds the subsidence tilt in the stream bed.

Site R1 is situated upstream of Longwall 24, whilst R2 is located at north eastern upstream corner of Longwall 25, and upstream of Longwall 26.

Pool R3 is located at the northern western end of Longwall 25 and upstream of Longwall 26 and R4 is located over Longwall 27 as shown in **Drawing 1**.

Pool R5 is located downstream of Longwall 27, whilst R6 is situated over the middle of Longwall 29 and contains the permanently ferruginous pool RC2.

Pool R7 is located over mid Longwall 30, R8 is over the tailgate side whilst R9 is located over the maingate side of Longwall 31.

Pool R10 is situated over mid Longwall 32 and R11 is located over mid Longwall 32A as shown in **Drawing 1**.

The majority of pools over and downstream of Longwalls 25 to 32 show evidence of subsidence related pool holding capacity effects, whilst R11 does not, as shown in **Figure 2**.

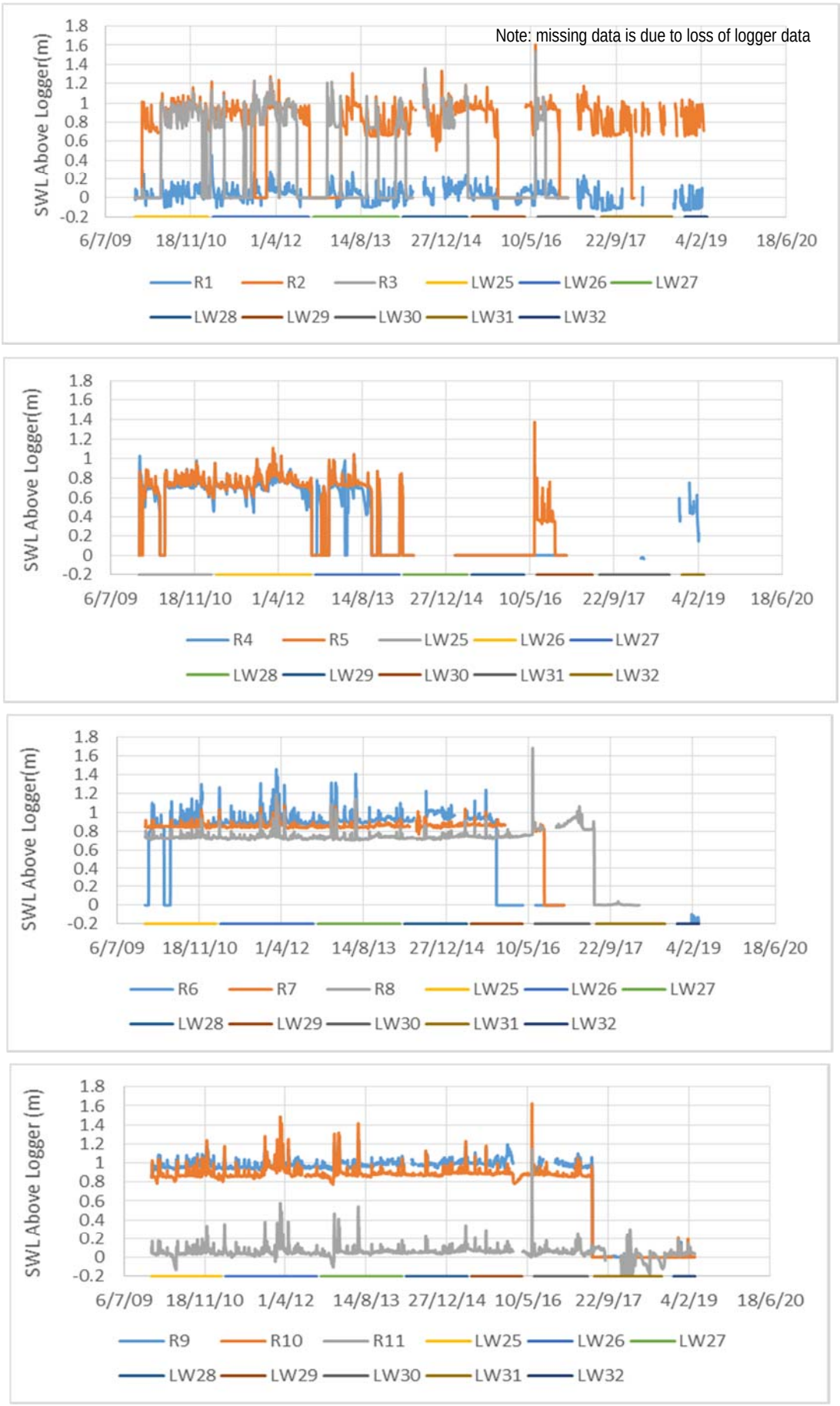


Figure 2 Redbank Creek Pool Depth

3.5.5 Redbank Creek Water Quality

Redbank Creek has had an EC range from 22 – 3,290uS/cm and pH between 3.10 and 7.50, with the creek generally being more acidic and saline at RC2 as shown in **Figure 3**.

During extraction of Longwall 31, pH in Redbank Creek distinctly acidified at all monitored sites, whilst salinity did not show a specific trend, except for higher salinity during low flow periods.

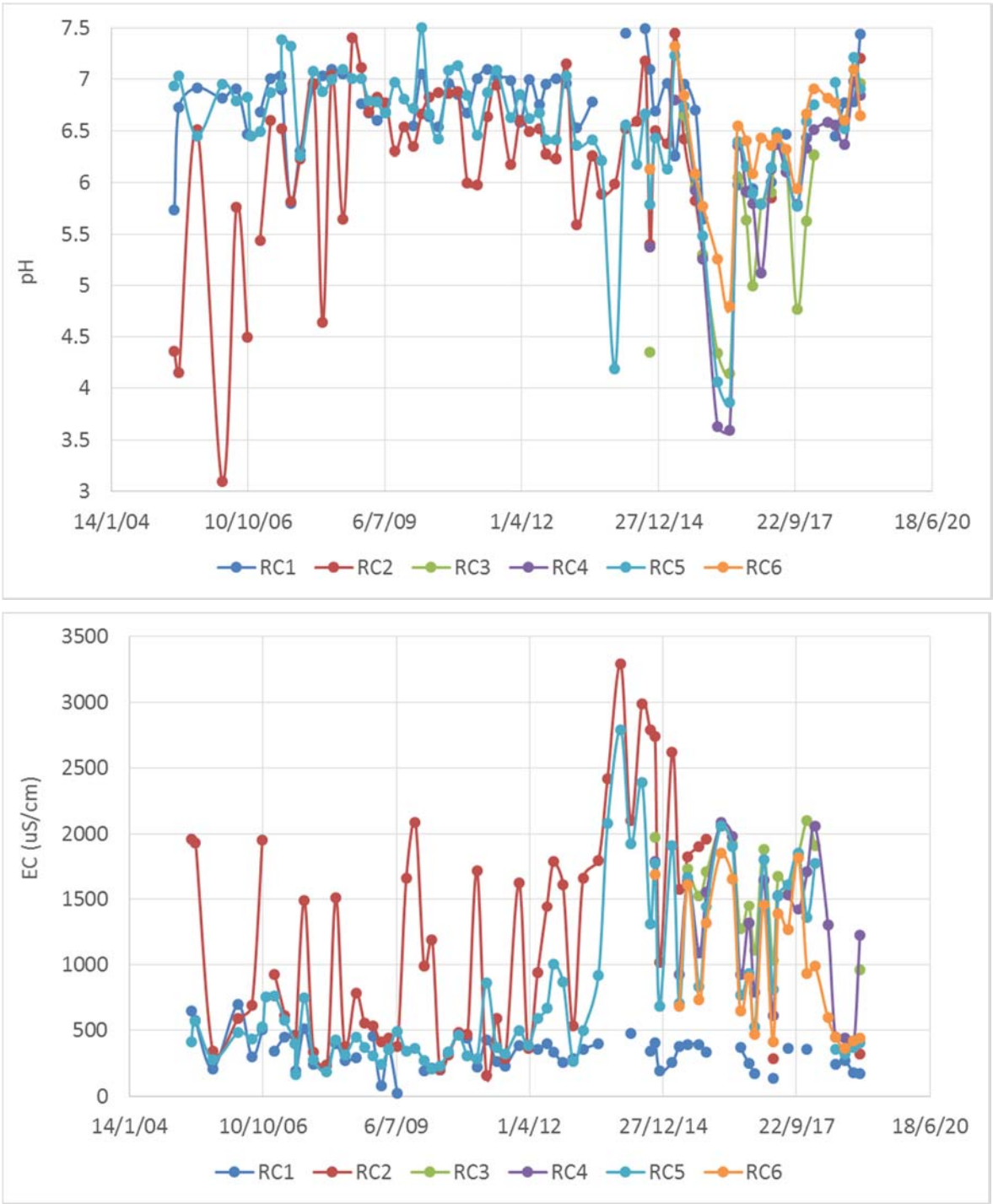


Figure 3 Redbank Creek Field Water Quality

Enhanced salinity and lower pH is predominantly associated with the more ferruginous seeps in the stream.

Redbank Creek generally contains elevated iron and, occasionally, above ANZECC 2000 Protection of 95% of Freshwater Aquatic Species trigger level manganese at RC2 in association with the upstream tributary seepage as shown in **Figure 4**.

The stream reach at RC2 (a.k.a. Site 37) has had a definitive ferruginous hydroxide precipitate in the standing pool since monitoring was started in early 2005 which is present due to upwelling and re-oxygenation of chemically reduced waters in the creek between sites 30 to 35.

Ferruginous seeps are also present at a tributary entering Redbank Creek downstream of the railway tunnel at Site 36, as well as sites RC37, RR2, RB3-6, RR7-11, RRS12, RW13, RB14 and RR15 - 29.

The iron and manganese levels vary with rainfall in the catchment, with lower concentrations after wetter periods, however a definitive rise in iron has been observed at RC2 and for manganese at RC2 and RC5 since Longwalls 27 to 30 undermined Redbank Creek.

Manganese also rose during extraction of Longwall 30 at Sites RC3 to RC6 (at which time RC1 and RC2 were dry).

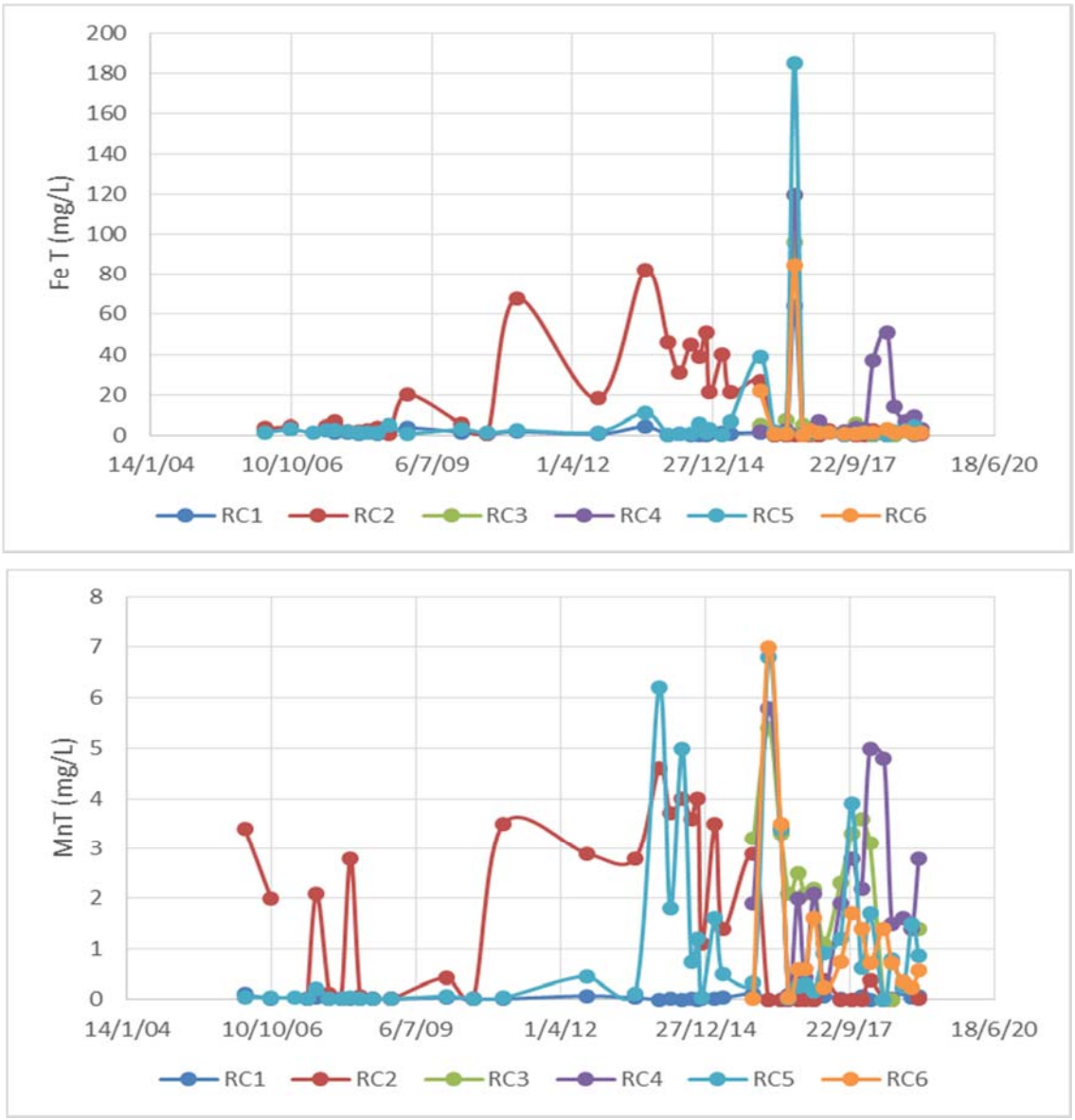


Figure 4 Redbank Creek Iron and Manganese

The creek can have total nitrogen (TN) up to 15mg/L and total phosphorous (TP) up to 0.47mg/L, which can be above the ANZECC 2000 SE Australian Upland Stream criteria at all monitored sites as shown in **Figure 5**.

The above criteria nutrients are present in the creek due to urban, rural / residential and industrial runoff in the catchment, and are not related to mining influences.

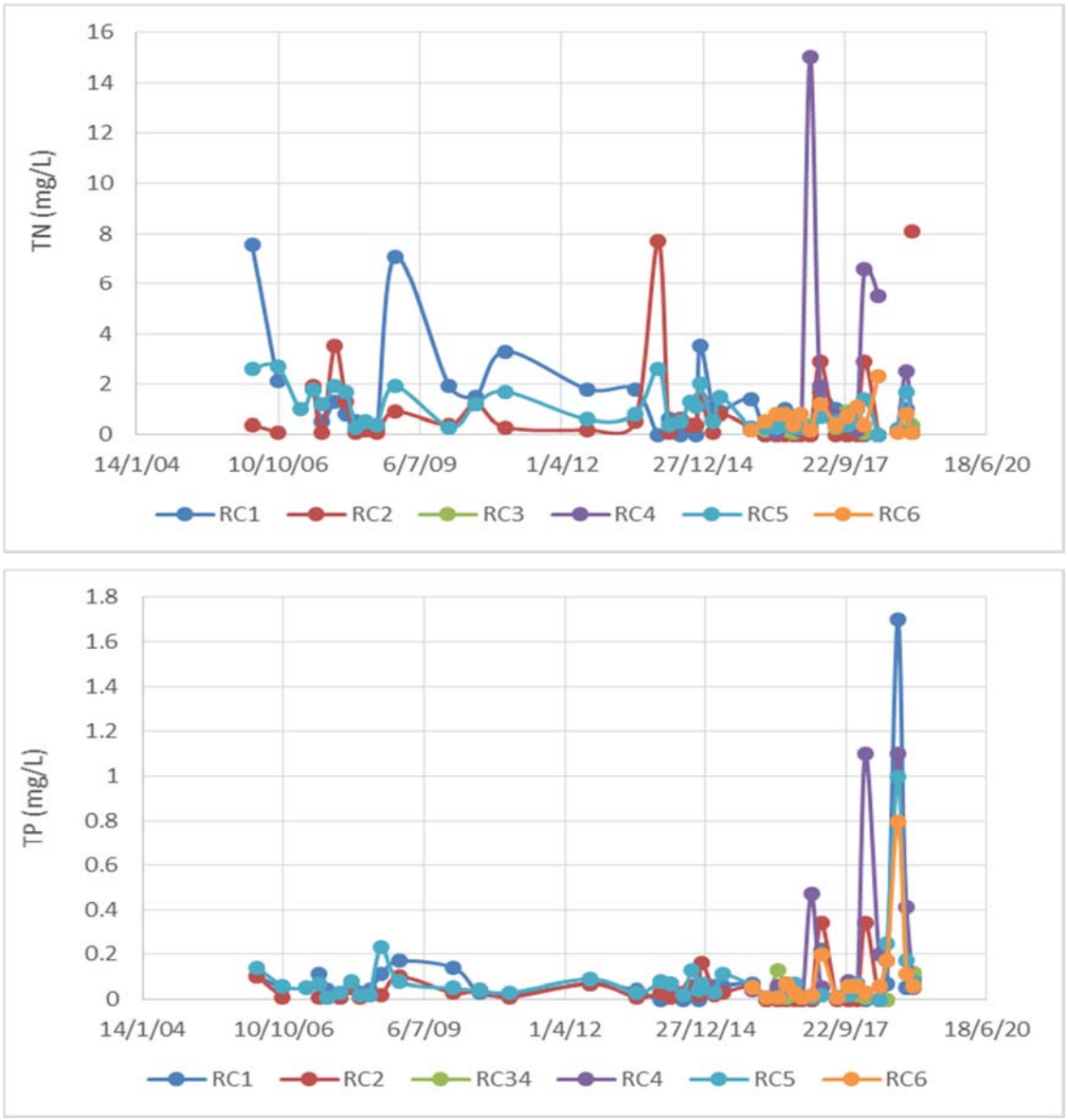


Figure 5 Redbank Creek Nutrients

Redbank Creek can also exceed the ANZECC 2000 trigger levels for filterable aluminium (<0.26mg/L), although the peak levels occurred during late 2007 and early 2008, with no observable increase above background levels during the Longwall 26 to 30 mining period.

Copper can reach up to 0.013mg/L, however no sustained increase as a result of Longwalls 28 to 30 is observed as shown in **Figure 6**.

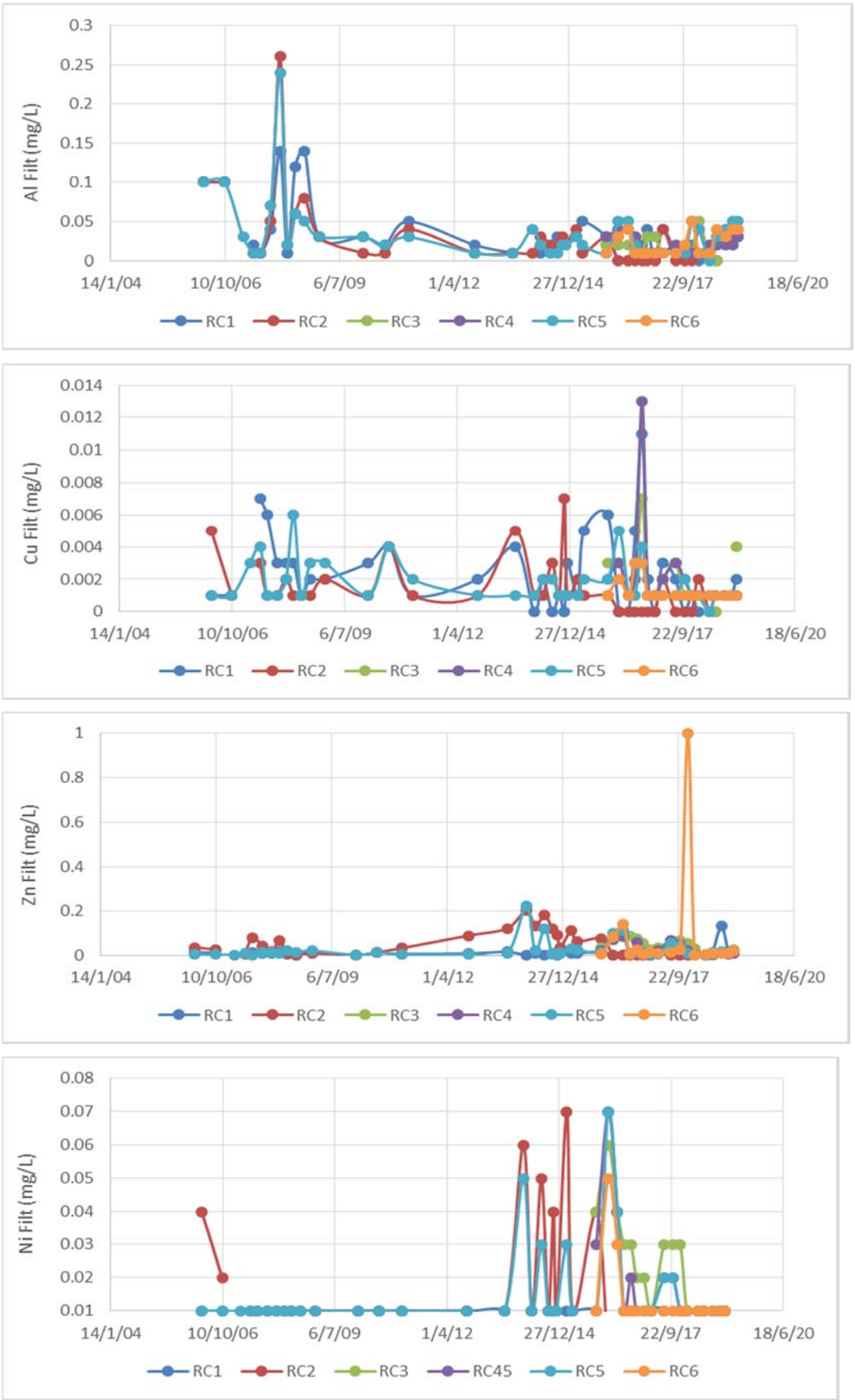


Figure 6 Redbank Creek Metals

Zinc can reach up to 1.0mg/L as shown in **Figure 6**, with its concentration being observed to rise at RC2 since late 2010, and since August 2013 at RC3 with an erratic, although generalised reduction since February 2014 and subsequent rise after extraction of Longwall 29 and after Longwall 31.

Nickel has also significantly increased at all sites since August 2013, reaching up to 0.07mg/L.

Both the zinc and nickel concentration increases indicate a response in the Redbank Creek water quality due to undermining of Redbank Creek by Longwalls 27 to 31 and the associated enhanced through flow of waters through freshly cracked sandstone.

3.6 Dams

Seventeen generally small dams directly overlie Longwall 31 as shown in **Drawing 1**.

All of the dams are located within rural residential properties apart from the two large dams at the southern end of LW31 which are associated with a plant nursery.

All dams have had variable water levels in response to rainfall recharge and / or water extraction rates.

No direct evidence of dam wall or floor cracking was reported by landowners, and the associated adverse water level, water storage or water quality effects due to subsidence associated with Longwall 31.

3.7 Groundwater

3.7.1 Open Standpipe Piezometers and Private Bores

Regular manual and data logger based standing water level monitoring was initiated in June 2004, with the piezometers being installed on various times at locations as summarised below;

- P1 - 450m south west of Longwall 22;
- P2 - within a remnant coal exploration bores over Longwall 23B;
- P3 - within a remnant coal exploration bore over the chain pillar between Longwall 25 and 26;
- P4 - within an undeveloped, unsecured block of land, 300m northeast of Longwall 26;
- P5 - 950m north-west of Longwall 26 that was used for general domestic / irrigation water. Monitoring ceased in P5 in August 2010 due to a request from the property tenant;
- P6 - 1.1km east of Longwall 26 in the old Jay-R Stud; and
- P7 and P8 - within the Inghams Turkey property, between the eastern end of Longwall 25 and 26 and the Bargo Gorge.
- P9A – adjacent to Redbank Creek within the Hanson cement works over the Longwall 31 / 32 chain pillar
- P9B,C – replaced the discontinued P9B and P9C VWP loggers within the Hanson cement works over the Longwall 31 / 32 chain pillar
- P10A,B,C – adjacent to Redbank Creek within the Narellan Pools factory
- P11 – adjacent to Redbank Creek upstream of the Thirlmere Way culvert

The actively used private bores GW105254 (McPhee), GW107918 (Machin), GW109010 (Pescud) and GW109224 (Boissery) and GW105813 (Koorana) are fully sealed with pump equipment and their water levels are not able to be monitored.

The Pescud and McPhee private bores are located over Longwall 26. The Boissery and Machin bores are located to the south east of Longwalls 28 and 29 respectively, whilst the Koorana bore is located over Longwall 32.

All piezometers and bores are located as shown in **Drawing 1** whilst the monitored groundwater levels are shown in **Figure 7**.

No significant open standpipe piezometer water level reduction occurred during the Longwall 31 extraction period (except for the P9 series as discussed further in Section 3.7.5), and no complaints of adverse effects on private bore water levels or yield were received by the Colliery during extraction of Longwall 31.

The last impacted bore was at the Pescud property (GW109010), which was reported to the colliery in December 2015.

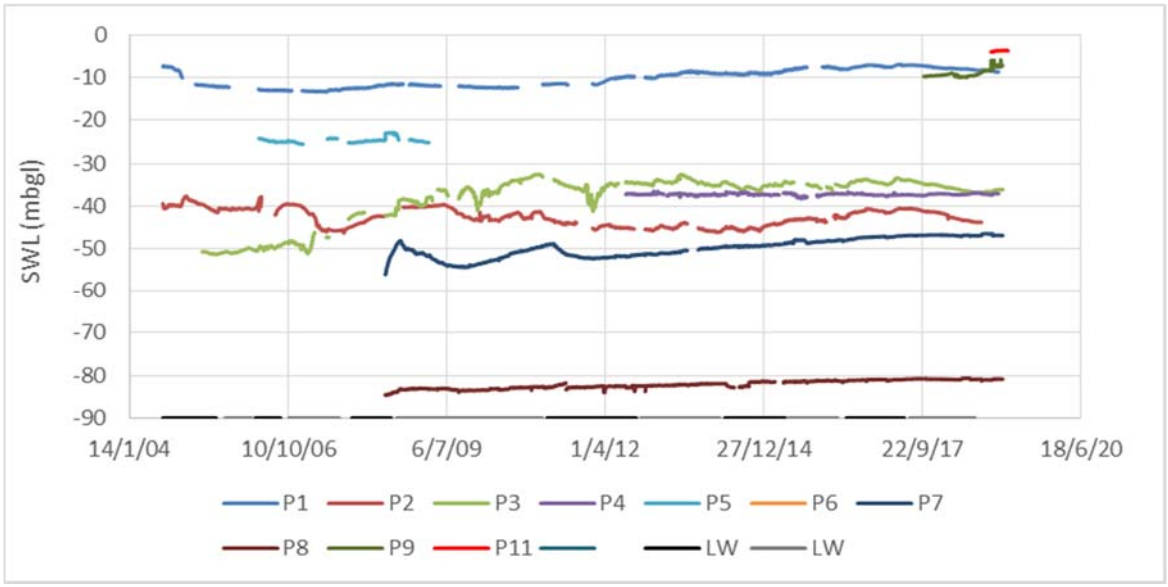


Figure 7 Standing Water Levels and Panel Extraction

3.7.2 Vibrating Wire Piezometers

Vibrating wire piezometers (VWP) TNC28 and 29 were discontinued prior to the start of Longwall 30 as they had been undermined and severed due to ground movements and are shown in the previous End of Panel report (GeoTerra, 2016).

The Bulli Seam has been dewatered in TNC28 and 29, whilst the Bulgo Sandstone has undergone partial depressurisation in TNC28 and TNC29, along with the Scarborough Sandstone in TNC29. TNC28 overlies Longwall 29, whilst TNC29 overlies the chain pillar between Longwalls 29 and 30. TNC29 was decommissioned prior to it being undermined by the longwall.

The TNC28 and 29 VWP data has not changed since the Longwall 29 End of Panel report (GeoTerra, 2016) and is not discussed further.

Ongoing monitoring at VWPs TNC36, 40 and 43 are shown in **Figure 8**.

TNC36 is located approximately 1600m north of Longwall 29, whilst TNC40 is located approximately 1300m north east and TNC43 is approximately 1050m north east of Longwall 29.

Partial depressurisation is observed in the Hawkesbury Sandstone at 97mbgl as well as in the Bulgo Sandstone (at 169 / 214 / 299mbgl) and the Bulli Seam in TNC36.

The Hawkesbury Sandstone (225mbgl) in TNC40 is undergoing partial depressurisation, along with the Bulgo Sandstone (at 252 & 352mbgl), whilst the Bulli Seam started significant depressurisation in April 2016.

Gradual depressurisation is observed in the Hawkesbury Sandstone (213mbgl) as well as in the Bulgo Sandstone (at 240 / 333 / 425mbgl) and Bulli Seam in TNC43.

None of the above depressurisation observations exceeded the TARP trigger level *(10m water level reduction for greater than 2 months)* as they do not exceed predictions outlined in the groundwater model prepared for the Environmental Application (EA) for the deeper strata and the Bulli Coal Seam, where depressurisation greater than 10m was predicted.

No shallow strata exceeded the Longwall 31 TARP Trigger during the Longwall 31 extraction period.

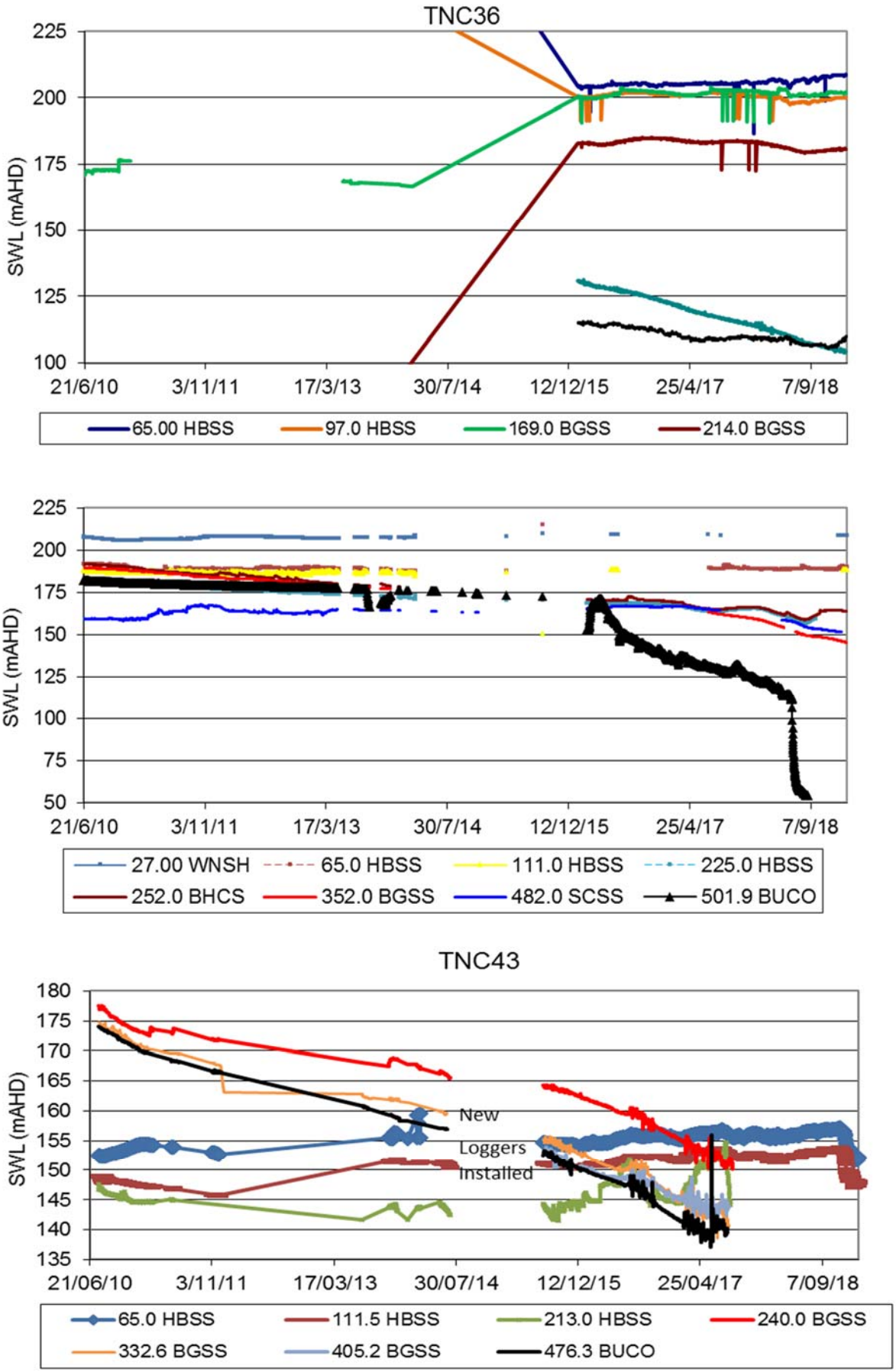


Figure 8 Vibrating Wire Piezometer TNC36, 40 and 43 Groundwater Levels

VWP array intakes were installed at 10, 20 and 50m below the initial water table strike depth (18m) at Site P9 in the Hanson cement works over the chain pillar between Longwall 31 and 32.

The P9 series monitoring results are discussed further in Section 3.7.5.

3.7.3 Aquifer / Aquitard Interconnection

The available data from the open standpipe piezometers, coal exploration and private bores, as well as the piezometric head monitoring in TNC28 and TNC29 have not indicated any adverse breaching or interconnection between the Hawkesbury Sandstone and Bulgo Sandstone, or through the Bald Hill Claystone.

Hydraulic connection has been instigated between the Bald Hill Claystone and Bulgo Sandstone in TNC28 as well as between the base of the Scarborough Sandstone and the Wombarra Shale in TNC29 during extraction of Longwalls 22 to 30.

Significant step changes in depressurisation also occurred in TNC40 in the Bulli Seam during mid-June 2018, whilst TNC43 had a definitive step change in the 65 and 111.5mbgl intakes in the Hawkesbury Sandstone during late October 2018, after all other loggers in the bore discontinued readings in late August 2017.

No significant depressurisation step changes have yet been observed in TNC36.

3.7.4 Groundwater Seepage To The Underground Workings

To date, no loss of stream flow from Redbank Creek into the Tahmoor mine workings has occurred.

3.7.5 Interconnection of Redbank Creek and the Adjacent Shallow Groundwater

A definitive reduction in pool depth and downstream overland connective flow occurred within Redbank Creek in the concrete weir based pool (R9 / RC3) on and after 10/3/18 as shown in **Figure 9,** when Longwall 31 was approximately 140m south of the creek bed.

The R9 / RC3 weir pool is located approximately 125m upstream of the P9 open standpipe and VWP array.

Connective stream flow and ponding re-appeared in the creek at and downstream of Redbank Creek site RB28, which is approximately 90m downstream of the R9 weir and approximately 25m downstream of the P9 piezometer location.

The creek has basically been dry for the majority of time after it was impacted by subsidence, and only holds water for short periods after significant rainfall / runoff in the catchment.

The P9 piezometers also showed a gradual reduction in water level in the deepest (P9D at 68mbgl) intake since installation (10/10/2017), whilst the shallowest piezometer (P9A at 5m below the first intersected water level of 18mbgl), did not show a definitive depressurisation.

The two middle piezometers (38 and 48mbgl) showed a minor ongoing, gradual depressurisation since installation.

A definitive step change in depressurisation, particularly in the deepest intake, occurred in all piezometers around the 21st to 23rd of April 2018, when Longwall 31 had progressed 40m north of the creek bed, and had just undermined the piezometers.

The depressurisation maximised at 6.55m below its starting depth in the deepest piezometer around 10th May 2018, after which its level (erratically) recovered to slightly above its initial level. The higher rates of recovery correlate to rain periods.

Both VWP intakes at 38mbgl and 48mbgl (P9B and PC) failed to record any further readings after 19th May 2018, when they sheared off.

P9B and P9C were replaced with open standpipe piezometers on 28/11/2018. After that time they have both shown a heightened response to rainfall in the catchment and recharge of pools in Redbank Creek, compared to before they were undermined.

Observation of the P9 piezometers, pool levels in Redbank Creek and rainfall indicates undermining of the creek and P9 piezometers by Longwall 31 has increased the fracture connection with the creek and enables a heightened recharge / discharge response after rain events within the shallow strata.

It has also been observed that the pre-undermining separation of the four individual hydrographs has modified so that the upper two intakes are at an equivalent elevation, whilst the two deeper intakes are also at an equivalent, deeper elevation. The separation between the two post undermining systems occurs at around 10.5m below surface.

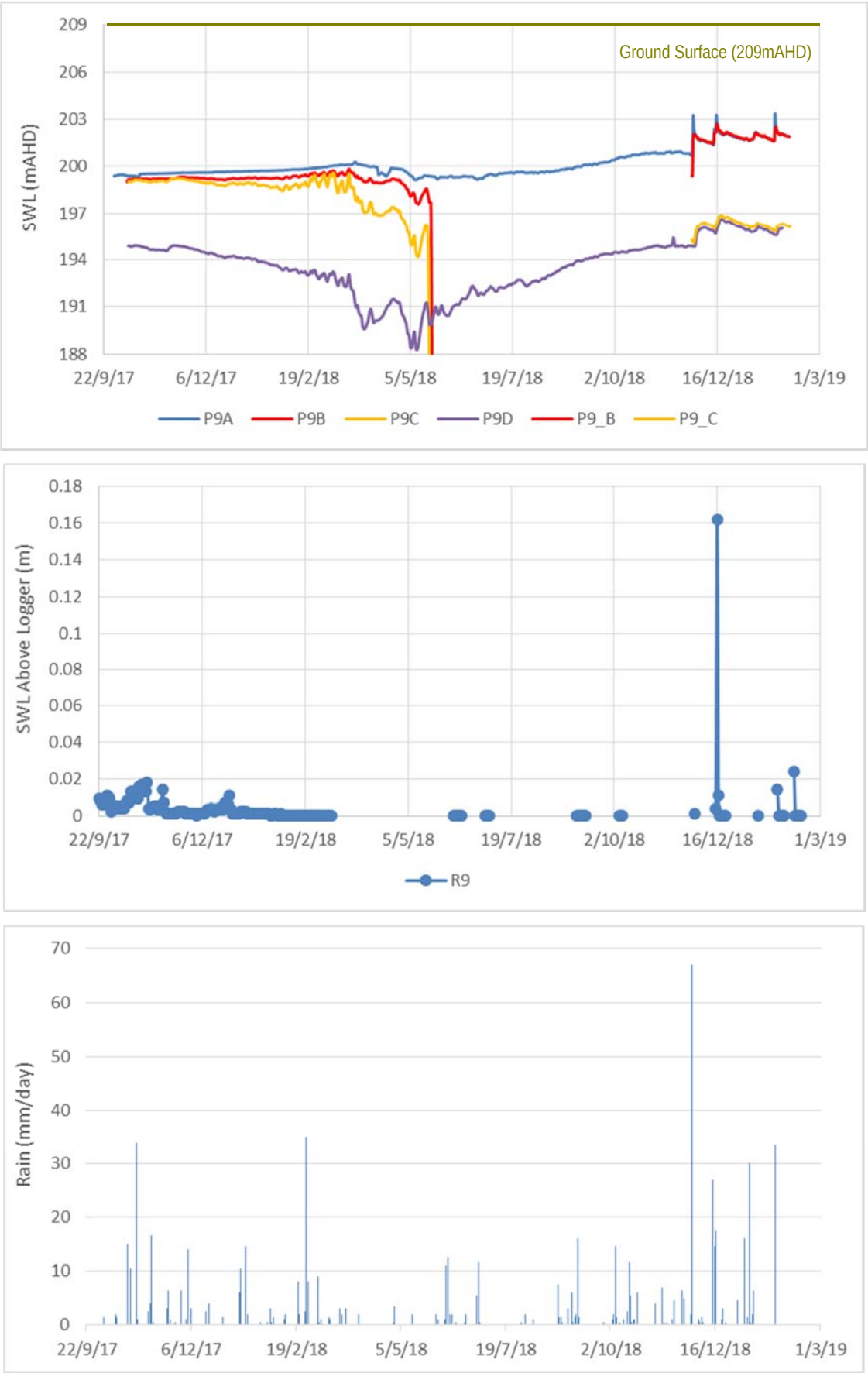


Figure 9 **P9 Series Groundwater Levels, Pool R9 Water Level and Rainfall**

3.7.6 Groundwater Quality

Groundwater in the study area has generally brackish salinity (459µS/cm to 12,250µS/cm) with acid to circum-neutral pH (3.06 to 7.6) as shown in **Figure 10** and **Figure 11**.

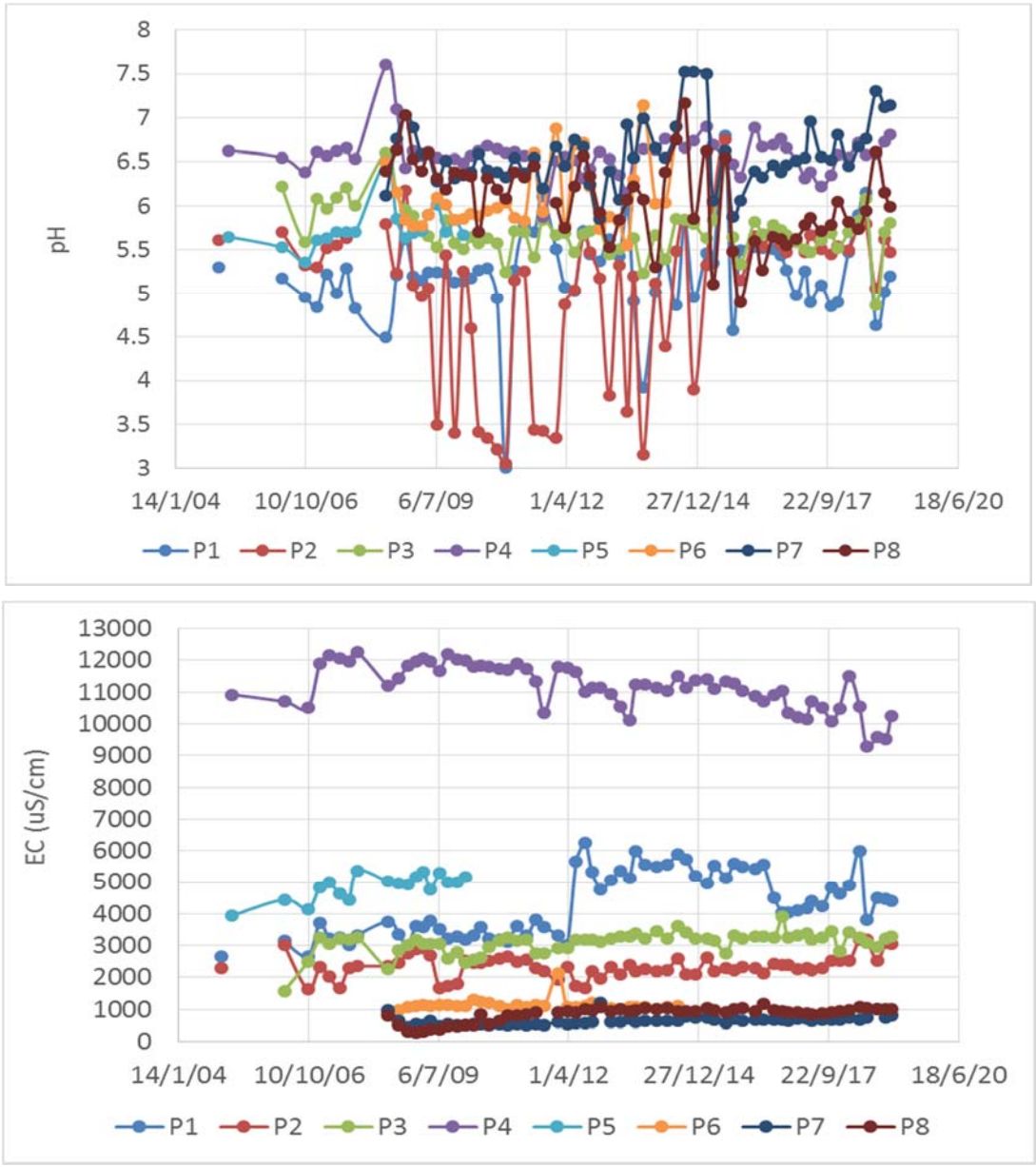


Figure 10 Field Groundwater Quality

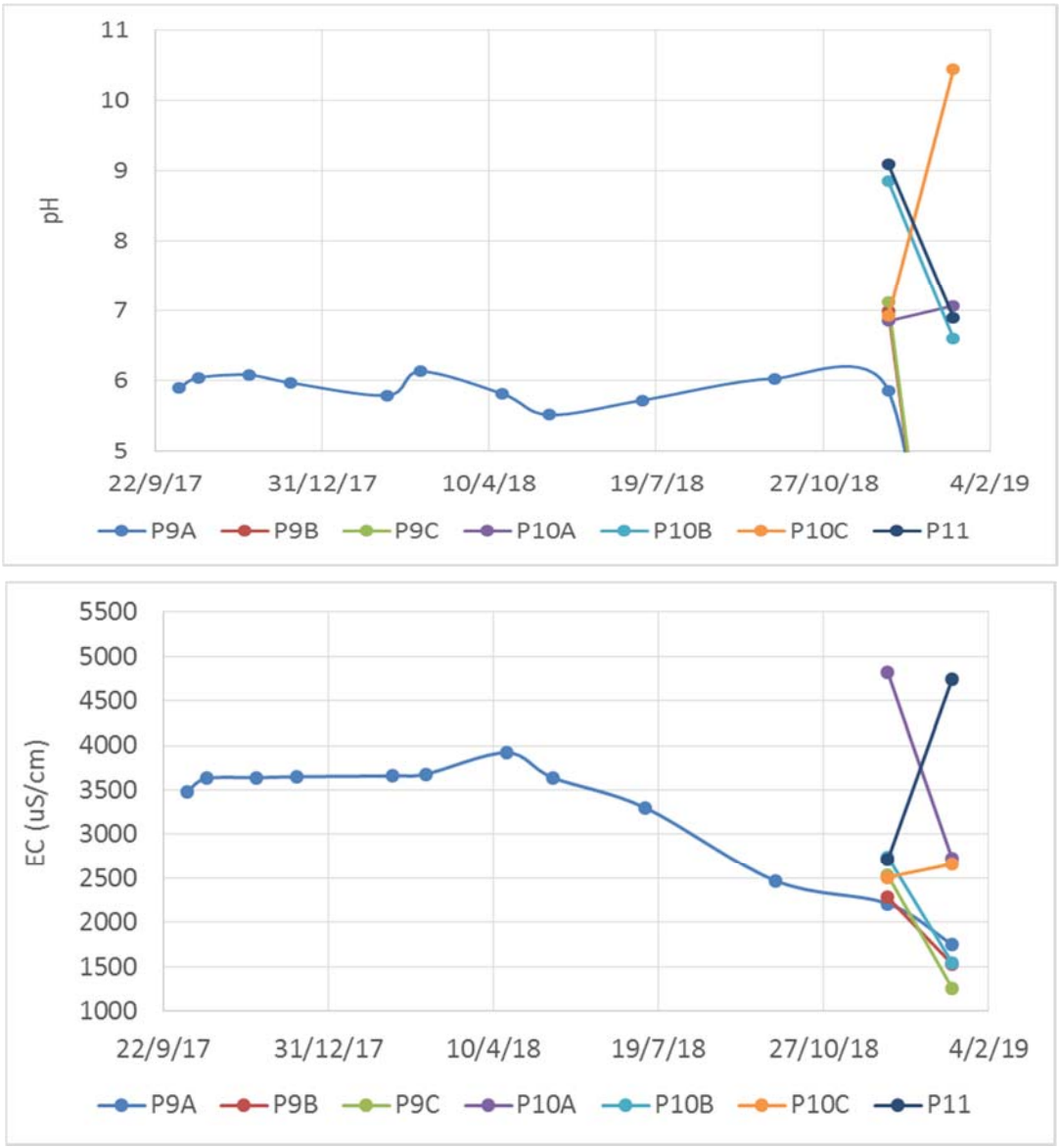


Figure 11 Field Groundwater Quality

Laboratory analyses obtained to date indicate that the bore water generally is outside ANZECC 2000 criteria (default trigger values for physical & chemical stressors in SE Aust upland rivers / 95% protection of freshwater species / livestock / irrigation) for:

- pH;
- Electrolytical conductivity;
- Sodium;
- Hardness;
- Total nitrogen, total phosphorous, as well as; and
- Filterable manganese, copper, zinc, nickel, aluminium and, to a small degree, lead.

The exceedance varies depending on the applicable guideline applied for the end use of the water.

Groundwater in the Longwall 22 to 31 subsidence area is suitable for selected livestock and limited irrigation use, but not for potable water.

No complaints regarding groundwater quality changes have been reported in the study area during the monitoring period.

No adverse change to groundwater quality in the subsided bores has been observed, along with no distinctive increase in salinity, iron or manganese.

4. SUBSIDENCE IMPACT MANAGEMENT

During and after extraction of Longwall 31, the LW31 TARP criteria triggers that occurred involved the "*re-direction of surface water flows and pool level / flow decline of >20% during mining compared to baseline variability for > 2 months, considering rainfall / runoff variability*" on the following dates;

- 24/5/18 RB14 (LW30), RR20, 21, 22, Weir 26/RC3 (LW31)
- 07/6/18 RR29 (LW32)
- 15/6/18 RW13 (LW30), RR23 and RR27(LW31)
- 21/6/18 RR16 (LW30), RR24, 25 (LW31)
- 28/6/18 RR15 (LW30), RR18, 19 (LW31), RR28 (LW32), and
- 05/7/18 RB17 (LW31)

Accordingly, the colliery prepared and submitted a Corrective Management Action Plan (SIMEC, 2018) on 31/12/2018 to address the ongoing monitoring, management and subsequent remediation of Redbank Creek.

5. CONCLUSIONS

Based on monitoring of streams, dams and groundwater conducted prior to, during and after extraction of Longwall 31, the following conclusions can be made:

- Stream bed cracking, associated with a reduction in stream flow and mostly complete drying up of pools has been observed in Redbank Creek due to extraction of Longwall 31 (and preceding longwalls) to Site RR32, downstream of Longwall 32;
- Connected stream "through-flow" has been interrupted or discontinued (outside of storm events) over Longwalls 26 to 32, with connected flow (albeit with reduced pool levels) recommencing at RR29;
- The "*re-direction of surface water flows and pool level / flow decline of >20% during mining compared to baseline variability for > 2 months, considering rainfall / runoff variability*" TARP was triggered at 16 sites between RW13 and RR29 between 24/5/18 and 5/7/18
- Significant depressurisation of the Bulli Seam has been observed in the vibrating wire piezometer bore at TNC40 and TNC43 along with partial depressurisation in the upper and middle Hawkesbury Sandstone in TNC43
- Up to 6.55m of depressurisation was observed in the 68mbgl VWP intake at P9, adjacent to Redbank Creek and over the Longwall 31/21 chain pillar, which subsequently recovered to just above its initial water level, and;
- No adverse effects on private bore yield or water quality have been reported during or after Longwall 31 extraction.

6. REFERENCES

ANZECC 2000 Australian and New Zealand Guidelines For Fresh and Marine Water Quality

GeoTerra, 2009 Longwall Panels 27 to 30 Surface Water & Groundwater Assessment

GeoTerra, 2013 Tahmoor Colliery Groundwater Management Plan

GeoTerra, 2017 End of Longwall 30 Surface Water, Dams and Groundwater Monitoring Report

Mine Subsidence Engineering Consultants Pty Ltd 2009 Longwalls 27 to 30 Subsidence Predictions and Impact Assessment for Natural Features and Items of Surface Infrastructure

Mine Subsidence Engineering Consultants Pty Ltd 2019 End of Panel Subsidence Monitoring Report for Tahmoor Longwall 31

SIMEC, 2018 Redbank Creek Corrective Management Action Plan

Tahmoor Underground, 2017 Tahmoor Colliery Longwall 31 Environmental Management Plan

LIMITATIONS

TNC40
P5
RC5
P11
V06g
V10a
R11
RC6
R10
P10A,B,C
V10b
P4
V10c
P9VWP
P9A,B,C
RC4
TNC29
R8
RC3/ R9
R7
GG11n
LW 32
LW 31
GW105813
REDBANK CREEK
RC2/ R6
R5
GG32f
LW 30
R3
LW 29
R4
RC1/ R2
LW 28
TNC43
GG37a
TNC28
GG38d
LW 27
McPhee
P3
M5
MYC3
Pescud
Machin
P2
MYC2
M6
MYRTLE
M4
M7
CREEK
M3
M2
Boissery
MYC
P1
M1
MYC1
TNC27
P6
P8
8548
P7
35753
Douglas
Pool J
Pool K

LEGEND

- PIEZOMETER
- BORE
- STREAM FLOW SITE
- STREAM WATER QUALITY SITE

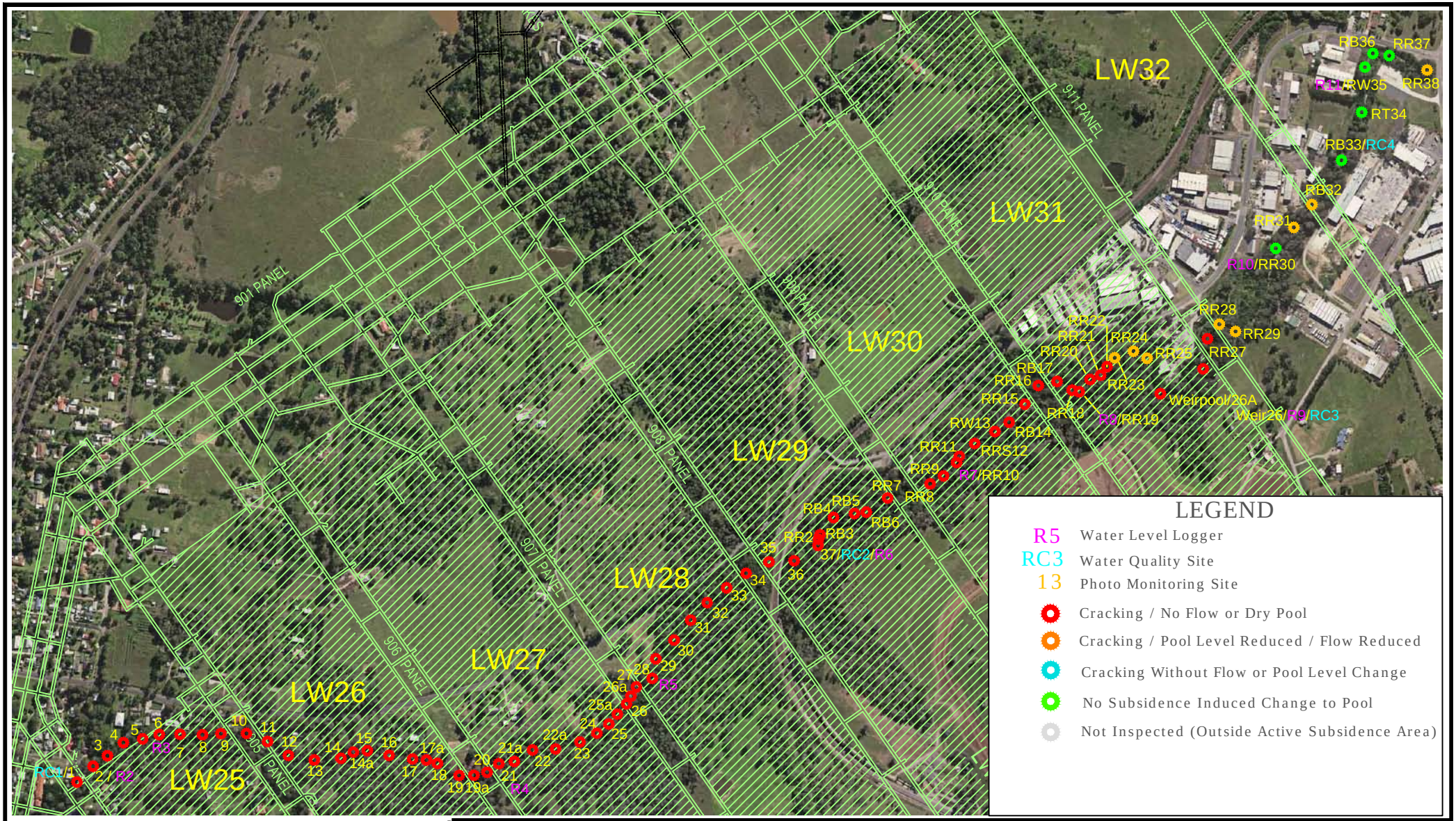
PROJECT:	TA35
DRAWN:	A. DAWKINS
DATE:	19 03 2019
SCALE:	1:30 000

SIMEC MINING LTD
TAHMOOR COLLIERY

WATER MONITORING LOCATIONS

GeoTerra

DRAWING 1



100 0 100 300 500

Scale (metres)

PROJECT:	TA35
DRAWN:	A. DAWKINS
DATE:	26.11.2018
SCALE:	As shown

TAHMOOR COAL PTY LTD
REDBANK CREEK

CREEK STATUS (26 November 2018)

GeoTerra

DRAWING 2

APPENDIX A

REDBANK CREEK END OF LONGWALL 31
SELECTED PHOTOGRAPHS

RR15

RR19 / R8

RR22

RR24

Weir 26 (upstream)

Weir 26/ RC3 / R9

RB28

RR29

RR30 / R10

RB32

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Ecology End of Panel Report
Tahmoor Longwall 31

Prepared for Tahmoor Colliery | 31 March 2019

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Document control

Project number	Client	Project manager	LGA
4838	Tahmoor Colliery	Luke Baker	Wollondilly Shire

Version	Author	Review	Status	Date
D1	Lucy Porter/ Sarah Hart	Luke Baker	Draft	27 March 2019

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Table of Contents

1. Introduction

1.1 Background

Tahmoor Coal Pty Ltd (Tahmoor Colliery) has completed extraction of Longwall 31. Tahmoor Colliery is required to develop an End of Panel (EoP) Report for Longwall 31, to comply with Subsidence Management Plan Approval.

Niche Environment and Heritage (Niche) was commissioned by Tahmoor Colliery to conduct an EoP assessment of the terrestrial and aquatic ecological values within the limit of subsidence of Longwall 31 (Study Area).

This report takes into consideration the predicted and observed impacts on terrestrial and aquatic ecological values within the Study Area in order to assess the impacts against the relevant Trigger Action Response (TARPs) associated with the Tahmoor Colliery (2015) Longwall 31 Environmental Management Plan. In particular, this assessment has utilised monitoring data collected as part of the following monitoring campaigns and specialist studies:

- Niche (2018a) Tahmoor North Longwall 31, Stream Health Assessment, Prepared for Tahmoor Coal.
- Niche (2018b) Tahmoor North, Aquatic Baseline Monitoring, Prepared for Tahmoor Coal.
- Niche (2018c) Tahmoor North, Riparian and Amphibian Monitoring, Prepared for Tahmoor Coal.
- Niche (2014) Tahmoor North Longwalls 31 to 37 Terrestrial Ecology Assessment, Prepared for Tahmoor Coal December 2014.
- Mine Subsidence Engineering Consultants (MSEC) (2019) Tahmoor Coking Coal Operations - Longwall 31 End of Panel Subsidence Monitoring Report for Tahmoor Longwall 31.
- Geoterra (2019). Longwall 31 Surface Water, Dams and Groundwater End of Panel Monitoring Report, Tahmoor, NSW. Report No. TA31-R1.

2. Subsidence Monitoring Results

2.1 Subsidence Monitoring Results Summary (MSEC)

The EoP Subsidence Report for Longwall 31 prepared by MSEC (2019 – MSEC1001) is a comprehensive report which addresses all aspects of the recorded subsidence parameters resulting from the extraction of Longwall 31.

Subsidence has the potential to impact terrestrial ecological values. Table 1 outlines the observed subsidence impacts and the potential consequences for terrestrial ecological values relevant to Longwall 31. As indicated in Table 1, overall the recorded subsidence on natural landscape features resulting from the extraction of Longwall 31 was similar to those predicted.

Table 1. Observed impacts from Longwall 31 due to subsidence and their correlation to potential terrestrial ecology impacts

Natural feature	Summary of predicted impacts (MSEC 2019)	Subsidence monitoring results (MSEC 2019)	Correlation to Terrestrial Ecological Values
Redbank Creek	Potential cracking in creek bed. Potential surface flow diversion. Potential reduction in water quality during times of low flow. Potential increase in ponding.	Stream bed cracking and loss of pool holding capacity has been observed in numerous pools and stream reaches in Redbank Creek over Longwalls 25 to 31 and future Longwall 32. Changes in salinity has been observed downstream of Redbank Creek subsidence zone, along with elevated nickel, zinc, iron and manganese. Increased ferruginous and salinity levels have been observed in Redbank Creek over Longwalls 29 and 30 and future Longwall 31. The location of the sites are detailed in GeoTerra (2019).	Change in water levels due to ponding, flooding and inundation or desiccation has the potential to alter the distribution of water plant habitat for amphibians, drown riparian vegetation or remove foraging habitat for any fauna dependant on pools.
Steep slopes and Cliffs	Potential soil slippage and cracking to slopes. Large scale slope failures or cliff instabilities unlikely.	No impacts observed during the mining of Longwall 31.	Soil slippage may result in erosion causing vegetation loss, direct impacts to threatened fauna and disruption of habitat.
Natural vegetation	No anticipated impacts	No impacts observed during Longwall 31	Subsidence has the potential to change hydrology, thus resulting in changes to flora reliant upon such a hydrological regime.

3. Environmental Monitoring

3.1 Biodiversity Monitoring

Biodiversity monitoring has been undertaken as part of the Tahmoor North monitoring campaign, which includes the areas of Redbank Creek which occurs within the Study Area. The monitoring undertaken by Niche applicable to this assessment includes:

- Niche (2018a) Tahmoor North Longwall 31, Stream Health Assessment, Prepared for Tahmoor Coal.
- Niche (2018b) Tahmoor North, Aquatic Baseline Monitoring, Prepared for Tahmoor Coal.
- Niche (2018c) Tahmoor North, Riparian and Amphibian Monitoring, Prepared for Tahmoor Coal.
- Mine Subsidence Engineering Consultants (MSEC) (2019) Tahmoor Coking Coal Operations - Longwall 31 End of Panel Subsidence Monitoring Report for Tahmoor Longwall 31.
- Geoterra (2019). Longwall 31 Surface Water, Dams and Groundwater End of Panel Monitoring Report, Tahmoor, NSW. Report No. TA31-R1.

3.1.1 Amphibian and riparian monitoring

The Longwall 31 Study Area includes monitoring sites associated with the biodiversity (amphibian and riparian) monitoring program (Niche 2018c). This monitoring program collected riparian vegetation monitoring along Redbank Creek, which entailed traverses of the creek, and collection of flora plots/transect; and amphibian transects at set monitoring locations along Redbank Creek. Further monitoring sites are located along Stonequarry Creek, Cedar Creek, Newlands Gully, Matthews Creek, which a detailed methodology provided in Niche (2014).

To date, the biodiversity (amphibian and riparian) monitoring has been undertaken on the following dates:

Riparian vegetation monitoring:

- Summer monitoring 2017: 7th, 13th and 14th of December 2017
- Autumn monitoring 2017: 13th, 19th and 20th of April 2018.
- Summer monitoring 2018: 26th, 29th, 30th of December 2018 and 6th December 2018.

Amphibian monitoring:

- Summer monitoring 2017: 4th, 5th and 7th of December 2017
- Autumn monitoring 2017: 3rd, 8th 17th of May 2018.
- Summer monitoring 2018: 4th, 5th and 6th of December 2018.
- Autumn monitoring 2019: 19th, 20th and 21st March 2019 (not included in Niche 2018c).

3.1.2 Aquatic ecology monitoring

The Longwall 31 Study Area includes monitoring sites associated with the Biodiversity (Aquatic Ecology) Monitoring Program (Niche 2014), and Longwall 31 Stream Health Monitoring (Niche 2018a).

Aquatic ecological monitoring of the Longwall started in spring 2017 before the Redbank Creek was undermined by Longwall 31. Three sites were monitored at and downstream of Longwall 31. These location were surveyed again in Autumn 2018 post-undermining of Redbank Creek. The monitoring included:

- Physiochemical in situ surface water sampling
- Habitat assessment
- AUSRIVAS macroinvertebrate monitoring

- Quantitative macroinvertebrate monitoring.

3.1.3 Surface water, dam and groundwater monitoring

Surface water, dams and groundwater monitoring program for Longwall 31 has been conducted by GeoTerra since June 2004. The monitoring by GeoTerra has assessed the following features which relate to terrestrial ecology:

- Ephemeral or perennial nature and flow in streams over the panels
- Creek bed and bank erosion and channel bedload
- Stream and dam water quality
- Stream bed and bank vegetation
- Nature of alluvial land along stream banks
- Presence, size and integrity of dams and their water level
- Presence and use of groundwater bores
- Assessment of standing water levels and water quality.

The results of GeoTerra (2019) has been incorporated throughout this assessment where applicable.

4. Monitoring Results

4.1.1 Riparian monitoring results

During the Niche (2018c) monitoring, and Niche (2014) biodiversity impact assessment, it was confirmed that the native vegetation along Redbank Creek was in a degraded condition prior to mining due to historic clearing and high weed presence. For the most part, the vegetation along the banks of Redbank Creek consisted of the Threatened Ecological Community (TEC) Shale Sandstone Transition Forest within a degraded condition, which integrated with areas of Grey Myrtle Dry Rainforest community closer to the creek.

No areas of any vegetation die back have been recorded during the monitoring campaigns, or significant changes to vegetation were recorded across the monitoring to date.

4.1.2 Aquatic monitoring results

During the Niche (2014) biodiversity impact assessment, it was confirmed that Redbank Creek is unlikely to support habitat for any threatened amphibian species. To date, the Niche (2018c) monitoring has not recorded any threatened amphibian species, nor recorded any population of amphibians of a significant scale. This is largely attributed to the absence of water and pools within Redbank Creek within the Longwall 31 Study Area.

4.1.3 Aquatic ecology monitoring

Details of the monitoring are provided in Niche (2018a; 2018b) however in summary the monitoring presented similar results to surveys conducted in 2014 found Redbank Creek showed obvious signs of deterioration in stream condition with stream bed cracking, loss of pool holding capacity and loss of aquatic habitat.

The monitoring detected that most sites monitored were recorded low dissolved oxygen below ANZECC Default Tigger Values (DTVS), however pH was generally within DTVs. Stream health as indicated by AUSRIVAS and SIGNAL showed impairment of macroinvertebrate communities (that is, some sites were missing families expected to occur at the site naturally) which generally consisted of pollution tolerant macroinvertebrate families. Overall, it was considered that natural environmental stressors (predominantly

low flow) are likely to be driving these observations with local anthropogenic influences exacerbating these conditions. Monitoring suggested that high salinity/electrical conductivity recorded in Redbank Creek in autumn 2018 could be harmful to aquatic organisms.

The details of the Steam Health Assessment associated with Longwall 31 are provided in Niche (2018b). In general, the 2017 monitoring showed similar results to surveys conducted in 2013 and 2015 which found the riparian and channel condition in a disturbed condition, with rubbish and exotic species present. The water quality had consistently high salinity, and low dissolved oxygen, however pH was generally with ANZECC guidelines in 2017. Stream health as indicated by AUSRIVAS and SIGNAL showed impairment of macroinvertebrates (that is, sites that are missing families that expected to occur at the site naturally) and generally consisted of pollution tolerant macroinvertebrate families. Overall this indicated that Redbank Creek is in poor stream health which is likely due to a number of factors including natural environmental stresses, local pollution from the urban catchment and undermining of the Redbank Creek from previous longwall mining upstream of Longwall 31.

Redbank Creek is likely to have been impacted from longwall mining, particularly recent cracking as a result of longwall 31. This has resulted in loss of water holding capacity at monitoring Site 1, Site 2 and Site 3 and availability of aquatic habitat. Mine subsidence has also possibly led to the measured condition changes between spring 2017 and autumn 2018 i.e. increase in electrical conductivity/salinity concentrations (from approx. 1000- 3000 µS/cm) and changed macroinvertebrate community at Sites 1, 2 and 3. The Diptera family Chaoboridae was found to be dominant in autumn 2018 sampling at Sites 1,2 and 3. This family is pollution tolerant (SIGNAL 2) and are associated slow-flowing creeks, seepages, or swampy ground (MDFRC 2018). Therefore, while Redbank Creek was already in a very poor condition (2014 and spring 2017), its health appears to have declined between the monitoring seasons. This could be attributed to longwall mining and associated mine subsidence, however could also be attributed to the urban landscape context.

4.1.4 Surface water, dam and groundwater monitoring

The GeoTerra (2019) report details the results and reported impacts from the on-going monitoring of environmental values within the limit of subsidence of Longwall 31.

Impacts from mining of Longwall 31 identified by GeoTerra (2019) include the following:

- Stream bed cracking and loss of pool holding capacity has been observed in pools and stream reaches in Redbank Creek over Longwalls 25 to Longwall 32.
- Increased salinity over and downstream of the Redbank Creek subsidence zone, particularly at Sites RC3 and RC4, along with elevated iron, Total Nitrogen, Total Phosphorous, copper, zinc, nickel and manganese.
- Increased ferruginous and salinity levels have been observed over Longwall 29 - 32 in Redbank Creek.
- No adverse effect on plateau stream ecology has been reported.
- No localised stream ponding due to subsidence has been observed.

5. Impacts on threatened biodiversity

5.1 Field survey

A one day field inspection was undertaken by Sarah Hart (Ecologist – Niche) on the 22nd March 2019 along Redbank Creek within the predicted subsidence zone, to observe any areas of vegetation die back that may have been attributed to subsidence.

During field survey, no signs of vegetation die back were observed along the riparian zones within the limits of subsidence for Longwall 31. Furthermore, no threatened flora or fauna were recorded whilst traversing the area during the field survey.

5.2 Threatened ecological communities

Niche (2014) and Biosis Research (2009) recorded three Threatened Ecological Communities (TECs) within the vicinity of Longwall 31: Cumberland Plain Woodland, Shale Sandstone Transition Forest, and Moist Shale Woodland. These communities are listed as TECs under the NSW *Biodiversity Conservation Act 2016* (BCT) and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Both Niche (2014) and Biosis Research (2009) concluded mining within the vicinity of Longwall 31 is unlikely to have a significant impact on any of these TEC's.

Subsidence associated with the extraction of Longwall 31 is consistent with the subsidence impact assumptions in the Niche (2014) and Biosis (2009) report and no changes in any of these vegetation communities has been reported (GeoTerra 2019) or observed during the Niche survey inspection and monitoring. It should be noted that whilst Niche and GeoTerra were not able to inspect all areas of the TECs given the location of TEC patches within private properties, it is highly unlikely that subsidence would impact upon the TECs given they are not solely groundwater dependant, and any cracking of soil within the vegetation community is unlikely to result any significant floristic and structural changes.

5.3 Threatened flora

No threatened terrestrial or aquatic flora species were recorded in the study area during the Niche (2014) the monitoring undertaken by Niche, or survey conducted by Biosis Research (2009). However, within the vicinity of Longwall 31, potential habitat was determined for four threatened flora species that may potentially be impacted by subsidence: *Epacris purpurascens var. purpurascens* and *Pomaderris brunnea* Niche (2014) concluded that mining of longwall 31-37 is unlikely to have a significant impact on any of threatened flora. A similar conclusion was reached in Biosis Research (2009) in relation to Longwalls 27-30.

Subsidence associated with the extraction of Longwall 31 is consistent with the subsidence impact assumptions in Niche (2014) due to the following:

- No threatened flora were recorded during the Niche field survey.
- *Epacris purpurascens* var. *purpurascens*, and *Pomaderris brunnea* are relatively conspicuous and unlikely to remain undetected during the field survey.
- No threatened flora were recorded during the monitoring and Biosis (2009).

As such it is not likely that the extraction of coal from Longwall 31 has led to any impacts on these four threatened plant species.

5.4 Threatened fauna

Thirty-four threatened and/or migratory fauna were considered to have limited potential habitat within the study area (Niche 2014). These species include:

- Amphibians: Red-crowned Toadlet.
- Birds: Regent Honeyeater, Fork-tailed Swift, Great Egret, Bush Stone-curlew, Gang-gang Cockatoo, Glossy Black-Cockatoo, Brown Treecreeper (eastern subspecies), Varied Sittella, Little Eagle, White-throated Needletail, Swift Parrot, Square-tailed Kite, Hooded Robin (south-eastern form), Black-chinned Honeyeater (eastern subspecies), Rainbow Bee-eater, Black-faced Monarch, Satin Flycatcher, Turquoise Parrot, Barking Owl, Powerful Owl, Scarlet Robin, Speckled Warbler, Rufous Fantail, Masked Owl.
- Invertebrates: Cumberland Plain Land Snail.
- Mammals: Large-eared Pied Bat, Little Bentwing-bat, Eastern Bentwing-bat, Eastern Freetail-bat, Southern Myotis, Koala, Grey-headed Flying-fox, Greater Broad-nosed Bat.

The impact assessments completed as part of Niche (2014) and similar assessment completed by Biosis (2009) (which covered most of the Study Area), concluded that mining of Longwall 31 was unlikely to have a significant impact on a local population of any of these threatened fauna species as potential roosting/sheltering habitat for these species is outside the subsidence footprint of Longwall 31.

Subsidence associated with the extraction of Longwall 31 is consistent with the subsidence impact assumptions in the Niche (2014) report and the Biosis (2009) report, and the extraction of coal from the Longwall is not likely to have had a significant impact on any threatened fauna species.

No aquatic threatened species listed under the Fisheries Management Act 1991 (FM Act) occur within Redbank Creek. As such there in no impact to threatened aquatic fauna.

6. Assessment of predicted and observed impacts

The predicted and observed impacts on TEC's and threatened species (and their habitats) resulting from the Longwall 31 is provided in Table 2. The table focuses on the three main ecological values which were the subject of the assessment undertaken by Niche (2014) for the development of Longwalls 31 to 37.

Table 2: Summary of the predicted and observed impacts on general habitat and threatened flora and fauna Associated with Longwall 31

Ecological Values	Predicted Impact	Observed Impact based on Niche survey, GeoTerra (2019) and MSEC (2019)	Within Prediction (yes/no)
Endangered Ecological Communities (and other vegetation)	Potential gas emissions may result in small, isolated areas of vegetation dieback. Potential surface fracturing and gas emissions considered unlikely to result in alteration of species composition or distribution. Unlikely to have a significant impact on any plant communities.	No vegetation impacts have been observed or reported. No significant impacts to TECs or vegetation are likely to have occurred.	Yes
Threatened flora	Volume of water available for plant use is unlikely to be significantly impacted. It is considered unlikely that subsidence impacts would result in a broad change in the floristic composition of the riparian zone. No significant impact to threatened flora.	No vegetation impacts have been observed or reported. No significant impacts to flora and flora habitat. The Niche (2014) report assumed flow diversion and pool level changes would occur as a result of mining Longwalls 31 to 37. Furthermore, the Biosis (2009) assessment which includes portions of Longwall 31 has similar assumptions. Given, such predictions were considered in the impact assessment, and no threatened amphibians were regarded as having potential habitat in the watercourses of Longwall 31, observations are within the predicted impacts for flora, fauna and TECs.	Yes
Threatened fauna and fauna habitat	Changed surface water conditions, such as effects to pools and streams. Impacts to steep slopes and cliffs. Impacts of gas emissions on water quality and riparian vegetation. No significant impacts to any threatened fauna.	No vegetation impacts have been observed or reported. No significant impacts to fauna and fauna habitat. The Niche (2014) report assumed flow diversion and pool level changes would occur as a result of mining Longwalls 31 to 37. Given, such predictions were considered in the impact assessment, and no threatened amphibians were regarded as having potential habitat in the watercourses of Longwall 31, observations are within the predicted impacts for flora, fauna and TECs.	Yes

7. Trigger Action Response Plan

An address of each of TARPS related to terrestrial and aquatic ecology are provided in Appendix A.

In summary, based on the field observations and monitoring completed by Niche to date, and the GeoTerra (2019) assessment, no TARPS associated with terrestrial flora and fauna (amphibians and riparian) have been triggered which have led to any significant terrestrial ecology impacts to date. This is due to the following:

- Impacts do not exceed that predicted in Niche (2014) Biodiversity impact assessment.
- No threatened amphibians recorded during monitoring by Niche (2018c).
- No threatened amphibians recorded during monitoring by Niche (2018c).
- No significant decline in amphibian populations likely given the low abundance currently along Redbank Creek.
- No vegetation die back has been observed during the monitoring or field survey.
- The riparian monitoring has not detected any significant changes in flora within the Redbank Creek monitoring sites during the monitoring year.

Similarly, in relation to the aquatic ecology (macroinvertebrates) TARPs, these are unlikely to have been exceeded due to the following:

- Redbank Creek is in a relatively poor condition prior to Longwall 31 mining.
- AUSRIVAS and SIGNAL completed as part of Niche (2018a) indicated that the poor health of Redbank Creek within the Longwall 31 Study Area is likely due to a number of factors including natural environmental stresses, local pollution from the urban catchment and undermining of the Redbank Creek from previous longwall mining upstream of Longwall 31.
- Whilst the monitoring to date along Redbank Creek detailed in Niche (2018a) indicated by AUSRIVAS and SIGNAL showed impairment of macroinvertebrates following mining, Redbank Creek was in a poor steam health state prior to mining of Longwall 31.
- Continuation of macroinvertebrate and steam health monitoring along Redbank Creek is recommended to provide further data for analysis in regards to the potential impacts of longwall mining impacts.

8. Conclusion

This report compares the observed impacts of subsidence associated with the extraction of Longwall 31 at Tahmoor Colliery against the impacts predicted prior to extraction of coal from the Longwall in relation to biodiversity values. This assessment is based on a review of monitoring observations and measurements undertaken by Niche (2014; 2018a, 2018b; 2018c), MSEC (2019), and GeoTerra (2019).

The impacts which have occurred within the limit of subsidence for Longwall 31 are within the parameters of the predicted impacts outlined in the terrestrial ecological assessment for Longwalls 31 to 37 (Niche 2014).

No TARPs associated with terrestrial and aquatic ecology have been exceeded based on the specialist studies, field survey and monitoring results to date.

It is recommended that the current monitoring program continue along Redbank Creek in order to assist in the early detection of TARP exceedances associated with the future longwall activities.

References

Biosis Research (2009) Tahmoor Colliery Longwalls 27-30 Impacts of Subsidence on Terrestrial Flora and Fauna Final Report.

GeoTerra (2019). End of Longwall 31 Streams, Dams & Groundwater Monitoring Report, Tahmoor, NSW. Report No. TA19-R1. Mine Subsidence Engineering Consultants

MSEC (2019) Glencore: Tahmoor Colliery - Longwall 31 End of Panel Subsidence Monitoring Report for Tahmoor Longwall 30.

Niche (2018a) Aquatic baseline monitoring –Tahmoor North. Prepared for Tahmoor North

Niche (2018b) Aquatic streamhealth assessment for longwall 31. Prepared for Tahmoor Colliery.

Niche (2018c) Biodiversity Monitoring (Riparian and Amphibian Monitoring) Tahmoor North. Prepared for Tahmoor Colliery.

Niche (2014) Tahmoor North Longwalls 31 to 37 Terrestrial Ecology Assessment, Prepared for Tahmoor Coal December 2014

Appendix A: TARP Trigger Observations and Impacts associated with Longwall 31

Natural feature	Impact	Trigger	Monitoring	Timing and frequency	By whom	TARPs triggered?
Flora and fauna	Macroinvertebrates	None	Stream Health Assessment	Prior to undermining Redbank Creek End of Panel Reporting	Niche	Stream Health Monitoring has been completed by Niche. Details provided in Niche 2018a.
	Macroinvertebrates	Impacts occurring to the significance of stream health	ERG to consider any additional management and monitoring actions	Within 1 week	ERG	Redbank Creek is in a relatively poor condition prior to Longwall 31 mining. AUSRIVAS and SIGNAL completed as part of Niche (2018a) indicated that the poor health of Redbank Creek within the Longwall 31 Study Area is likely due to a number of factors including natural environmental stresses, local pollution from the urban catchment and undermining of the Redbank Creek from previous longwall mining upstream of Longwall 31. Whilst the monitoring to date along Redbank Creek detailed in Niche (2018a) indicated by AUSRIVAS and SIGNAL showed impairment of macroinvertebrates following mining, Redbank Creek was in a poor steam health state prior to mining of Longwall 31. Monitoring is recommended to continue to assist in interpreting this TARP.
			Prepare remediation plan in consultation with OEH and Fisheries	After active subsidence is complete	Tahmoor Colliery	
Flora and fauna	Amphibian	None	Record and monitoring prior to undermining Redbank Creek	Prior to undermining Redbank Creek	Niche	No threatened amphibians recorded during monitoring by Niche (2018c).
Flora and fauna	Amphibian	Impacts occurring to the significance of an amphibian population	ERG to consider any additional management and monitoring actions	Within 1 week	Niche	No threatened amphibians recorded during monitoring by Niche (2018c). No significant decline in amphibian populations detected during monitoring to date.
			Prepare remediation plan in consultation with OEH	After active subsidence is complete	Tahmoor Colliery	
Flora and fauna	Riparian	None	Record and monitoring	Prior to undermining Redbank	Niche	Riparian monitoring has not detected any

Natural feature	Impact	Trigger	Monitoring	Timing and frequency	By whom	TARPs triggered?
			prior to undermining Redbank Creek	Creek		significant changes in flora within the monitoring sites (Niche 2018c).
				End of Panel Reporting	Niche	
Flora and fauna	Riparian	Impacts occurring to the significance of ecology in riparian zone	ERG to consider any additional management and monitoring actions	Within 1 week	Niche	No vegetation die back has been observed during the monitoring or field survey. The riparian monitoring has not detected any significant changes in flora within the monitoring sites (Niche 2018c).
			Prepare remediation plan in consultation with OEH	After active subsidence is complete	Tahmoor	

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Our services

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Terrestrial
Freshwater
Marine and coastal
Research and monitoring
Wildlife Schools and training

Heritage management
Aboriginal heritage
Historical heritage
Conservation management
Community consultation
Archaeological, built and landscape values

Environmental management and approvals
Impact assessments
Development and activity approvals
Rehabilitation
Stakeholder consultation and facilitation
Project management

Environmental offsetting
Offset strategy and assessment (NSW, QLD, Commonwealth)
Accredited BAM assessors (NSW)
Biodiversity Stewardship Site Agreements (NSW)
Offset site establishment and management
Offset brokerage
Advanced Offset establishment (QLD)

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27 March 2019

Ms Fiona Robinson
Environment Coordinator
Tahmoor Colliery
Remembrance Drive
Tahmoor, NSW 2573

Via email: Fiona.Robinson@simecgfg.com

Dear Fiona,

Re: Tahmoor Colliery Longwall 31 End of Panel Reporting: Heritage review and reporting

As outlined in the Management Plan and Aboriginal Heritage Impact Permit (AHIP #3781) for the Aboriginal archaeological site Redbank Creek-1 (AHIMS ID #52-2-3254), Niche Environment and Heritage (Niche) has undertaken a further site inspection of Redbank Creek-1 to assess any observable impacts may have occurred to the site during the extraction of Longwall 31 with representatives from the following Registered Aboriginal Parties (RAPs):

- Cubbitch Barta Native Title Claimants
- Tharawal Local Aboriginal Land Council

Peter Falk, of Peter Falk consultancy has now retired and will not need any further consultation in regards to this project.

The inspection found that no new impacts have occurred at Redbank Creek-1 (AHIMS ID #52-2-3254) from the extraction process.

The following Historical Heritage Sites were assessed as part of this End of Panel assessment:

- Mill Hill; and
- Korana Homestead

The following recommendations have been made:

- Tahmoor Colliery should continue their consultation with the Aboriginal community in regards to Redbank Creek-1 (AHIMS ID #52-2-3254) as required by AHIP #3781; and
- Redbank Creek-1 (AHIMS ID #52-2-3254), Mill Hill and the Korana Homestead should continue to be monitored during the extraction of Longwalls 32

Please do not hesitate to contact me should you require any further information.

Yours sincerely

Renée Regal- Aboriginal Heritage Team Leader

Statement of management objective

The management objective of Redbank Creek-1 (AHIMS ID #52-2-3254) is to ensure that any impacts to the site resulting from the extraction of Longwall 31 are reduced and minimised over the long term. The impacts to be minimised include; adverse effects to the art panels of the site, through further movements of the shelter, or through changes to water seepage patterns due to subsidence related cracking.

Background and introduction

Niche was commissioned by Tahmoor Colliery to conduct an End of Panel assessment of the Aboriginal cultural heritage and Historical heritage sites within the limit of subsidence of Longwall 31 at Tahmoor Colliery.

The site inspections for this End of Panel assessment were carried out by Renée Regal (Aboriginal Heritage Team Leader--Niche), Sarah Hart (Ecologist- Niche) on 22 March 2019, Glenda Chalker (RAP-Cubbitch Barta Native Title Claimants) and Jason Mitchell (RAP- Tharawal Local Aboriginal Land Council).

Strata Control Technologies (SCT) (2014) predicted that the extraction of Longwalls 31 would have less than 20% chance of harming Redbank Creek-1. Such a risk is considered relatively high in the context of the Southern Coalfields, therefore an Aboriginal Heritage Impact Permit (AHIP) for Redbank Creek-1 (AHIMS ID #52-2-3254) has been obtained.

During this assessment no observable impacts as a result of mining were identified at the Aboriginal archaeological site of Redbank Creek-1 (AHIMS ID #52-2-3254). However, changes from seepage due to mould growth at the lower levels of the shelter were observed. It is unclear at this stage whether these changes can be attributed to mining. Further damage was evident to the back of the shelter at site Redbank Creek-1 and its deposit from wild goats rubbing against the sandstone and living in the shelter.

Niche (2014) identified three European heritage sites that could be impacted by subsidence from Longwall 31. Based on the predictions by MSEC (2014), Koorana Homestead is located directly above Longwall 32 and could experience minor impacts. Mill Hill is located at the end of Longwall 31 and could experience minor impacts. The Rural Landscape located on Thirlmere Way is unlikely to experience impacts from subsidence.

Koorana Homestead is listed as an item of local heritage significance on the Wollondilly Local Environmental Plan (LEP) 2011 ('Koorana Homestead, outbuildings and trees' – item ID:1207). Niche heritage consultants (2017) have prepared a Statement of Heritage Impact (SoHI) with the input from MSEC (subsidence engineers) and John Matheson & Associates (structural engineer). The SoHI for Koorana Homestead was prepared in consultation with the property owner and has been approved by Wollondilly Shire Council.

The site was inspected by MSEC during their works for this End of Panel assessment and there were no observed impacts as a result of mining.

Subsidence results summary (MSEC)

The End of Panel Subsidence Report for Longwall 31 prepared by MSEC (MSEC1001_Revision A) is a comprehensive report which addresses all aspects of the recorded subsidence parameters resulting from the extraction of Longwall 31.

In relation to matters that may affect Aboriginal cultural heritage values, MSEC notes the following (MSEC1001_Revision A: Table 4.1):

- In relation to Redbank Creek, stream bed cracking and loss of pool holding capacity has been observed in numerous pools and stream reaches in Redbank Creek over Longwall 31.
- No impacts were observed during the extraction of Longwall 31 to the steep slopes and cliffs.
- There were no impacts observed to Redbank Creek-1
- There were no impacts observed at Mill Hill or Korana Homestead.

Aboriginal community consultation

Aboriginal community consultation has continued as outlined in the recommendations made by Biosis Research (2009) and Niche (2014).

The following Aboriginal groups were contacted via email and telephone in March 2019 to organise a site inspection and sent a copy of the Longwall 31 End of Panel report:

- Cubbitch Barta Native Title Claimants
- Tharawal Local Aboriginal Land Council

The following RAPs registered their interest to attend:

- Mrs Glenda Chalker, Cubbitch Barta Native Title Claimants
- Rebecca Ede, Tharawal Local Aboriginal Land Council

A draft copy of this report was sent to the RAPs on 28 March 2019. Comments will be incorporated once they have been received.

Previous site assessment summaries

Historical Heritage

Niche (2014) identified three European heritage sites that could be impacted by subsidence from Longwall 31. Based on the predictions by MSEC (2014), Koorana Homestead is located directly above Longwall 32 and could experience minor impacts, Mill Hill is located at the end of Longwall 31 and could experience minor impacts and the Rural Landscape located on Thirlmere Way is unlikely to experience impacts from subsidence.

Koorana Homestead is listed as an item of local heritage significance on the Wollondilly Local Environmental Plan (LEP) 2011 ('Koorana Homestead, outbuildings and trees' – item ID: 1207). Niche heritage consultants (2017) have prepared a Statement of Heritage Impact (SoHI) with the input from MSEC (subsidence engineers) and John Matheson & Associates (structural engineer). The SoHI for Koorana

Homestead was prepared in consultation with the property owner and has been approved by Wollondilly Shire Council.

Niche were engaged by Tahmoor Colliery to prepare a SoHI for Mill Hill with input from MSEC (subsidence engineers) and John Matheson & Associates (structural engineer). The SoHI for Koorana Homestead will be prepared in consultation with the property owner was approved Wollondilly Shire Council on 4 October 2017.

The Rural Landscape adjacent to Thirlmere Way is partly located above Longwall 31. The vertical subsidence transitions from the maximum values directly above the proposed longwalls to slightly reduced values above the chain pillars. These variations in the vertical subsidence of around 200 mm to 300 mm occur over distances of 320 metres and, therefore, are not visually perceptible. It is unlikely, therefore, that the vertical subsidence would reduce the visual aesthetics or the heritage value of the land (MSEC 2014).

Aboriginal Heritage

Redbank Creek-1 (AHIMS ID #52-2-3254) was recorded with AHIMS in the 1990s prior to any detailed assessments of the site which occurred as a result of environmental assessments of potential subsidence effects associated with longwall mining. The Aboriginal archaeological site was inspected and assessed by Biosis in 2009 and re-recorded by Niche in 2014, as part of Tahmoor Colliery's AHIP application process. Summaries of both assessments are outlined below.

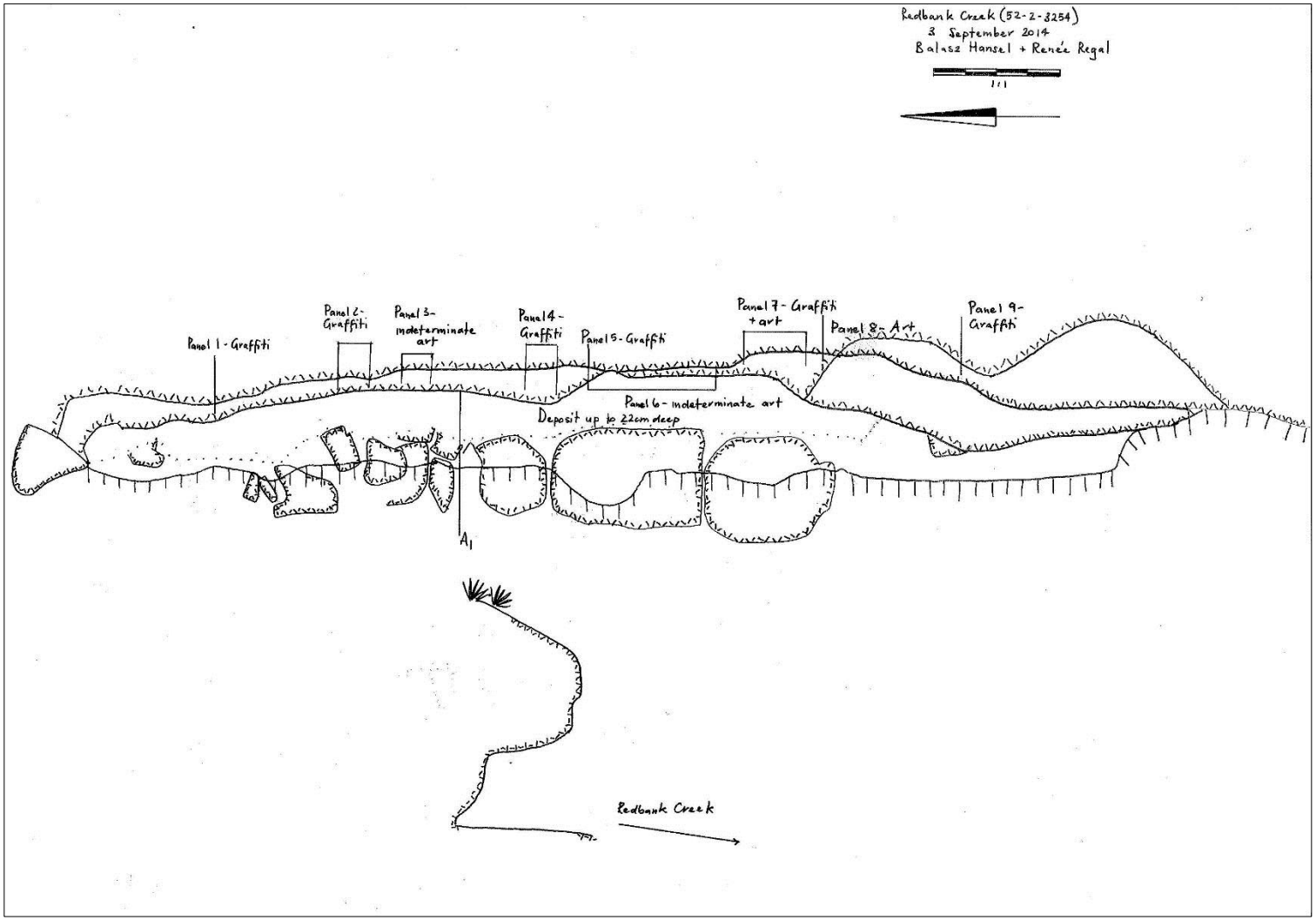
Redbank Creek-1 52-2-3254

This Aboriginal archaeological site is a shelter with art and deposit. The Aboriginal archaeological site was assessed in 2009 by Biosis, who recorded the following details:

The site has a large overhang that measures 24x4x3m with a living area approximately 10x5m; The shelter was formed by blockfall and cavernous weathering and faces north west; Grey loamy sand to an approximate depth of 35cm covers the floor of the shelter and 18 artefacts were identified; The art consists of one complete infill macropod and one infill indeterminates. Biosis also identified a number of new indeterminates under graffiti (Biosis 2009:72).

Biosis assessed that the condition of the shelter remained the same as its original recording, with the exception of faded and damaged artwork due to graffiti. The shelter was relatively dry with little microflora damage. The deposit had been disturbed by goats (Biosis 2009:72).

Niche (2014) conducted a detailed condition assessment of the site to be used as a baseline for any future assessments of the site's condition prior to any subsidence induced movements. The recording of the site included completing a revised site plan and section drawing (Drawing 1), additional photographs of the entire site, and noting features that would act as monitoring points. Attempts were made to find the previously identified stone artefacts within the drip-line, but they could not be located. It was considered that the artefacts had been disturbed through the extensive disturbance to the Aboriginal site by goats. The art was concluded to be in similar condition to its original recording in 1994.



Drawing 1. Revised site plan and section drawing of Redbank Creek-1 (Source: Niche 2014)

Subsidence summary

Strata Control Technologies (SCT) (2014) undertook a subsidence assessment for Redbank Creek-1. The assessment found that:

Site 52-2-3254 is associated with a sandstone cliff formation that is approximately 40m long, 6m high, and has an overhang of up to 4m. The probability of a rock fall at this site is assessed as being approximately 3 % based on experience of subsiding similar cliff formations elsewhere at Tahmoor Mine. The probability of perceptible impacts to the cliff formation such as cracking, shear movements, and possible dislocation of small pieces is assessed as being less than 20%. The bed of Redbank Creek adjacent to the site is considered likely to become fractured with surface flow diversion into the sub-surface fracture network (SCT 2014:i).

The assessment also found that intense rainfall in early 2013 had resulted in high levels of natural ground movement particularly in the vicinity of Dog Trap Creek, located near Redbank Creek. Natural rock falls, block movements, opening up of cracks in the ground, tree root invasion, and sediment rich water flowing out from the back of the overhanging rock formations caused discolouration of the back walls and the depositing of sediment. No mining had occurred in this area and the assessment demonstrated that such natural changes have the potential to degrade archaeological sites, irrespective of mining activity (SCT 2014:i).

MSEC (2014) prepared a management plan for potential impacts to Redbank Creek-1. The level of risk associated with impacts on the rock overhang, resulting in impacts on the artwork were assessed as moderate to very slight to low.

Monitoring measures of the site outlined in the plan are:

Ground Survey

Survey pegs are located along the valley sides of Redbank Creek to monitor subsidence and horizontal movements. They will be surveyed by Tahmoor Colliery on a minimum frequency of once per month when Redbank Creek is located with the active subsidence zone for each of Longwalls 29 to 31.

The survey results will inform the CHMP of the general nature of subsidenec movements in the vicinity of the site and when the rates of change in subsidenec have reduced to low levels.

Visual Inspections

Visual inspections of Redbank Creek will be undertaken by Tahmoor Colliery on a weekly basis during the period of active subsidence. The inspector will check the condition of Redbank Creek 1 from a remote distance as part of these inspections. For safety reasons, detailed inspections will not be undertaken during periods of active subsidence as if a rock fall occurs, there may be little warning beforehand.

*A detailed visual inspection will be undertaken by an archaeologist within 4 months of the completion of extraction of each of Longwalls 29, 30 and 31 and findings distributed to Office of Environment and Heritage and Aboriginal Stakeholders in the End of Panel Report (*MSEC 2014:11).

This End of Panel report has been written in accordance with the MSEC 2014 Management Plan for Redbank Creek-1.

Site inspection and results

A site inspection and assessment was carried out on 22 March 2019 by Renée Regal (Team Leader-Aboriginal Heritage) and Sarah Hart (Ecologist) and the following Registered Aboriginal Parties (RAPs):

- Mrs Glenda Chalker, Cubbitch Barta Native Title Claimants
- Mr Jason Mitchell, Tharawal Local Aboriginal Land Council

The purpose of the assessment was to observe and document the current conditions of Redbank Creek-1 so that any changes since the previous recordings could be documented. A summary of the findings are outlined in Table 1.

Table 1: Results

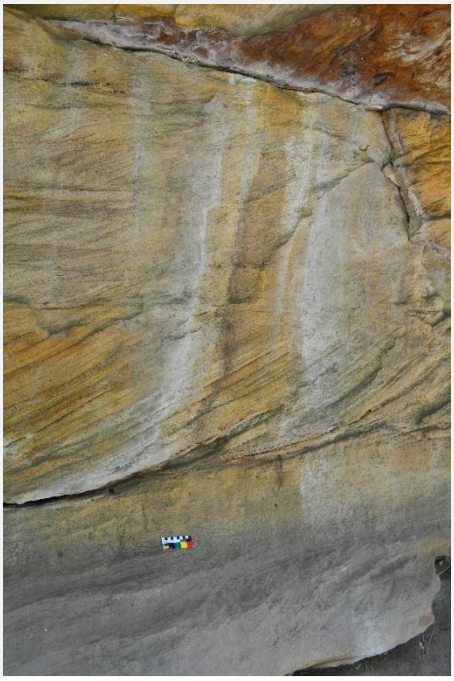
AHIMS Site #	Site Name	Results of Inspection	Photos
52-2-3254	Redbank Creek-1	The condition of the site has not changed due to mining related impacts since the Niche 2014 condition assessment of the site. The floor and back wall of the shelter however have suffered some damage as a result of wild goats living in the shelter. Seepage and mould growth are evident to the lower levels of the shelter	 Plate 1: View of Redbank Creek-1, photograph taken facing north  Plate 3: Naturally occurring mineral that was identified previously when monitored.

Plate 5: Overview of artefacts found within the shelter dripline.

Discussion and Conclusion

There were no observable changes as a result of the extraction of Longwall 31 to Redbank Creek-1.

The Trigger Action Response Plan (TARP) (Table 2) contains the Performance Measures along with the proposed Corrective Management Actions for Aboriginal heritage sites; as outlined in the Longwalls 27 to 30 SMP (Xstrata Coal Tahmoor 2013) and the Tahmoor Colliery Longwall 31 Environmental Management Plan (Tahmoor 2017).

The recommendations made below are designed to allow Tahmoor Colliery to discharge its obligations under the aforementioned management plan.

Recommendations

Based on community consultation with Aboriginal Stakeholders, baseline recordings, geotechnical assessments by Dr Ken Mills of SCT, Daryl Kay of MSEC, and Aboriginal Cultural Heritage Assessments by Niche (2014) and Biosis Research (2009), the following recommendations have been made for Redbank Creek-1 (AHIMS ID# 52-2-3254), Mill Hill, Korana Homestead and the Thirlmere Rural Landscape.

Recommendation 1:

Tahmoor Colliery should continue their consultation with the Aboriginal Community in regards to Redbank Creek-1 (AHIMS ID# 52-2-3254).

Recommendation 2:

Redbank Creek-1 (AHIMS ID# 52-2-3254), Mill Hill and Korana Homestead should continue to be monitored during the extraction of Longwalls 32.

Table 2: Trigger Action Response Plan

Feature	Monitoring			Management	
	Prior to Mining	**During Mining**	**Post Mining**	**Trigger**	**Action**
Aboriginal sandstone shelter sites: 52-2-3254	Baseline archival recording prior to Longwall mining Re-recording of the principal components identified by Sefton (Sefton 2000) Macro and micro recording using digital photography (Navin Officer 2003) Detailed elevation plans of shelter walls recording structural and surface features including but not limited to the art itself, graffiti, joints, bedding planes, exfoliation scars, cracks, mineral and micro-organism growth, drip line and water seepage locations.	First impact assessment recording following initial subsidence movement of site Sandstone shelter and sites will be monitored during mining.	Further impact assessment recording twelve months after subsidence movement of the sites.	**Negligible** Change in shelter conditions not attributable to natural weathering or preservation that do not alter the heritage values of the place- e.g. mineral growth or micro-organism growth. Changes external to the shelter that effect cracking, boulder slumping, rock and/or tree falls. NO MAJOR TRIGGERS OBSERVED, CONTINUE WITH APPROVED ACTIONS **Major** Change in shelter condition not attributable to natural weathering or preservation- change in drip line or seepage, e.g. cracking or exfoliation of overhang or shelter, movement or opening of existing planes and joints. NO MAJOR TRIGGERS OBSERVED, NO ACTION REQUIRED. **Severe** Change in shelter conditions not attributable to natural weathering or preservation- e.g. cracking or exfoliation of art panel, movement of existing planes and joints in panel, block fall within the shelter or overhang, shelter or overhang collapse.	Continue with monitoring program if safe to do so. COMPLETED BY THIS REPORT Condition assessment and photographic record COMPLETED BY THIS REPORT Notify other relevant specialists COMPLETED BY THIS REPORT Notify key Stakeholders e.g. Aboriginal Groups, DRE and OEH COMPLETED BY THIS REPORT Report in End of Panel report and AEMR. COMPLETED BY THIS REPORT Continue with proposed monitoring program Condition assessment recorded Notify relevant technical specialists and seek advice on any Corrective Management Action (CMA) required. Notify key stakeholders e.g. Aboriginal Groups, DRE, OEH. Implement agreed CMAs as approved. Report in mitigation report, End of Panel Report and AEMR. Continue with proposed monitoring program Condition assessment recorded

		NO SEVERE TRIGGERS OBSERVED, NO ACTION REQUIRED.	Immediately notify relevant Aboriginal Groups, government agencies, other resource managers and relevant technical specialists and seek advice on any CMA required. Site visits with stakeholders if required. Develop site CMA in consultation with key stakeholders within 1 month. Completion of works following approvals Issue CMA report within 1 month of works completion Conduct initial follow up monitoring and reporting within 2 months of CMA completion if required. Report in mitigation report, End of Panel Report and AEMR.
Koorana Homestead	Baseline heritage and structural assessments. Surveys and visual inspections as outlined in Property Subsidence Management Plan (PSMP) Review monitoring data	None outlined.	Include in Subsidence Monitoring Report, End of Panel Report and Annual Review COMPLETED BY THIS REPORT
Mill Hill	Baseline heritage and structural assessments. Surveys and visual inspections as outlined in Property Subsidence Management Plan (PSMP) Review monitoring data	None outlined.	Include in Subsidence Monitoring Report, End of Panel Report and Annual Review COMPLETED BY THIS REPORT

References

Biosis Research 2009 *Longwalls 27-30 Subsidence Management Plan.* An unpublished report for Xstrata, Tahmoor Colliery

MSEC 646-46 RevA 2014. *Glencore Tahmoor Colliery- Longwalls 28-31: Management Plan for Potential Impacts to Item of Cultural Significance; Redbank Creek 1.* An unpublished Management Plan for Tahmoor Colliery

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Strata Control Technologies TAH4182_REV1. 2014. *Subsidence Assessment for Archaeological Site 52-2-3254, Redbank Creek.* An unpublished report for Tahmoor Colliery.

Tahmoor Colliery (2017) *Tahmoor Colliery LW 31Environment Management Plan*. An unpublished report for Tahmoor Colliery

Xstrata Coal Tahmoor 2013 *Longwalls 27 to 30 Environment Management Plan*. An unpublished report for Tahmoor Colliery.

Appendix 1: Aboriginal Community responses to the draft report