mine subsidence
ENGINEERING CONSULTANTS

SIMEC Mining:

Tahmoor Coal - Longwall 32

End of Panel Subsidence Monitoring Report for Longwall 32

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A	First issue	DJK	Mar-20
B	Final issue	DJK	Mar-20

Report produced for:- Compliance with conditions attached to the SMP Approval set by DTIRIS.

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.

MSEC (2018). Tahmoor Coking Coal Operations – Modification of SMP Application for Longwall 32. (Report MSEC969, Revision B, July 2018), prepared by Mine Subsidence Engineering Consultants.

MSEC993-R01 to MSEC993-R54 – Subsidence Monitoring Reports, issued during the extraction of Longwall 32 between November 2018 and November 2019.

MSEC994-R03 to MSEC994-R56 – Main Southern Railway Monitoring Reports, issued during the extraction of Longwall 32 between November 2018 and January 2020.

GeoTerra (2020). Longwall 32 Surface Water, Dams & Groundwater End of Panel Monitoring Report, Tahmoor, NSW. Report No. TA35-R1, March 2020.

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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 Coal to comply with conditions of the SMP Approval for Tahmoor Longwall 32 dated 14 September 2018.

This report includes:-

- A summary of the subsidence and environmental monitoring results for Longwall 32.
- 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 32 is shown in Drawing No. MSEC1085-01, which 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 32. 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 32

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
Longwall 32	29 October 2018	26 September 2019

The predicted movements and impacts resulting from the extraction of Longwall 32 were provided in Report No. MSEC647 (2014, Revision A) and Report No. MSEC969 (2018, Revision B). The comparisons provided here are based on the subsidence predictions provided in these reports.

Longwall 32 was approximately 2,380 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 32. This chapter also provides comparisons between the observed and predicted movements resulting from the extraction of Longwall 32.

Chapter 3 of this report summarises the surveys and inspections undertaken during the mining of Longwall 32.

Chapter 4 of this report describes the reported impacts on surface features resulting from the extraction of Longwall 32 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 32 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 32 (beyond creeks)

Monitoring Line	Maximum Observed Subsidence (mm)	Maximum Observed Tilt (mm/m)	Maximum Observed Tensile Strain (mm/m)	Maximum Observed Comp. Strain (mm/m)
Incremental due to LW32 only	975	8.8	1.3	-2.1
Total after LW32	1089	8.9	1.9	-4.5

The maximum observed incremental subsidence was greater than predicted maximum incremental subsidence for Longwall 32, which was 700 mm. This is greater than the typical range of accuracy of the predictions, though the potential for increased subsidence above Longwall 32 was raised in the subsidence prediction reports.

The maximum predicted total subsidence within the SMP Area for Longwall 32 was 1025 mm, which is slightly less than the maximum observed subsidence of 1089 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 32 are summarised in Table 2.2. The maximum value for each parameter (not including creeks) is highlighted in blue.

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)
LW32 centreline	LW32 Inc	975	5.5	1.3	-0.3
Wonga Road	LW32 Inc	0	0.6	0.2	-0.1
Coachwood Crescent	LW32 Inc	2	0.1	0.1	-0.0
Nepean Fault Line 1	LW32 Inc	32	0.4	0.3	-0.6
Nepean Fault Line 2	LW32 Inc	72	0.6	0.3	-0.4
Nepean Fault Line 3	LW32 Inc	71	0.7	0.5	-0.3
Tahmoor Rising Main	LW32 Inc	20	0.4	0.2	-0.4
Picton Rising Main	LW32 Inc	37	0.4	0.3	-0.3
Remembrance Drive	LW32 Inc	267	1.9	0.6	-2.1
	Total	307	2.4	0.6	-2.1
Stilton Lane	LW32 Inc	762	5.6	0.7	-1.3
	Total	1063	8.0	1.9	-2.6
Bridge St	LW32 Inc	828	5.1	0.5	-0.8
	Total	1039	5.1	0.7	-4.5
Redbank Place	LW32 Inc	452	0.8	0.1	-0.1
	Total	514	0.7	0.3	-0.1
Bollard Place	LW32 Inc	198	2.5	0.6	-0.0
	Total	186	2.5	0.4	-0.1
Thirlmere Way	LW32 Inc	128	1.7	0.3	-0.5

Monitoring Line		Maximum Observed Subs (mm)	Maximum Observed Tilt (mm/m)	Maximum Observed Tensile Strain (mm/m)	Maximum Observed Compressive Strain (mm/m)
	Total	131	1.7	0.5	-0.6
Optical Fibre Line	LW32 Inc	87	1.0	0.4	-0.4
	Total	**1089**	4.4	1.1	-4.2
Thirlmere Carrier (East)	LW32 Inc	887	**8.8**	0.7	-1.1
	Total	884	**8.9**	0.6	-1.0
Thirlmere Carrier	LW32 Inc	828	0.2	0.4	-0.2
	Total	855	3.1	1.4	-0.7
Main Southern Railway (2D) (incl. creek)	LW32 Inc	785	7.5	1.3	-1.6
	Total	1065	8.7	1.4	-9.6

2.1.2. Observed subsidence during the extraction of Longwall 32

Extensive ground monitoring above previously extracted longwalls at Tahmoor Mine has allowed detailed comparisons to be made between predicted and observed subsidence, tilt, strain and curvature during the mining of Longwalls 22 to 32.

The extraction of longwalls at Tahmoor 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.

During the mining of Longwall 24A at Tahmoor Mine, substantially increased subsidence was observed and further increases in observed subsidence compared to the predicted subsidence was observed in Longwall 25. The increased levels of subsidence were a very unusual event for the Southern Coalfield and immediate investigations were undertaken to identify why it occurred. The conclusions of these studies were published in 2011 in a paper by W. Gale and I. Sheppard, which advised that the increased levels of subsidence were likely to be associated with the proximity of these areas to the Nepean Fault and the Bargo River Gorge and a recognition of the impact of a weathered zone of joints and bedding planes above the water table, which reduced the spanning capacity of the strata below this highly weathered section. This later recognition was determined after extensive computer modelling of factors that may have caused the increased subsidence.

Further subsidence monitoring occurred over Longwalls 26 to 32 within and around this zone of increased subsidence since 2011. The observed zone of increased subsidence extended over the Longwalls 24A to 27, though the extent of the increase in subsidence has reduced in magnitude as each longwall was extracted. Monitoring during the mining of Longwalls 28 to 30 has found that subsidence behaviour had returned to normal levels.

Whilst subsidence movements had returned to normal levels, it was considered possible that increased subsidence might return to higher than normal levels during the mining of Longwalls 31 and 32 (Report MSEC969). The potential was discussed in light of revised mapping of the Nepean Fault as comprising a series of en echelon faults, rather than one continuous geological structure. The mapping showed that subsidence may have returned normal levels as the fault echelon structure that is linked to increased subsidence above Longwalls 24A to 27 terminated beyond Longwall 29, as shown in Fig. 2.2.

Prior to the mining of Longwall 32, it was considered possible that subsidence might return to higher than normal levels during the mining of Longwall 32, as it would mine adjacent to another fault echelon structure as shown in Fig. 2.2. It was noted, however, the observations above previously extracted Longwalls 30 and 31 indicated that subsidence has been developing close to normal levels.

The monitoring results during the mining of Longwall 32 showed, however, that increased subsidence has developed above the commencing end of Longwall 32 at levels similar to those observed above Longwall 26, as shown in Fig. 2.1. The magnitude of subsidence reduces along the panel as the longwall face progressed to the north, though subsidence was generally at the higher end of the previously observed range.

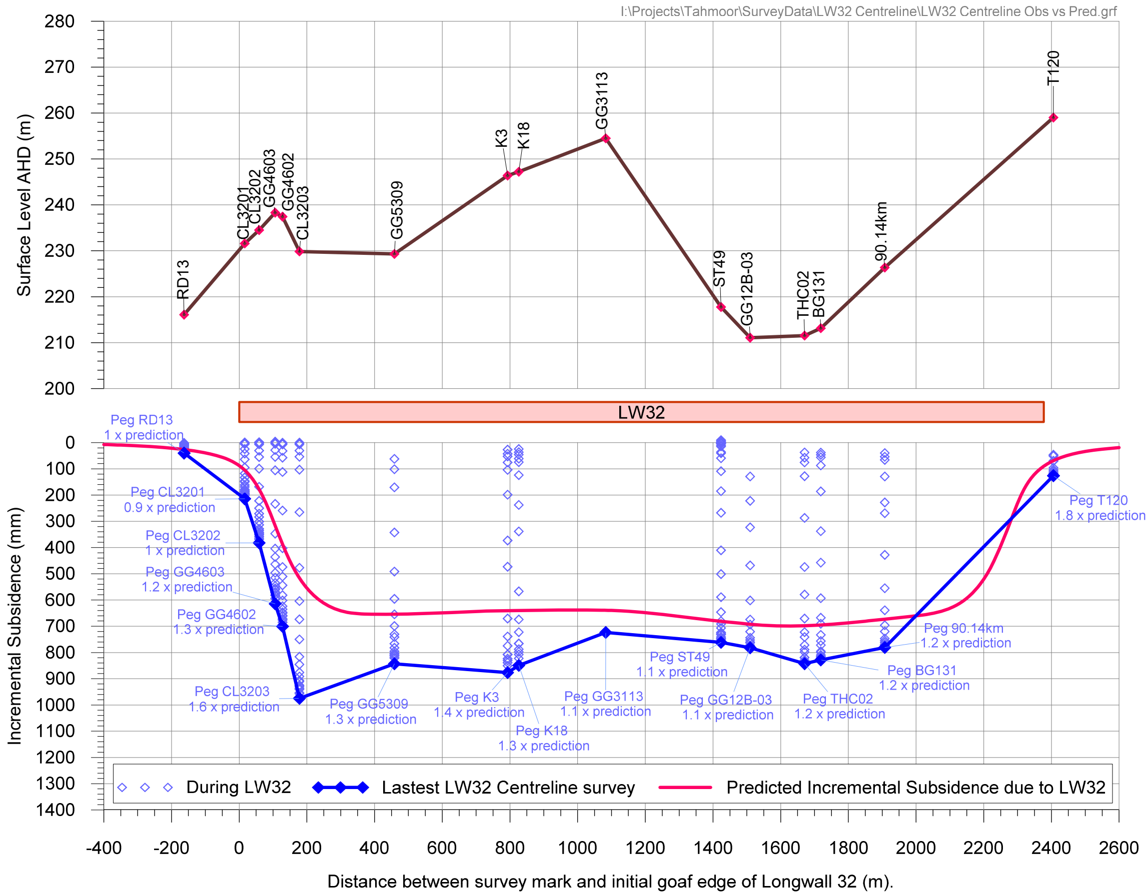

Fig. 2.1 Observed incremental subsidence along centreline of Longwall 32

The observation above the commencing end of Longwall 32 has shown that increased subsidence has developed where mining has occurred close to the mapped first order fault echelon structures. In this case, Peg CL3203 is located approximately 700 metres to the west of the mapped first order fault and the commencing end of the panel is located at the head of a fault ramp, in between two fault echelons. As observed during the mining of Longwalls 24A to 26, the magnitude of subsidence was reduced over the unmined, solid coal side of Longwall 32. Many survey pegs were installed across the mapped first order fault structure and associated second order geological structures to the side of Longwall 32. No increased differential subsidence movements were observed to the side of Longwall 32.

It should be noted that the potential impacts of increased subsidence on the structures and infrastructure within the overlying areas above the extracted longwalls were successfully managed by Tahmoor Coal through the implementation of effective subsidence management plans, including in areas where increased subsidence was observed.

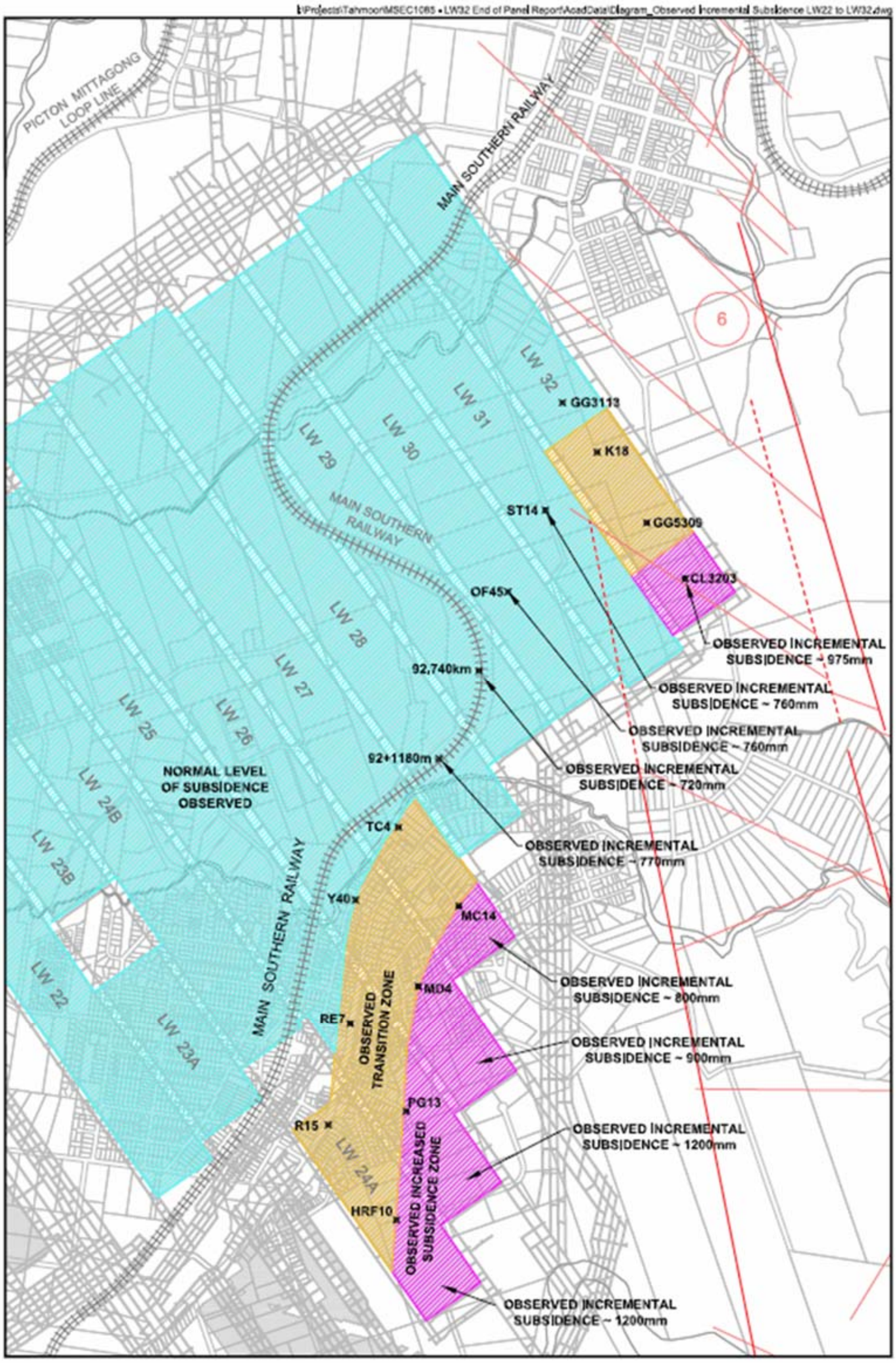

Fig. 2.2 Zones of increased subsidence over Longwalls 22 to 32

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 32, for survey bays located directly above goaf, is shown in Fig. 2.3. 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.

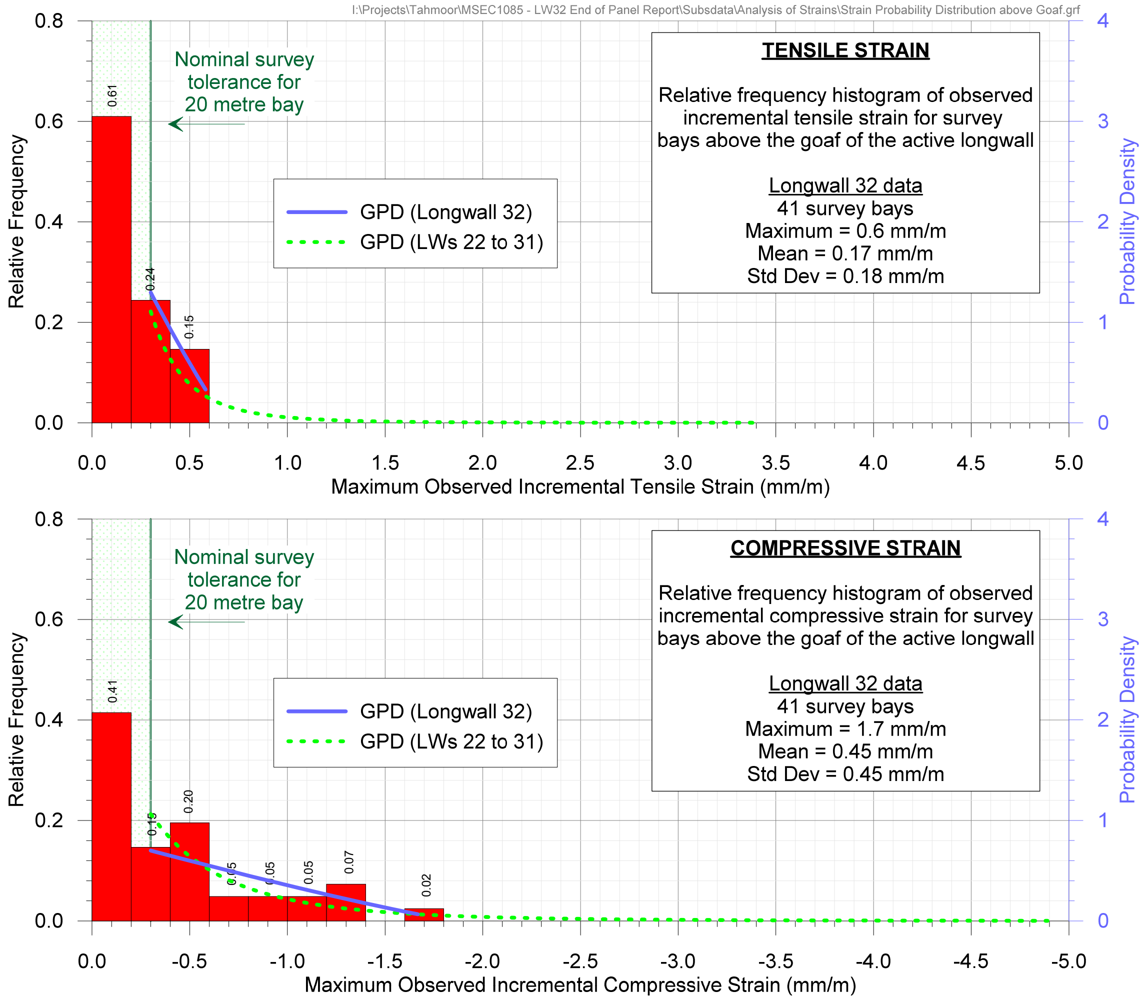

Fig. 2.3 Observed incremental strain for survey bays above goaf resulting from the extraction of Longwall 32

A *Generalised Pareto Distribution (GPD)* has been fitted to the raw strain data for Longwall 32, as shown in blue. The probability distribution functions for previous monitoring during the mining of Longwalls 22 to 31 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 32 was similar to that observed during the mining of Longwalls 22 to 31.

2.2. Identification of non-systematic subsidence movements

A plan showing the locations of observed non-systematic movements at Tahmoor is shown in Fig. 2.4. 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 59 locations (not including valleys) have been identified over the extracted Longwalls 22 to 32, of which 4 new locations were observed during the mining of Longwall 32.

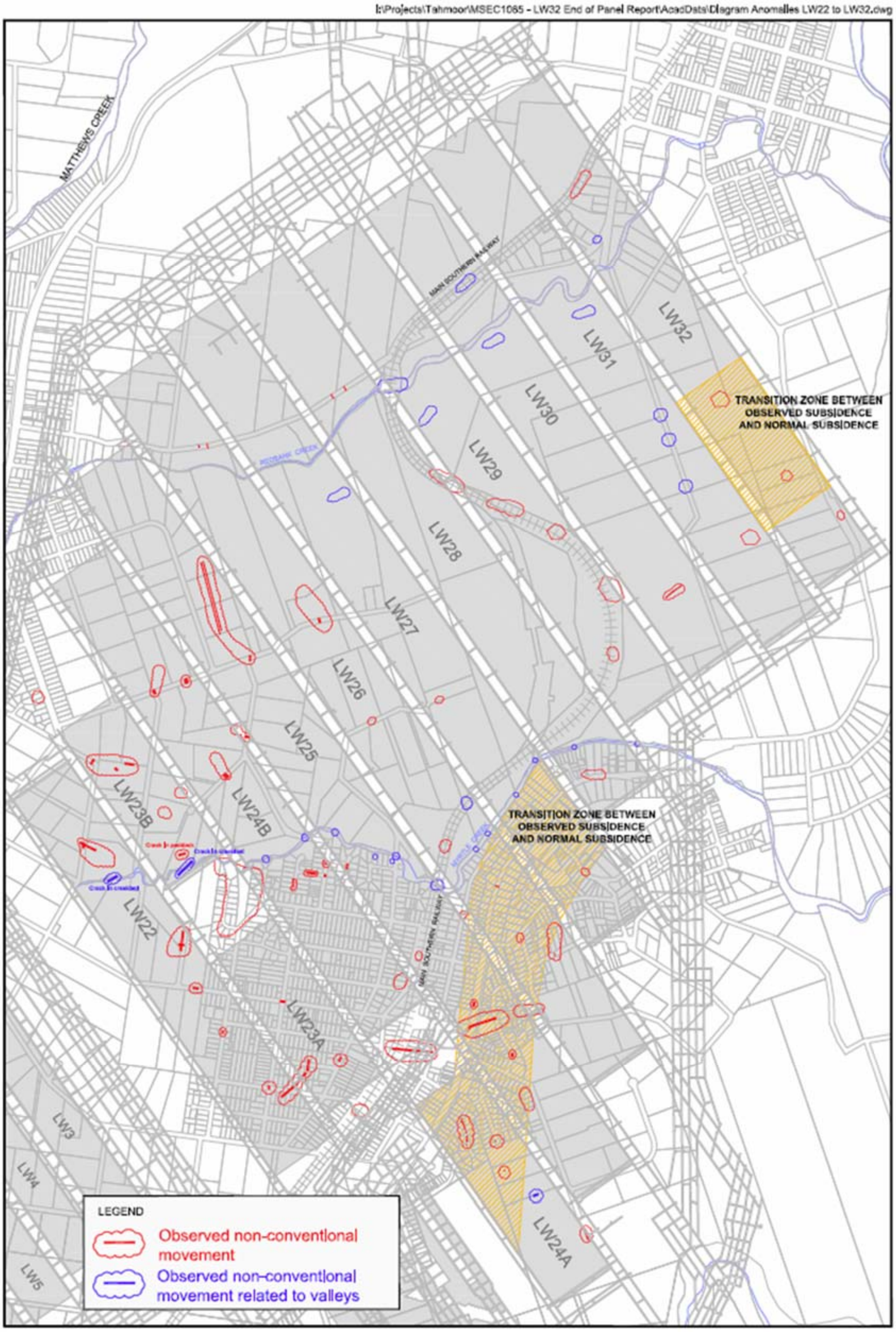

Fig. 2.4 Map of locations of potential non-systematic movements

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 32

Monitoring line or location	Maximum change in vertical alignment during LW32 (mm)	Maximum incremental strain during LW32 (mm/m)	Type	Impacts on surface features
Main Southern Railway at 90.060 km to 90.180 km	62 mm over 60 m bay	-1.7	Non-conventional movement	Change in track geometry, requiring Temporary Speed Restriction of 60 km/hour between 11 & 21 August 2019. Track resurfaced during and after this period to maintain track safety and operations. Minor cracks observed to neighbouring industrial properties.
Remembrance Drive Pegs RD26 to RD27	30 mm over 49 m bay	-2.2	Non-conventional movement	Cracks and compressive humps observed alongside of road pavement. Leak to water main, which was immediately repaired.
Bridge Street Pegs BG128 to BG129	9 mm over 49 m bay	-0.9	Valley closure	Cracks and compression observed in concrete kerb. Minor leak to water hydrant connection, which was immediately repaired.
Pegs GG5304 to GG5305	100 mm over 24 m bay	-7.4	Non-conventional movement	Compression hump developed in pavement between house and pool, with impacts also extending to the pool gates, one corner of house and external sheds. Ongoing repairs conducted at the property.
Structure GG32	-	-	Non-conventional movement	Compression hump developed in the driveway on eastern side of shed. Additional structural supports installed to shed. No survey pegs in this location.

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 monitoring lines have been installed along Bridge Street and the Thirlmere Carrier (East) line and in cleared pasture land along the top of the Redbank Creek valley, as shown in Fig. 2.5. Relative 3D surveys have provided measurements of total valley closure during the mining of previously extracted longwalls.

Access was not provided by the landowner on the majority of the survey pegs along the southern side of Redbank Creek during the mining of Longwall 32. This unfortunately prevented the surveyors from conducting the relative 3D surveys. Access has recently been granted by the landowner and it is planned to conduct a survey for Longwall 32 in late March 2020.

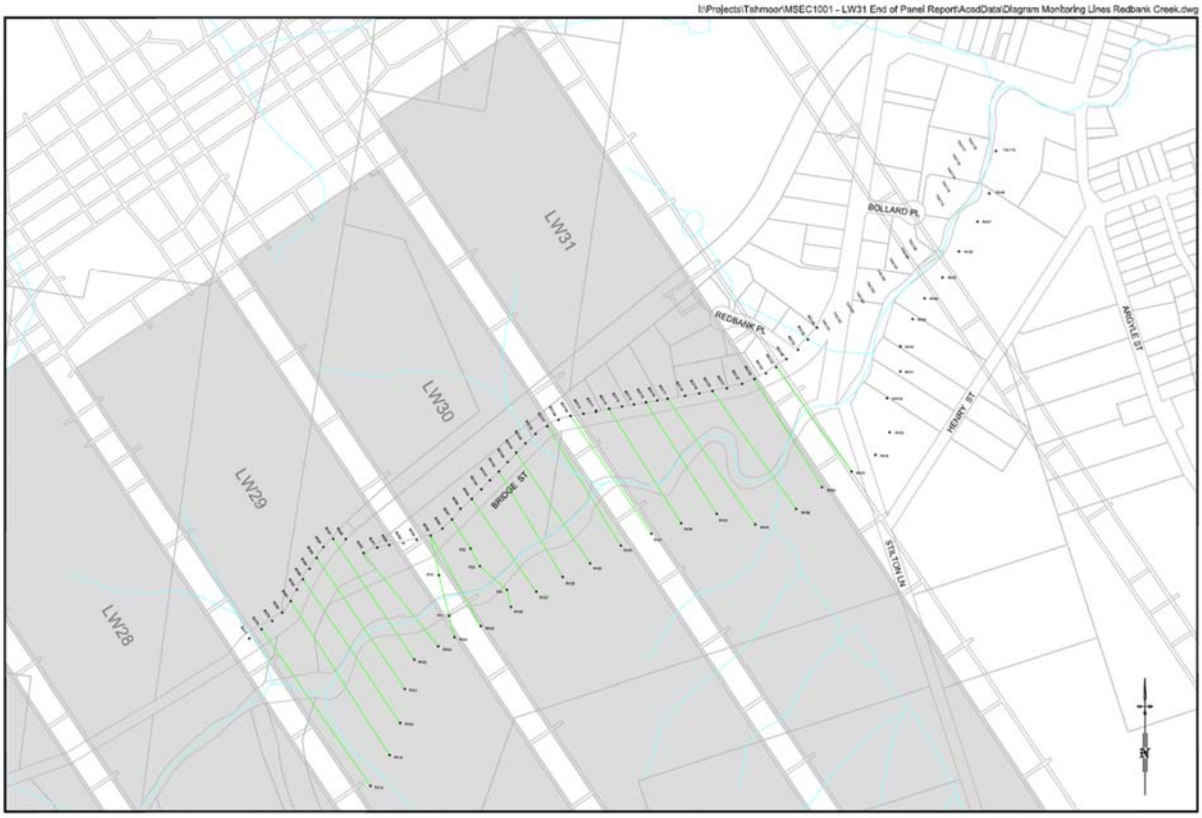

Fig. 2.5 Location of survey marks across Redbank Creek

Survey pegs were, however installed across the sewer aqueduct crossing of Redbank Creek between Pegs THC18 and THC19, which is located approximately 200 metres to the side of the longwall panel. No measurable valley closure was observed during the mining of Longwall 32. Additional marks were installed on the aqueduct structure itself, with no measurable changes observed.

Survey pegs were also installed where Remembrance Drive crosses Redbank Creek between Pegs RD91 and RD92, which is located approximately 360 metres to the side of the longwall panel. No measurable valley closure was observed during the mining of Longwall 32. Additional marks were installed on the road and pedestrian bridge structures, with no measurable changes observed.

2.4. Main Southern Railway

The Main Southern Railway was surveyed in either 2D or 3D for a total of 22 times on a monthly to weekly basis during the extraction of Longwall 32. Details of the monitoring undertaken are provided in the monitoring reports prepared by MSEC on behalf of Tahmoor Coal and these reports have been provided to ARTC throughout the mining period.

The Main Southern Railway experienced maximum incremental subsidence of 785 mm and maximum total subsidence of 1065 mm during the mining of Longwall 32.

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

- Observed maximum incremental subsidence is greater than predicted maximum subsidence. The difference is within 15% of the prediction, which is within the typical range of accuracy. Observed maximum total 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.
- A bump was observed in the subsidence profile and closure was measured across the cutting batters between 90.060 km to 90.180 km.
- Observed ground strains along the railway corridor were 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 32. Rail stresses exceeded the Blue trigger on two occasions during the mining of Longwall 32, 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 32. 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 7 ground surveys, 6 extensometer surveys and 8 detailed visual inspections were undertaken for the Redbank Creek Culvert and Embankment on a monthly basis in accordance with the agreed management plans with ARTC.

The Culvert has subsided between approximately 340 mm and 620 mm in total during the mining of Longwalls 27 to 32.

Observed absolute horizontal movements along the Main Southern Railway are shown in Fig. 2.6. 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. 2.7. 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. 2.8. 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 282 mm, the culvert barrel at the inlet has closed by 92 mm. Measured closure at the ends of the wingwall on the downstream end is 60 mm, and the culvert barrel at the inlet has closed 19 mm.

Fig. 2.6 Observed total horizontal movement along Main Southern Railway during the mining of Longwalls 27 to 32

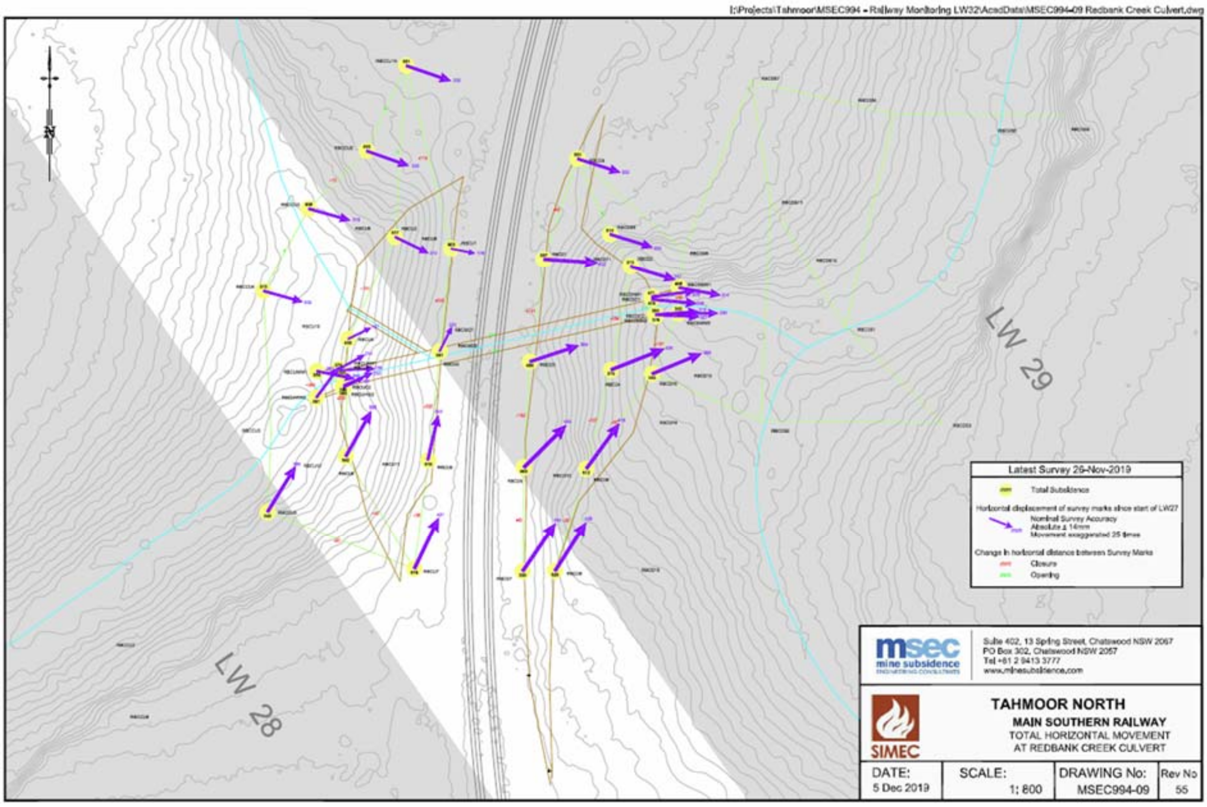

Fig. 2.7 Observed total horizontal movement at Redbank Creek Culvert and embankment during the mining of Longwalls 27 to32

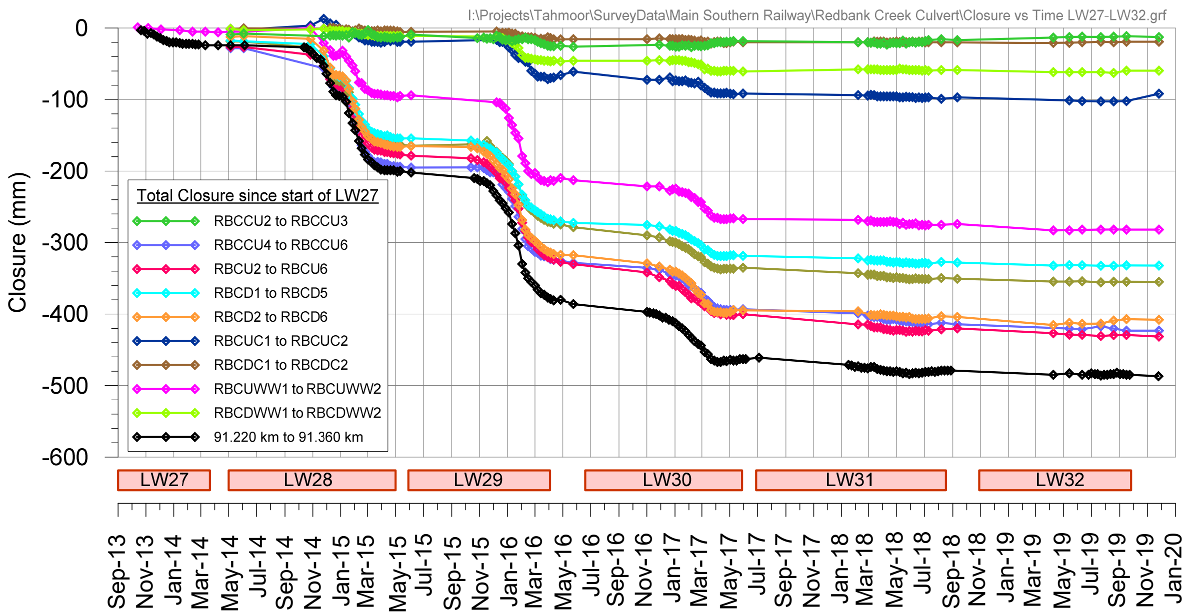

Fig. 2.8 Observed total valley closure over time across Redbank Creek Culvert at Main Southern Railway during the mining of Longwall 32 (includes closure from Longwalls 27 to 31)

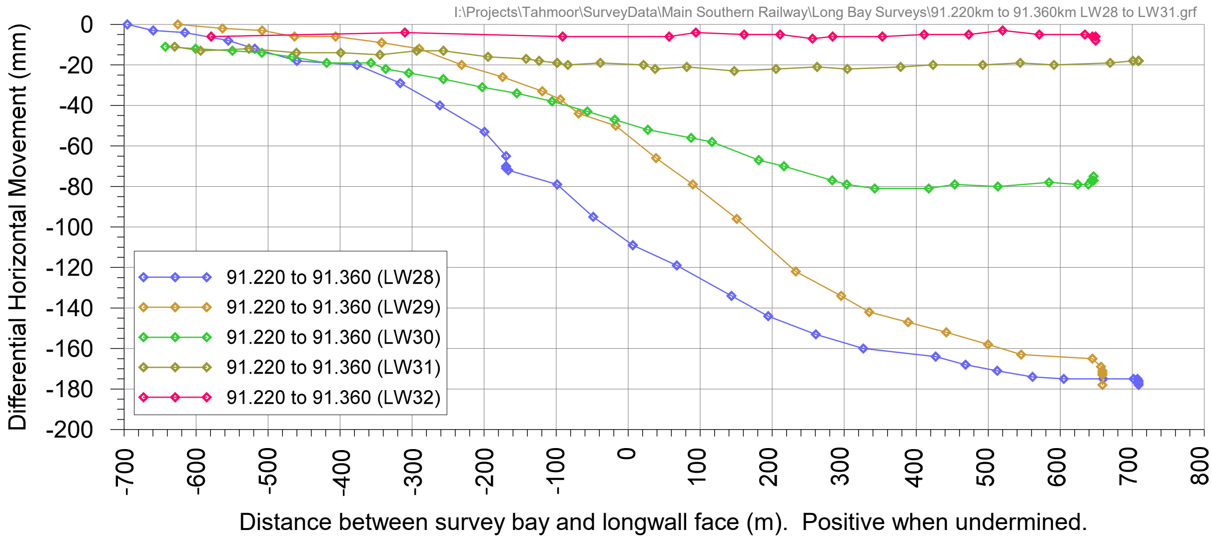

Fig. 2.9 Observed incremental valley closure as measured by long bay survey, relative to face distance, across Redbank Creek Culvert at Main Southern Railway during the mining of Longwalls 28 to 32

It can be seen from Fig. 2.9 that no measurable valley closure movements occurred during Longwall 32.

Observed subsidence along the base of the embankment on the upstream side is shown in Fig. 2.10. The results show valley closure focussing between Pegs RBCCU4 and RBCCU6, with upsidence observed at Peg RBCCU4. It can also be seen that no measurable change in ground strain was observed during the mining of Longwall 32.

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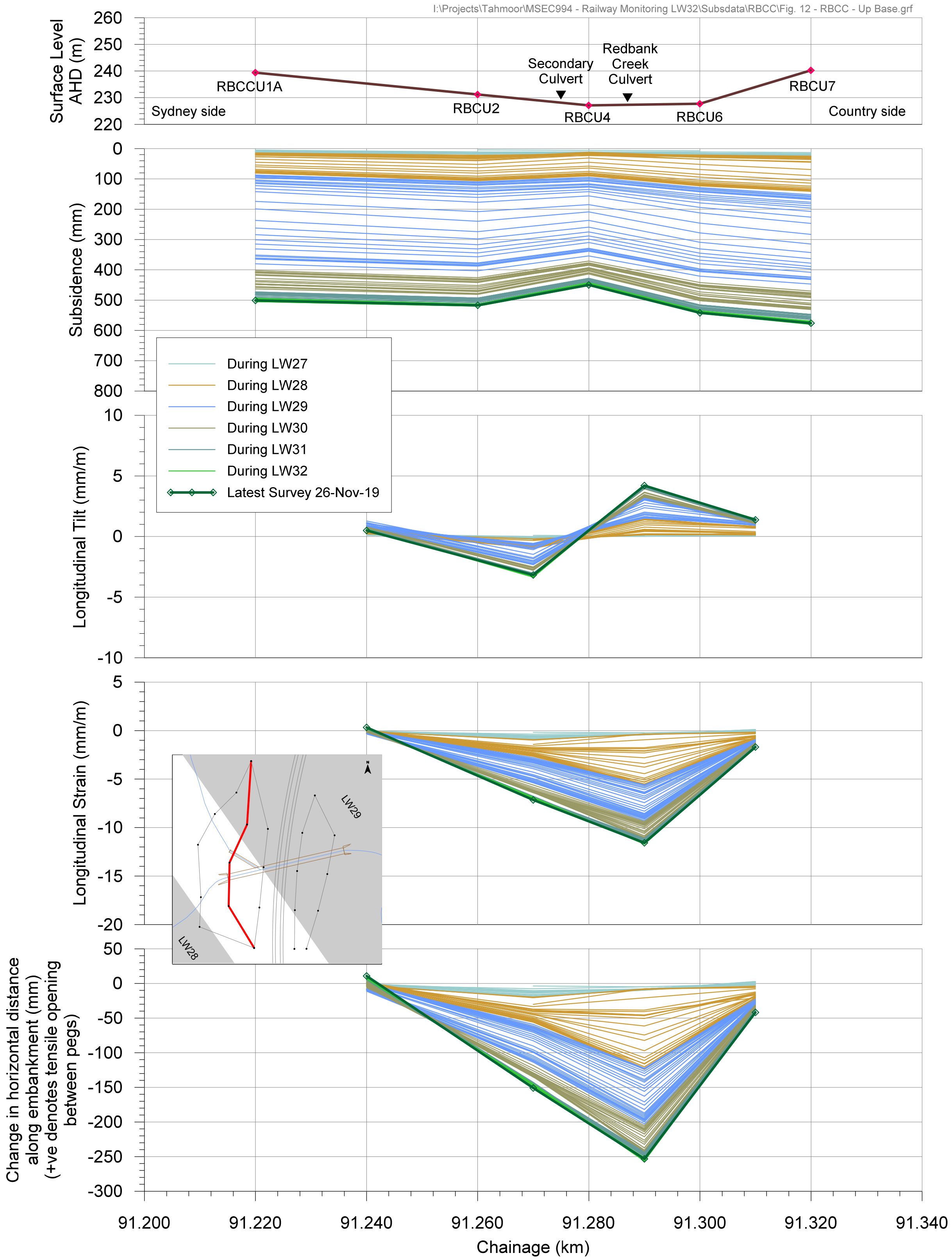

Fig. 2.10 Observed total subsidence, tilt and strain across the upstream base of Redbank Creek Culvert due to the mining of Longwalls 27 to 32

2.5. Picton Water Recycling Plant

2.5.1. Ground surveys

Extensive surveys were conducted on a weekly basis within the Picton Water Recycling Plant (PWRP) during the mining of Longwall 32. The survey marks extended across the mapped Nepean Fault structures, with results shown in Fig. A.04 to A.06.

Low level subsidence developed gradually within the PWRP, with very low measurable differential movements observed, including across the Nepean Fault structures.

Very little change was observed within the PWRP plant itself, with approximately 10 mm change in height from one end of the plant complex to the other. Very minor ground strains were observed along or across the Western Dam embankment.

2.5.2. Laser distancemeters

Laser distancemeters measured distances across each of the PWRP plant structures every 5 minutes. No measurable mining-induced changes were observed, with changes in distances observed over time with seasonal changes in temperature.

2.6. Sewer Infrastructure

Subsidence monitoring was undertaken along the Tahmoor Rising Main into the PWRP, Picton Rising Main into the PWRP, along streets and along the Thirlmere Carrier pipe during the mining of Longwall 32.

The Tahmoor Rising Main transports wastewater under pressure from a pumping station adjacent to Myrtle Creek into the PWRP. Weekly surveys measured low level subsidence movements, with no measurable differential movements, as shown in Fig. A.07.

The Picton Rising Main transports wastewater under pressure from a pumping station adjacent to Redbank Creek into the PWRP. Weekly surveys measured low level subsidence movements, with no measurable differential movements, as shown in Fig. A.08.

The Thirlmere Carrier is the main branch servicing the majority of Thirlmere township. Weekly surveys were undertaken along the Thirlmere Carrier during the mining of Longwall 32, with results shown in Fig. A.23 to Fig. A.26. Whilst the Thirlmere Carrier experienced the full range of subsidence movements above Longwall 32, observed differential movements were generally small.

Monitoring continued along Bridge Street between Pegs BG105 and BG106, where high compressive ground strains were previously observed. Cracks were identified by CCTV inspection in the Thirlmere Carrier on 25 July 2018 during the mining of Longwall 31.

As shown in Fig. 2.11, a small increase in compressive strain was measured between Pegs BG105 and BG106 since the completion of Longwall 31, with minor changes observed. Sydney Water has commenced plans to repair the damaged section of pipe.

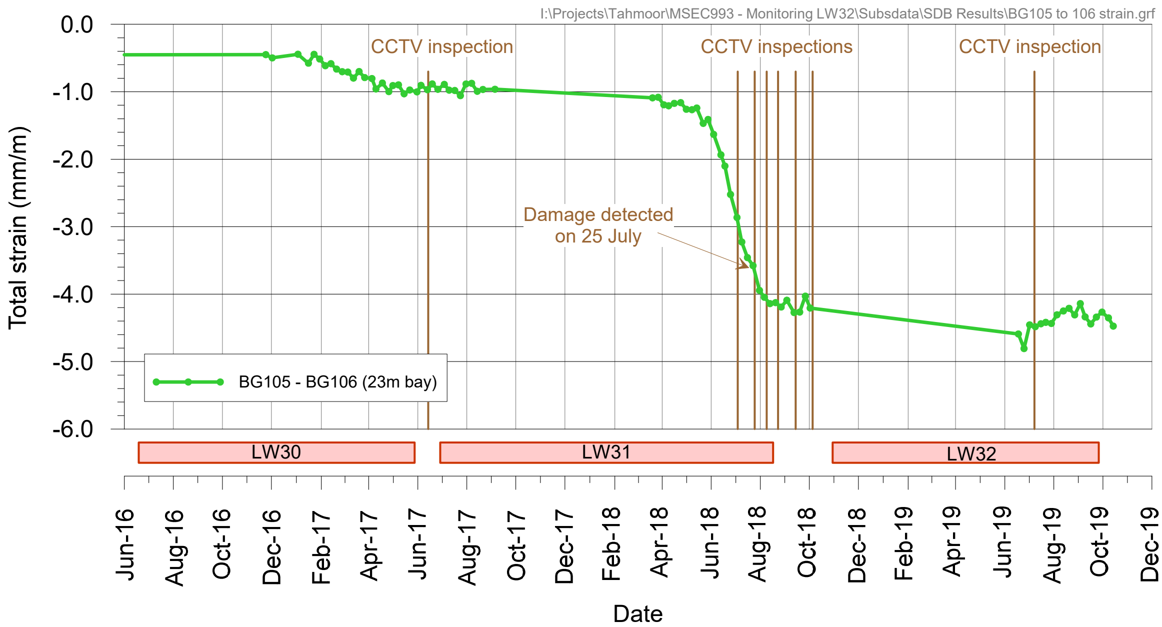

Fig. 2.11 Observed total strain between Pegs BG105 and B106 on Bridge Street

2.7. Power Pole Surveys

Surveys of nine 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 32, as expected.

Of the poles that were surveyed, maximum incremental subsidence of 794 mm was observed at Pole 628565 located on Bridge Street near the crossing over Redbank Creek above Longwall 32.

2.8. Wollondilly Shire Council

Surveys of the Remembrance Drive road bride and the concrete pedestrian bridge over Redbank Creek have measured changes within survey tolerance.

Measured changes in distance across Thirlmere Way over time are shown in Fig. 2.12. Ongoing small changes are also observed between Pegs T116A and T117, which are oriented along Thirlmere Way on the southern side of the road. No impacts are observed to the pavement or around the pegs. The crash barrier cable on the northern side of the road opposite Peg T118 is slack. An inspection by geotechnical engineer GHD Geotechnics found that one of the support posts had been struck by a vehicle. No issues were identified that were indicative of instability.

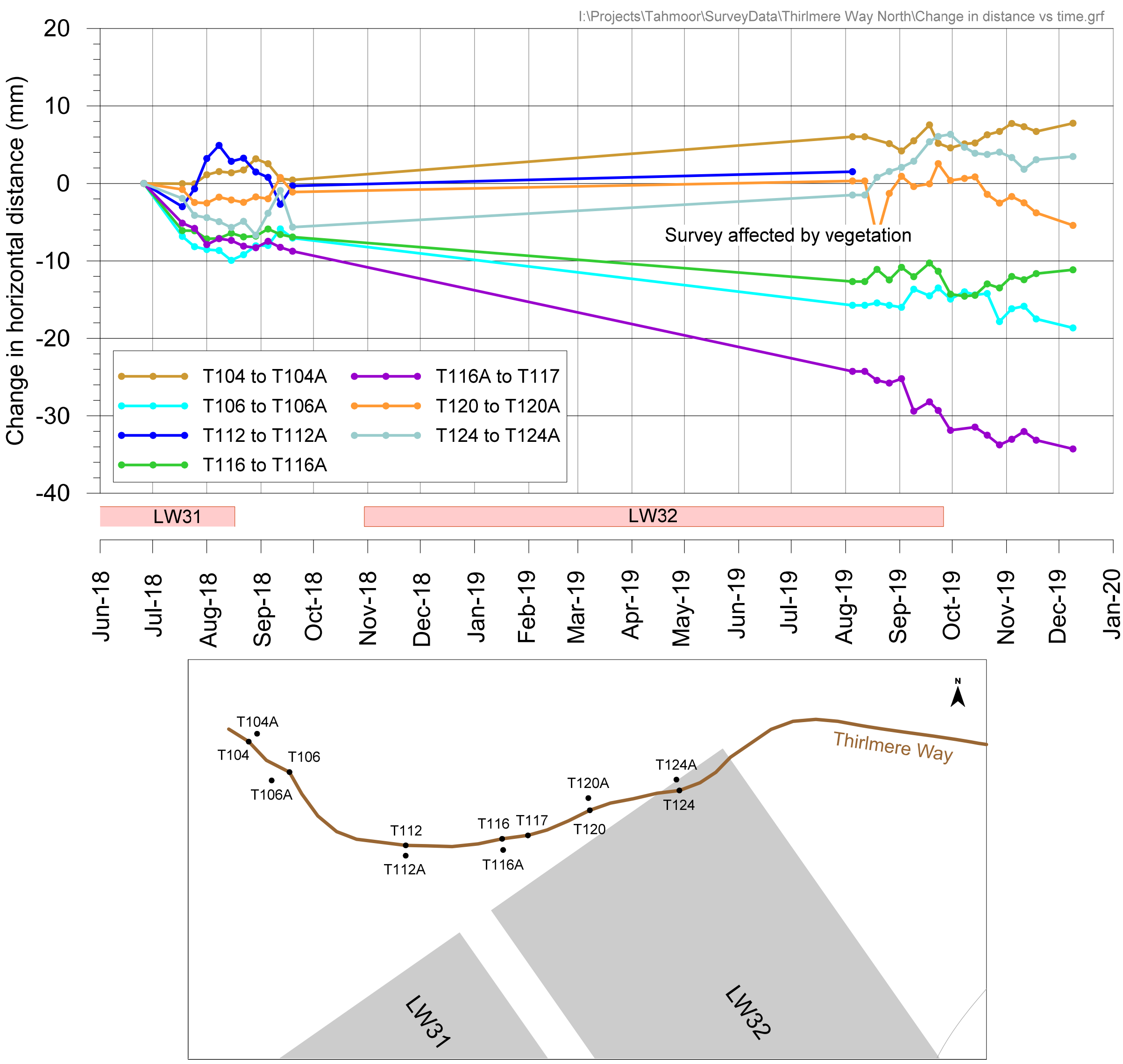

Fig. 2.12 Changes in horizontal distance across Thirlmere Way over time

The survey results were re-analysed as a local 3D survey between Pegs T114 and T118, which have been surveyed from a common survey control during the mining of LWs 31 and 32. The purpose of the analysis was to better understand relative horizontal movements between the survey marks.

It can be seen from Fig. 2.13 that a lateral rotation and shearing has developed over time at Pegs T116 / T116A, with a clear change in displacements at Peg T117. The movements have, however, developed very gradually over a period of 18 months.

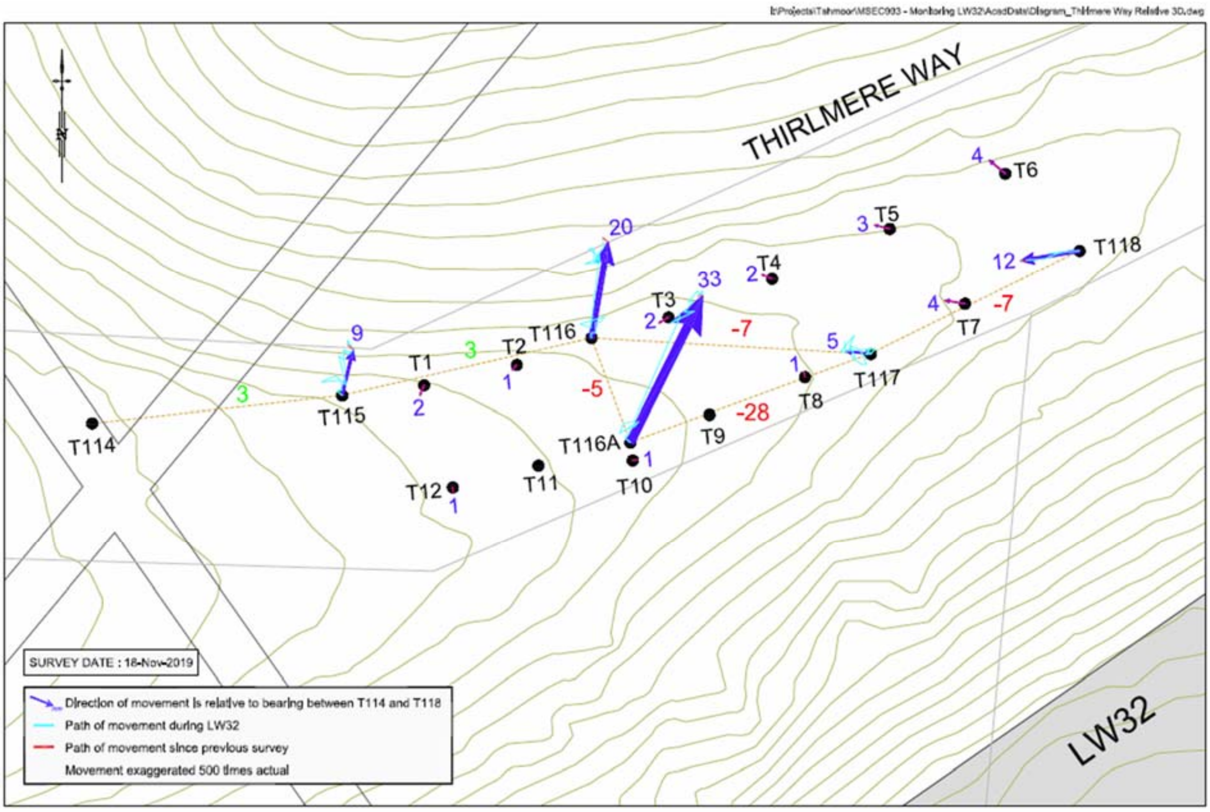

Fig. 2.13 Relative horizontal movements along Thirlmere Way between Pegs T114 and T118

2.9. Picton High School

2.9.1. Ground surveys

Extensive surveys were conducted on a weekly basis within and adjacent to the Picton High School (PHS) during the mining of Longwall 32.

Low level subsidence developed gradually within the PHS, with very low measurable differential movements observed. The PHS is currently undergoing major redevelopment, with demolition and earthworks generally occurring whilst Longwall 32 progressed passed the site.

2.9.2. Laser distancemeters and strain gauges

Laser distancemeters measured distances across the existing buildings every 2 hours. Strain gauges measured changes in strain of selected structural members.

No measurable mining-induced changes were observed, with changes observed over time with seasonal changes in temperature.

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2.10. Picton Industrial Area

2.10.1. Ground surveys

Extensive surveys were conducted on a weekly basis within and adjacent to properties within the Picton Industrial Area. Whilst the Picton Industrial Area experienced the full range of subsidence movements above Longwall 32, observed differential movements were generally small. Some differential movements were observed at individual properties with impacts observed. Changes were observed along and across the overhead crane rails but very little change in rail spans were observed.

2.10.2. Automated monitoring

Laser distancemeters measured distances across the span of the overhead crane rails. No measurable mining-induced changes were observed, with changes observed over time with seasonal changes in temperature.

Tiltmeters measured changes in verticality of hopper towers and machinery within the Picton Industrial Area. Changes in tilt were observed to gradually develop at each site, in magnitudes and directions that correlated well with results from ground surveys. Some machinery experienced mining-induced twist, which triggered detailed inspections and in some cases, the machinery was relevelled.

Strain gauges measured changes in strain of selected structural members on one hopper tower. No measurable mining-induced changes were observed, with changes observed over time with seasonal changes in temperature.

3.0 SUMMARY OF SURVEYS AND INSPECTIONS

Surveys and inspections were conducted to meet the requirements of the Surface, Safety and Serviceability Management Plans for Longwall 32. A timeline showing when each type of survey and inspection was conducted is shown in Fig. 3.1 below.

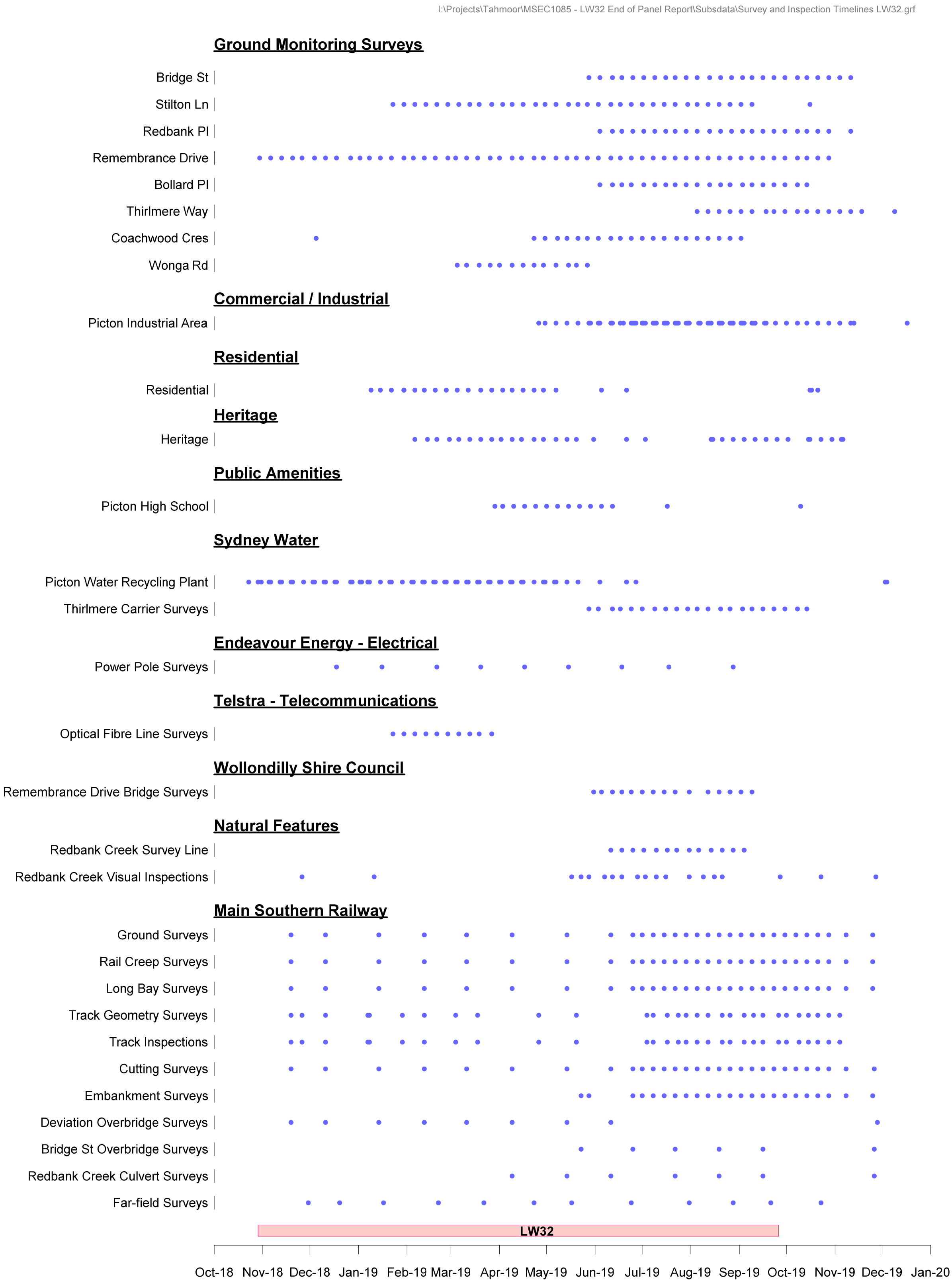

Fig. 3.1 Timeline of surveys and inspections during Longwall 32

A summary of surveys and inspections is provided in Table 3.1

Table 3.1 Surveys and inspections conducted during Longwall 32

Inspection / Survey	Responsibility	Number of Inspections / Surveys
Ground Monitoring Surveys		
	SMEC	235
Sub-Total		**235**
Natural Features		
Redbank Creek Survey Lines	SMEC	13
Redbank Creek Visual inspections	GeoTerra	19
Sub-Total		**32**
Main Southern Railway		
Ground Surveys	Southern Rail Surveys	29
Rail Creep Surveys	Southern Rail Surveys	29
Long Bay Surveys	Southern Rail Surveys	29
Track Geometry Surveys	BloorRail	30
Track Inspections	BloorRail	30
Cutting Surveys	Southern Rail Surveys	29
Embankment Surveys	Southern Rail Surveys	23
Deviation Overbridge Surveys	Southern Rail Surveys	9
Bridge St Overbridge Surveys	Southern Rail Surveys	6
Redbank Creek Culvert Surveys	Southern Rail Surveys	7
Far-field Surveys	Southern Rail Surveys	12
Sub-Total		**233**
Sydney Water - Sewer		
Picton Water Recycling Plant	SMEC	60
Thirlmere Carrier Pipe Surveys	SMEC	21
Picton and Tahmoor Rising Mains		64
Sub-Total		**145**
Endeavour Energy - Electrical		
Power Pole Surveys	SMEC	64
Sub-Total		**64**
Telstra - Telecommunications		
Optical Fibre Line Surveys	SMEC	10
Sub-Total		**10**
Commercial / Industrial		
Picton Industrial Area	SMEC	61
Sub-Total		**61**
Public Amenities		
Picton High School	SMEC	15
Sub-Total		**15**
Residential		
Residential	SMEC	24
Sub-Total		**24**
Heritage		
Koorana	SMEC	18
Mill Hill	SMEC	11
Fairley	SMEC	4
Sub-Total		**34**
Wollondilly Shire Council		
Remembrance Drive Bridge and Footbridge over Redbank Creek Surveys	SMEC	15
Sub-Total		**15**
Total		**868**

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 with predictions.

Table 4.1 Summary of predicted and observed impacts during Longwall 32

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 32 and downstream to Pool 33. 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 in areas outside of the active subsidence region. Interconnection between aquifers and aquitards was observed within 20m of the surface within the subsidence zone along Redbank Creek. No impacts on privately owned bores in regard to yield and serviceability occurred as a result of Longwall 32 extraction.. 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 32.
Natural vegetation	No impacts anticipated.	No impacts observed during Longwall 32.
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 and Remembrance Drive. Refer Section 4.4 for further details.
Water pipelines	Minor impacts possible to pipelines, particularly older cast iron pipes with lead joints.	Minor water leak on Remembrance Drive at site of increased compressive strain. Minor water leak at water hydrant at corner of Bridge Street and Redbank Place. 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 32. Refer Section 4.6 for further details.

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Surface Feature	Predicted Impacts	Observed Impacts
Picton Water Recycling Plant (PWRP)	PWRP unlikely to experience impacts and will remain safe and serviceable with management plans in place.	No impacts observed to the plant, dams and equipment during Longwall 32. Minor tensile cracks were observed across the access lane into the PWRP.
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.	No impacts on flows or pipes observed during Longwall 32. 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 32. Refer Section 4.9 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 32. Refer Section 4.10 for further details.
Public Amenities	Picton High School, Brethren Church and preschool on Bridge Street are unlikely to experience adverse impacts. Wollondilly Emergency Control Centre and HisHouse Church may experience adverse impacts but will remain safe and serviceable with management plans in place.	No impacts observed at Picton High School, Brethren Church and preschool on Bridge Street during Longwall 32. Wollondilly Emergency Control Centre and HisHouse Church remained safe and serviceable during and after Longwall 32, though both buildings experienced some impacts during mining.
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 32.
Fences	Potential for impacts to fences and gates.	No impacts reported to fences on farm properties during Longwall 32.
Farm dams	Potential adverse effects on dam walls and storage capacity. Please refer report by GeoTerra.	One dam was reported damaged during Longwall 32. 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 32. Please refer report by GeoTerra
Industrial, Commercial or Business Establishments	All structures expected to remain safe, serviceable and repairable with management plans in place. Potential impacts predicted to occur to structures, equipment and machinery.	Minor impacts on business and commercial establishments affected by Longwall 32. Establishments remained safe and serviceable during the mining of Longwall 32.
Areas of Archaeological Significance	Open camp sites above LWs 31 & 32 are unlikely to experience impacts. Grinding groove site above LW 32 may experience fracturing.	No impacts on archaeological sites observed during Longwall 32.
Areas of Heritage Significance	Potential low-level impacts at Mill Hill Homestead and Fairley Residence. Koorana Homestead may experience impacts but will remain safe, serviceable and repairable with management plans in place.	No impacts observed at Fairley Residence. Low level impacts observed at Mill Hill Homestead. Minor impacts observed at Koorana Homestead. All three properties remained safe, serviceable and repairable during Longwall 32.

Surface Feature	Predicted Impacts	Observed Impacts
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 4.13 for details.	While impacts occurred, houses were safe, serviceable and repairable during Longwall 32. Refer Section 4.13 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 two additional pools reported during the mining of Longwall 32. Impact observed to two pool gates during the mining of Longwall 32.
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.	Impacts observed to some sheds during Longwall 32.
External residential pavements	Cracking and buckling likely to occur, though majority minor.	Impacts to some external pavements were reported during Longwall 32.
Fences in urban areas	Some fences and gates could be slightly damaged. Most vulnerable are Colorbond fences.	No impacts to fences reported during Longwall 32.

4.2. Creeks

4.2.1. Redbank Creek

GeoTerra undertook an investigation into the effects of Longwall 32 on surface and ground waters in the area (GeoTerra, 2020).

During the mining of Longwall 32, new subsidence effects were observed at Sites RR28 to RB33. The new impact sites were observed above and downstream from Longwall 32.

Pools located directly above Longwall 32 and to the side of the longwall down to Pool RB33 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 32 at time of low flow.

Re-emergence of the connected stream “through-flow” has been observed downstream of future Longwall 32, at site RT34 (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 32 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 32, though increased ferruginous and salinity levels have been observed in the stream over Longwalls 29 to Longwall 32 down to site RB33.

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 32*, (Rev. 0, May 2017).

Table 4.2 Comparison against Triggers for Redbank Creek during Longwall 32

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 LW32 at 4 sites: Sites RR29, RR30 and RR31 above LW32, Site RB32 east of LW32.

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 32. The track condition deteriorated slightly in isolated locations as a result of mining and the track was resurfaced.

During the mining of Longwall 32 some of the triggers associated with the *Tahmoor Coal Longwall 32 Management Plan for Longwall Mining beneath the Main Southern Railway (Rev 2, August 2018)* were exceeded.

A change in track geometry was observed within a railway cutting at 90.110 km. A bump was observed in the subsidence profile and the sides of the cutting were observed to close. The changes could be observed from ground surveys, visual inspections and train driver reports. The changes resulted in a Temporary Speed Restriction (TSR) of 60 km/hour between 11 & 21 August 2019. The TSR was imposed as a precautionary safety measure. The track was resurfaced during and after this period to maintain track safety and operations. Tahmoor Coal investigated possible links between the observations on the track with minor cracks observed to neighbouring industrial properties. It was found that a small geological feature was oriented in a direction that linked the impacts in the rail cutting with minor impacts to concrete kerbs and external unsealed pavements to the north east of the rail impact site.

Some low level (Blue) rail stress triggers and switch displacement triggers were exceeded during the mining of Longwall 32 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.

4.4. Roads and bridges

4.4.1. Roads

Approximately 30 kilometres of asphaltic pavement lie directly above the extracted longwalls and a total of 56 impact sites have been observed. The observed rate of impact equates to an average of one impact for every 530 metres of pavement.

A bump formed on Remembrance Drive near the entrance to Sydney Water's Picton Water Recycling Plant, where increased compressive ground strains were measured. Wollondilly Shire Council was consulted and erected warning signs for rough surface and reduce speed. A 40 km/hr speed restriction was introduced on 25 January 2019, with Variable Message Boards installed to inform drivers. The bump was repaired on 7 February 2019.

Minor impacts were observed along Bridge Street during the mining of Longwall 32. This included impacts to a concrete kerb and small compressive bumps in the pavement shoulder between Pegs BG131 and BG133, which later extended across the pavement. As there have been minor changes measured in compressive strains, the appearance of compressive bumps may have been associated with the onset of warmer weather.

As discussed in Section 2.8, some differential movements were observed along Thirlmere Way above the finishing end of Longwall 32. The differential movements may be mining related but no signs of instability were observed during an inspection by GHD Geotechnics. No impacts have been observed to the road.

A collection of photographs of impacts is provided in Fig. 4.1.

Bump on Remembrance Drive

Bridge Street

Photographs courtesy of Colin Dove

Fig. 4.1 Impacts to road pavements during Longwall 32

4.4.2. Bridges

Surveys of the Remembrance Drive road bridge and the concrete pedestrian bridge over Redbank Creek have measured a maximum of 1 mm closure during Longwall 32, which is within survey tolerance.

4.5. Potable Water Infrastructure

Longwalls 22 to 32 have directly mined beneath approximately 6 kilometres of ductile iron concrete lined (DICL) pipe and 20 kilometres of cast iron concrete lined (CICL) pipe. Impacts were observed at two locations during the mining of Longwall 32.

Sydney Water was consulted on 19 December 2018 regarding the development of compressive ground strain between Pegs RD26 and RD27, where the bump had formed in the road pavement. Twice weekly focussed inspections were being conducted at this location. The water main was found leaking on the morning of 8 February 2019. The main was able to support water pressure and the Picton reservoir was 93% full at the time. The water main was repaired on the evening of 8 February. A photograph of the leak is shown in Fig. 4.2.

Photograph courtesy of Sydney Water

Fig. 4.2 Water leak on Remembrance Drive during Longwall 32

A minor water leak was observed on 21 August 2019 at the corner of Bridge Street and Redbank Place. The leak occurred at a stop valve and hydrant and was repaired on 22 August. A photograph of the leak is shown in Fig. 4.3.

Photograph courtesy of Building Inspection Services

Fig. 4.3 Water leak at hydrant at corner of Redbank Place and Bridge Street during Longwall 32

4.6. Gas Infrastructure

Longwalls 22 to 32 have directly mined beneath approximately 19 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.

Jemena was consulted regarding increased compressive strain along Remembrance Drive on 19 December 2018, and it was agreed to conduct a gas detection survey. The survey was conducted on 21 December with no leakage detected. The measured ground strain exceeded the Level 1 trigger level in the Jemena Management Plan in January 2019. Re-surveys were conducted on 7 and 25 January and 8 February with no leakage detected. Gas leak detection surveys were conducted on a weekly basis until rates of change in ground strain reduced to low levels.

4.7. Sewer Infrastructure

Longwalls 22 to 32 have directly mined beneath approximately 30 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 had 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. The works were delayed until the completion of Longwall 32.

- *Physical damage to pipes*
  There were no observations of damage during the mining of Longwalls 22 to 24 and Longwalls 27 to 30 and no observations of damage during the mining of Longwall 32. 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. 4.4.

Fig. 4.4 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. 4.4 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.

As discussed in Section 2.6, minor changes in ground strain were observed between Pegs BG105 and BG106 during the mining of Longwall 32. A CCTV was completed after the completion of Longwall 32, with plans to repair the damaged section of pipe in January 2020.

4.8. Picton Water Recycling Plant

Tahmoor Coal undertook surveys and visual inspections of structures and equipment within Sydney Water's Picton Water Recycling Plant on a weekly and monthly basis during the mining of Longwall 32.

All structures within the Picton Water Recycling Plant remained safe and serviceable during the mining of Longwall 32. No impacts were observed to structures and equipment. Minor tensile cracks were observed across the access lane into the plant.

4.9. Electrical Infrastructure

Longwalls 22 to 32 have directly mined beneath approximately 46 kilometres of electrical cables and 1100 power poles and no significant impacts have been recorded so far. However, minor changes in tension of some aerial cables has been observed.

4.10. Telecommunications Infrastructure

Longwalls 22 to 32 have directly mined beneath approximately 43 kilometres of buried copper cable and 4.6 kilometres of buried optical fibre cable and 10 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 to32.

4.11. Picton Industrial Area

Tahmoor Coal undertook intensive surveys and visual inspections of structures, equipment and machinery of commercial, industrial and business establishments within the Picton Industrial Area and along Wonga Road during the mining of Longwall 32.

All structures within the Picton Industrial Area and along Wonga Road remained safe and serviceable during the mining of Longwall 32. Minor impacts were observed to structures and external pavements.

Minor impacts have been observed at some properties within the Picton Industrial Area, including cracking and opening up of internal and external concrete slabs and masonry walls, cracks to tiled floors and binding of gates. Some sensitive machinery and product assembly platforms have been relevelled.

4.12. Picton High School

Tahmoor Coal undertook weekly and monthly ground surveys and visual inspections of structures within the Picton High School property during the mining of Longwall 32.

All structures at the School remained safe and serviceable during the mining of Longwall 32. No impacts were observed to structures.

4.13. Residential Establishments

All structures remained safe and serviceable during the mining of Longwall 32.

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

A summary of reported impacts following the completion of Longwall 32 is provided in Table 4.3. The count of residential structures includes only those structures that were predicted to experience more than 20 mm of subsidence due to the extraction of Longwalls 22 to 32.

Table 4.3 Summary of observed impacts to structures

	Total after LWs 22 to 31	Increment during Longwall 32
Number of structures within zone of influence (predicted subsidence > 20 mm)	1983	28
Number of properties with reported impacts (not including refused claims)	563	9
Number of properties with reported impacts that relate to main structures (e.g. house or shop)	499	8
Number of properties with reported impacts that only relate to associated structures	64	1

4.13.1. 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 32 only due to the time lag effect discussed previously. All properties that reported impacts during the mining of Longwall 32 were, however, located directly above or the maingate (solid coal) side of Longwall 32.

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 32.

A property on Remembrance Drive has reported impacts mainly to external paving and pool gates. The property is located directly above the centreline of Longwall 32. Impacts have also been observed to an external corner of the house. Weekly ground surveys have measured compressive ground strains between the pool and the rear of the house.

The property was first inspected by structural engineer John Matheson on 25 January. A pre-existing crack at an isolated location in one corner of the house has increased in width and has exceeded 5 mm (Category 3 in AS2870). The house remains safe and serviceable.

4.13.2. Swimming Pools

Two pools were reported damaged during the mining of Longwall 32, and two pool gates were damaged.

4.13.3. Associated Structures

Another property has experienced impacts to a shed and driveway. Cracks are observed to external brick walls, a low height retaining wall is leaning and internal columns have tilted. A ripple has developed in the driveway. The property was inspected by structural engineer John Matheson on 4 April. Soil was placed to support the low height retaining wall, as recommended. Cracking has also been observed in internal walls and cornices in a cottage on the property.

4.13.4. Dams

One dam was reported damaged during Longwall 32.

4.13.5. 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 32, with the exception of two pool gates.

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.

The maximum observed incremental subsidence was greater than predicted maximum incremental subsidence for Longwall 32, which was 700 mm. This is greater than the typical range of accuracy of the predictions, though the potential for increased subsidence above Longwall 32 was raised in the subsidence prediction reports.

The maximum predicted total subsidence within the SMP Area for Longwall 32 was 1025 mm, which is slightly less than the maximum observed subsidence of 1089 mm. The difference is within 15% of the prediction, which is within the typical range of accuracy.

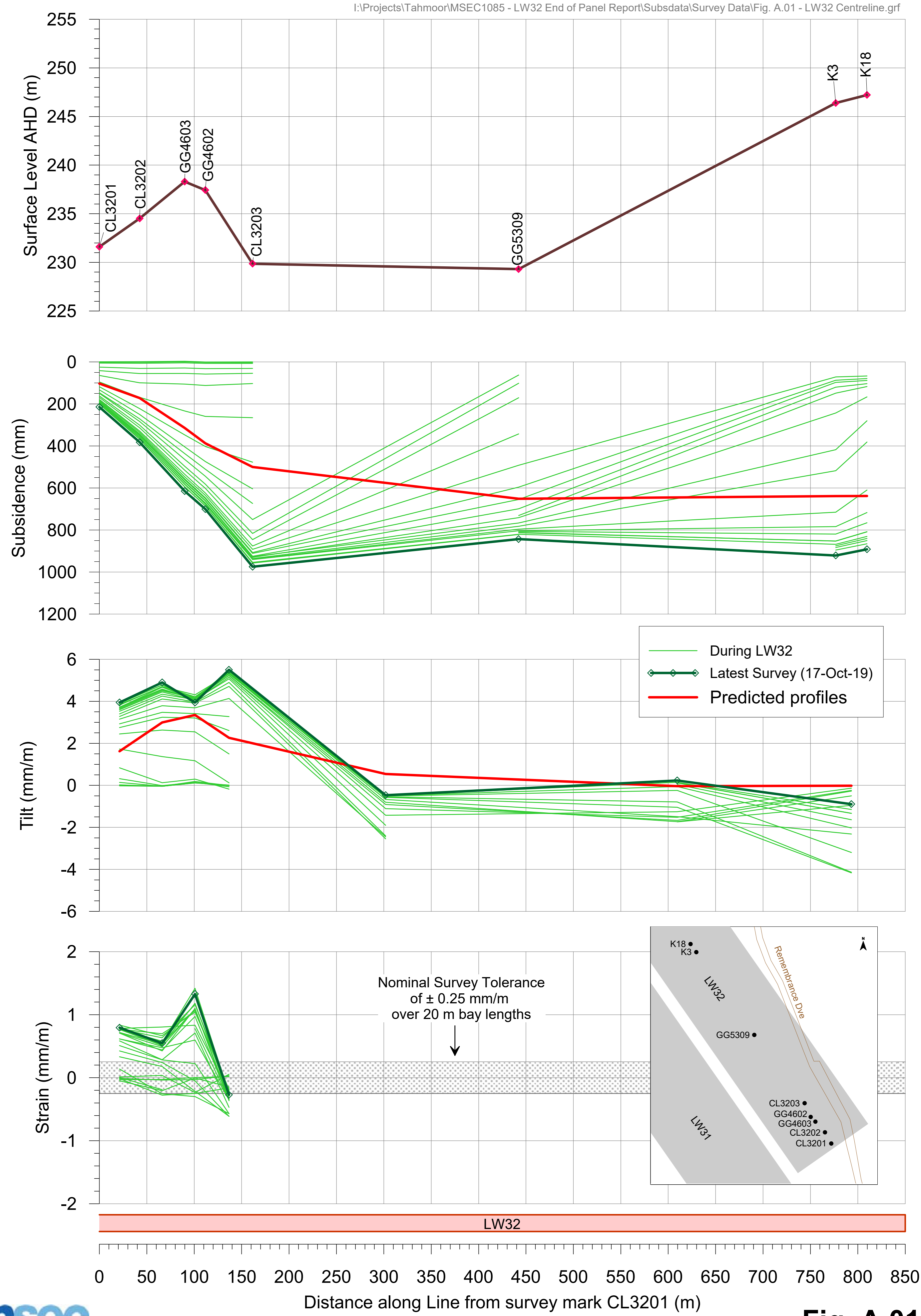
There is a reasonable correlation between observed and predicted impacts, particularly in relation to public infrastructure such as the Main Southern Railway, the Picton Water Recycling Plant, Picton High School, sewer mains, water mains, gas mains, and electrical and telecommunications infrastructure.

All structures remained safe and serviceable during the mining of Longwall 32.

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

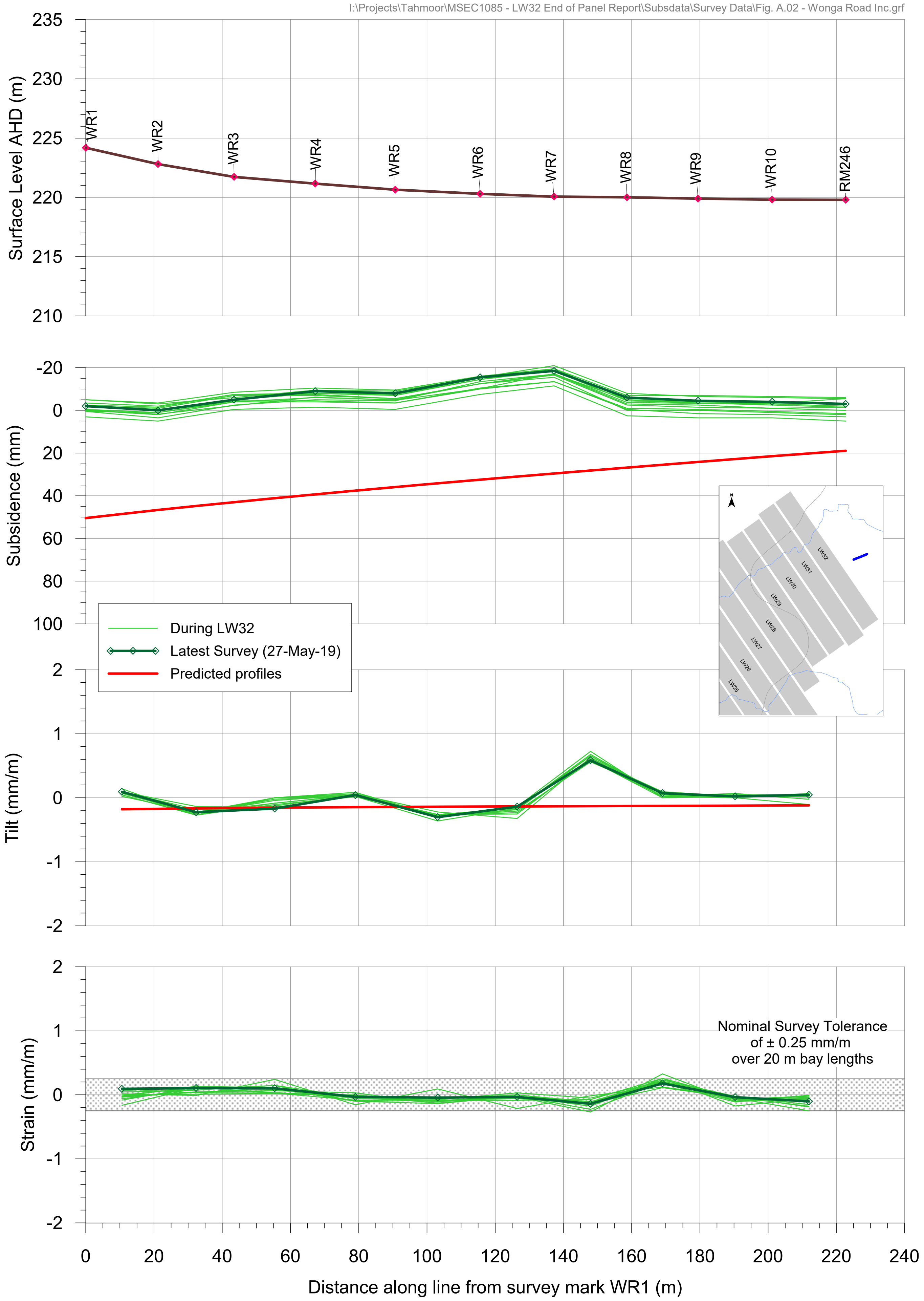
Tahmoor Coal - Longwall 32
Incremental subsidence profiles along the LW32 Centreline



msec

Fig. A.01

Tahmoor - Longwall 32
Incremental subsidence profiles along Wonga Road



msec

Fig. A.02

Tahmoor - Longwall 32
Incremental subsidence profiles along Coachwood Crescent

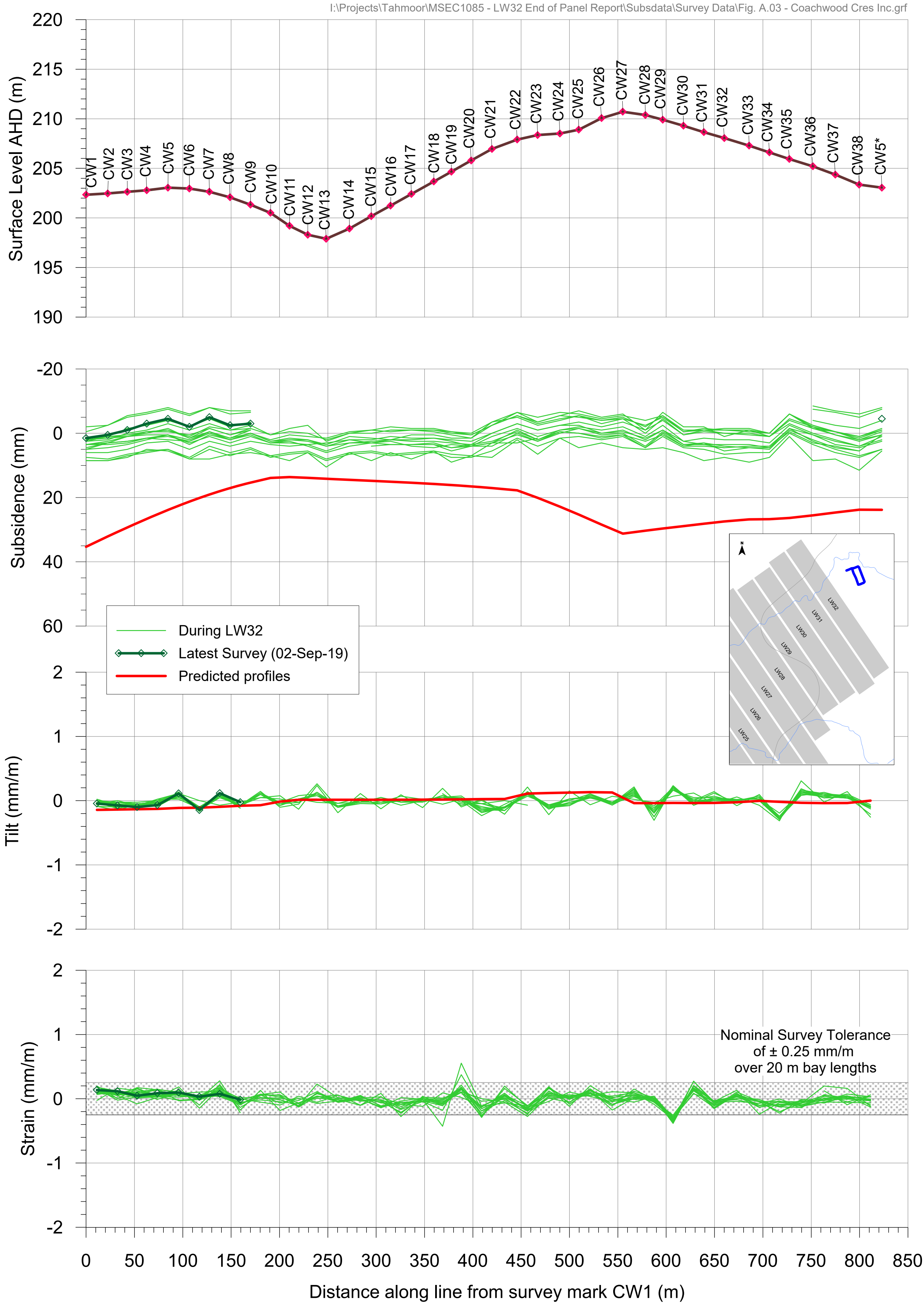


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Fig. A.03

Tahmoor - Longwall 32
Incremental subsidence profiles along Nepean Fault Line 1

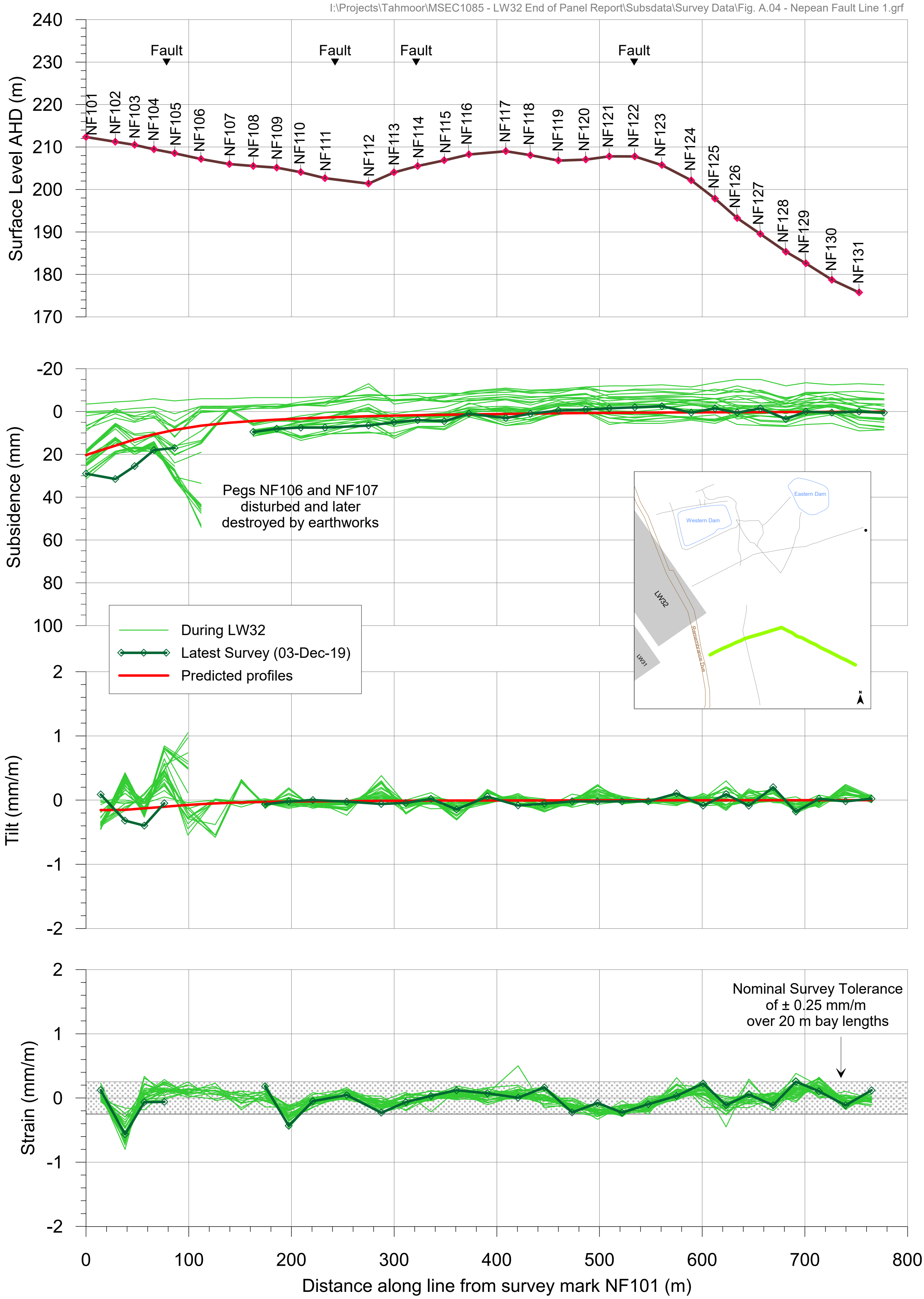
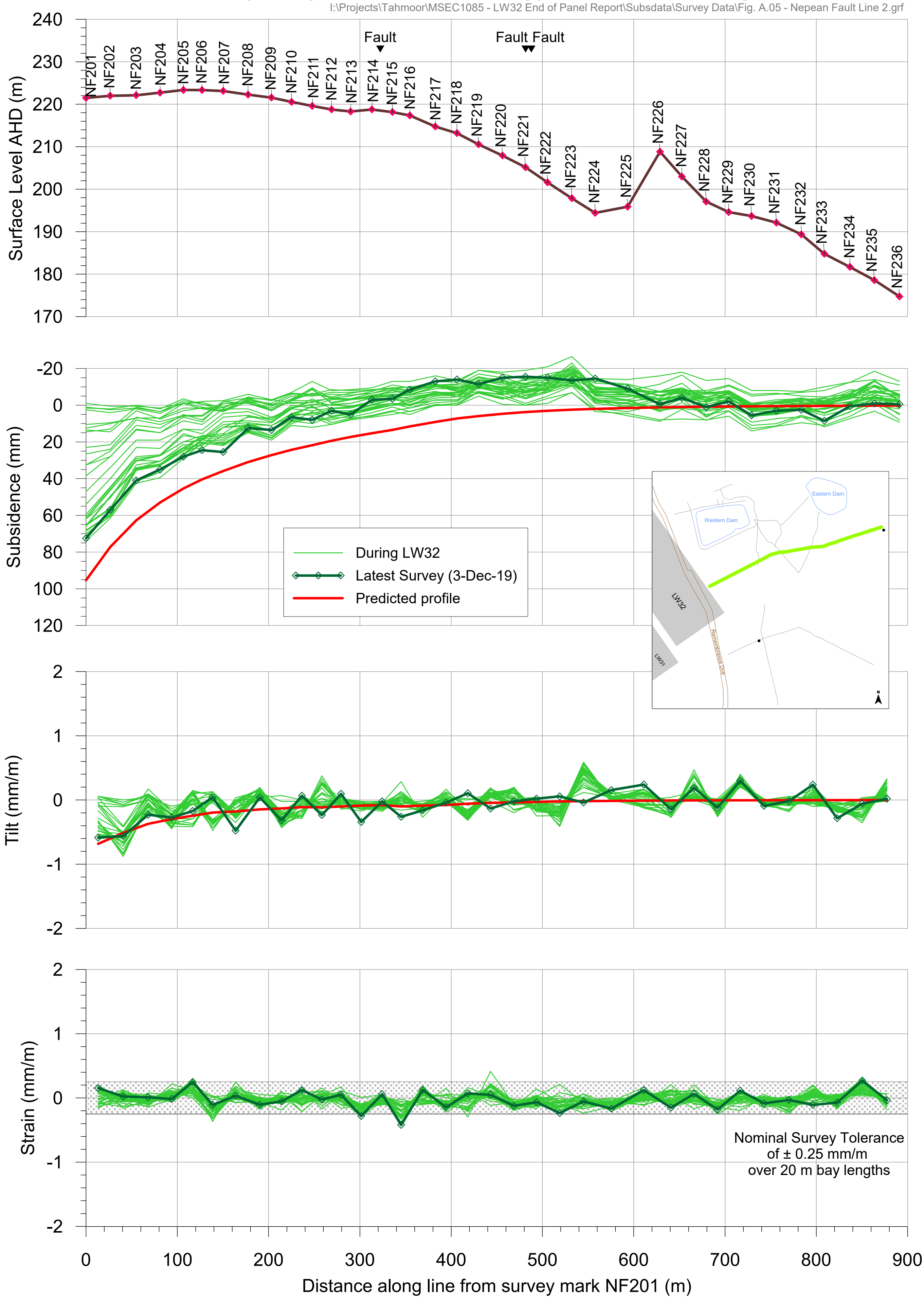


Fig. A.04

Tahmoor - Longwall 32
Incremental subsidenceprofiles along Nepean Fault Line 2
(along Endeavour Energy 66kV Powerline)

I:\Projects\Tahmoor\MSEC1085 - LW32 End of Panel Report\Subsdata\Survey Data\Fig. A.05 - Nepean Fault Line 2.grf



msec

Fig. A.05

Tahmoor - Longwall 32
Incremental Subsidence Profiles along Nepean Fault Line 3

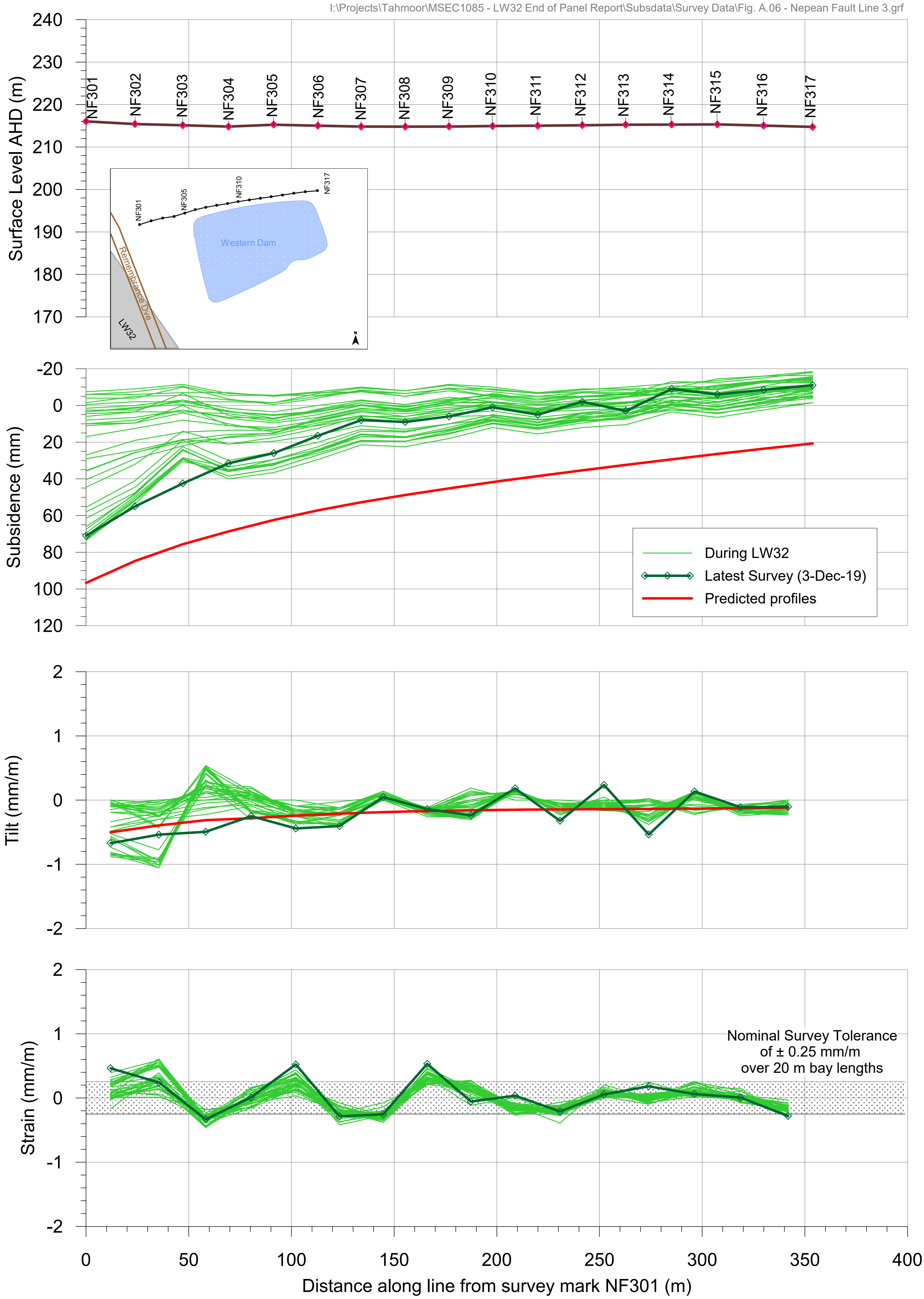


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Fig. A.06

Tahmoor - Longwall 32
Incremental subsidence profiles along Tahmoor Rising Main

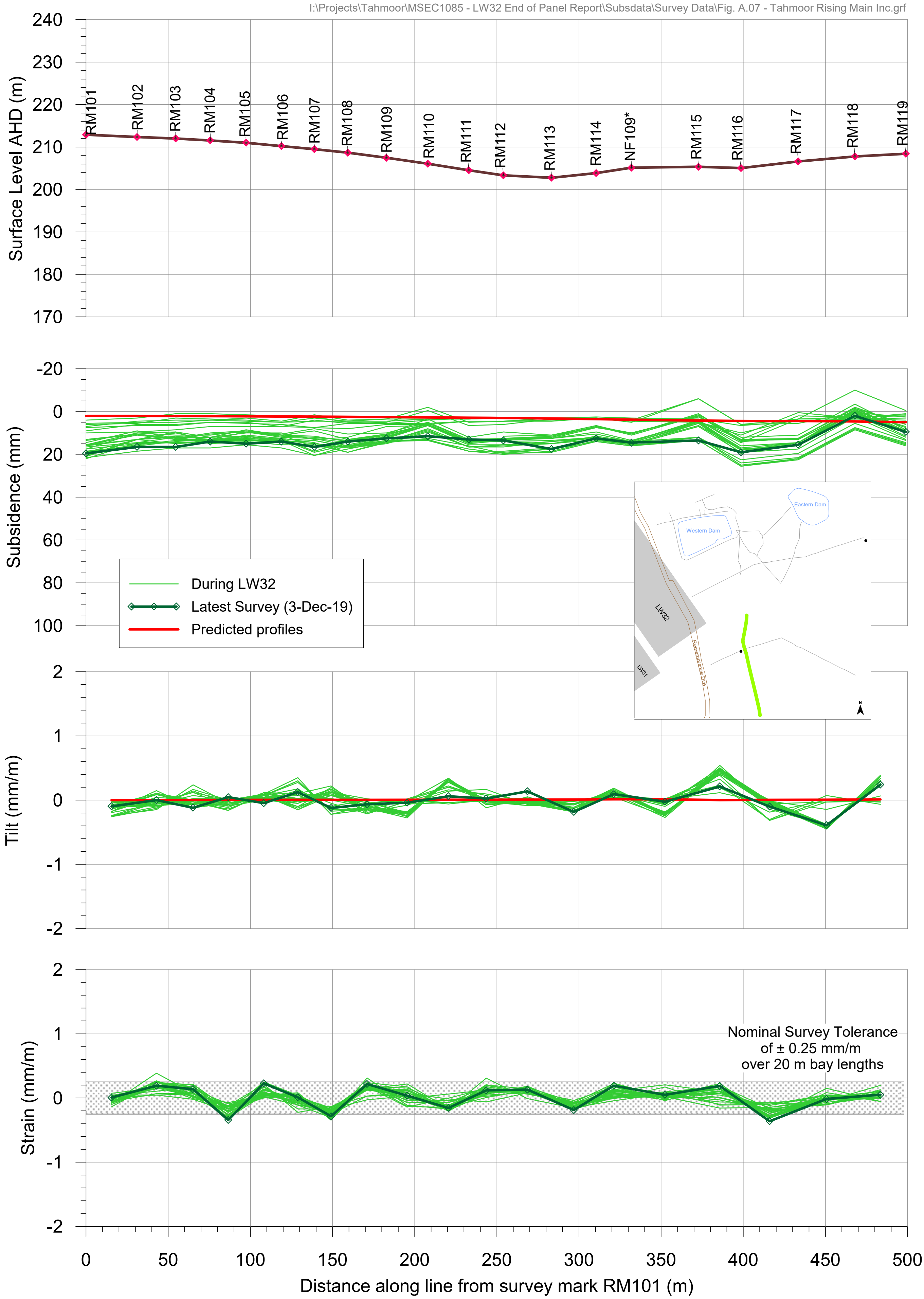

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Fig. A.07

Tahmoor - Longwall 32
Incremental subsidence profiles along Picton Rising Main

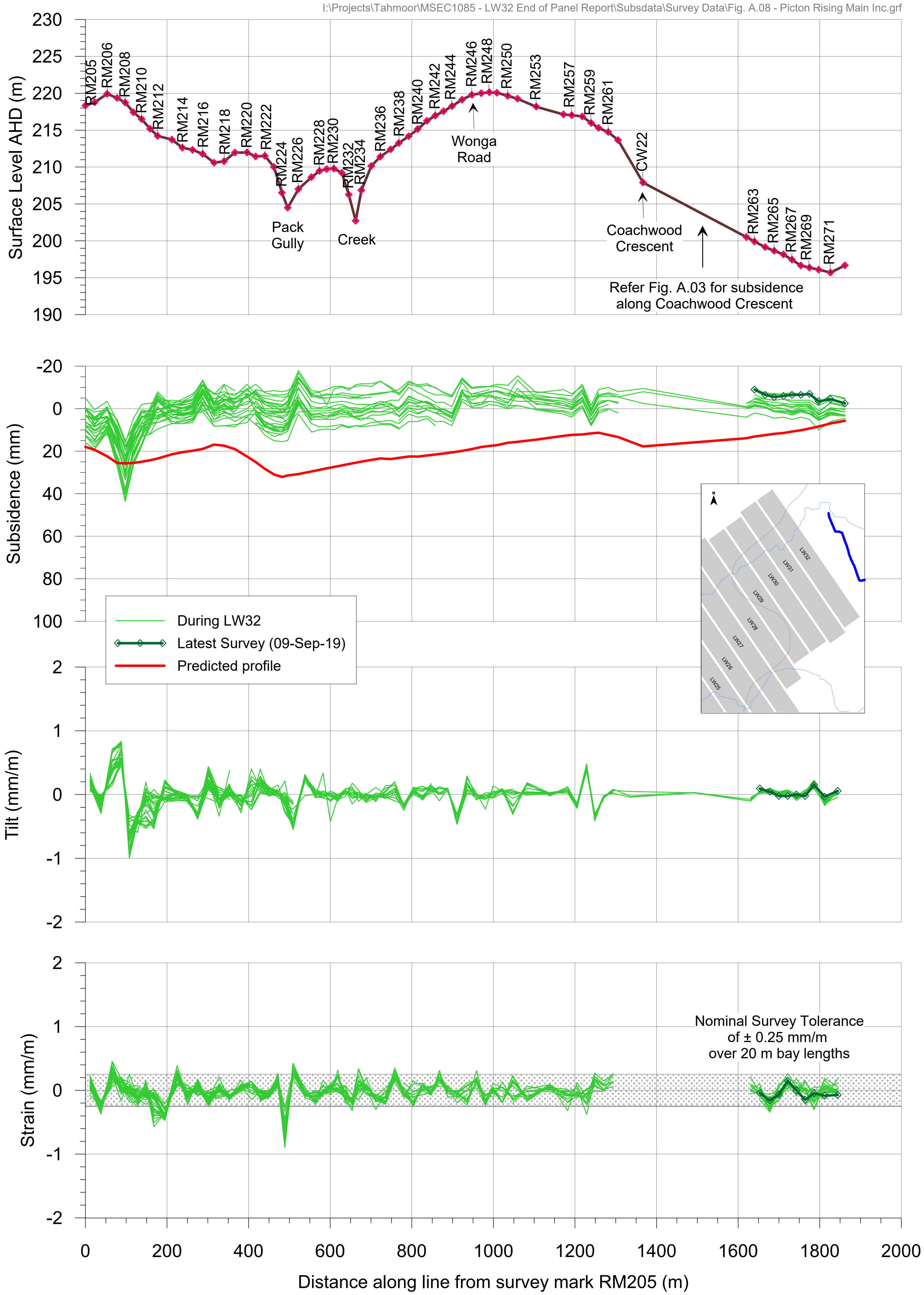
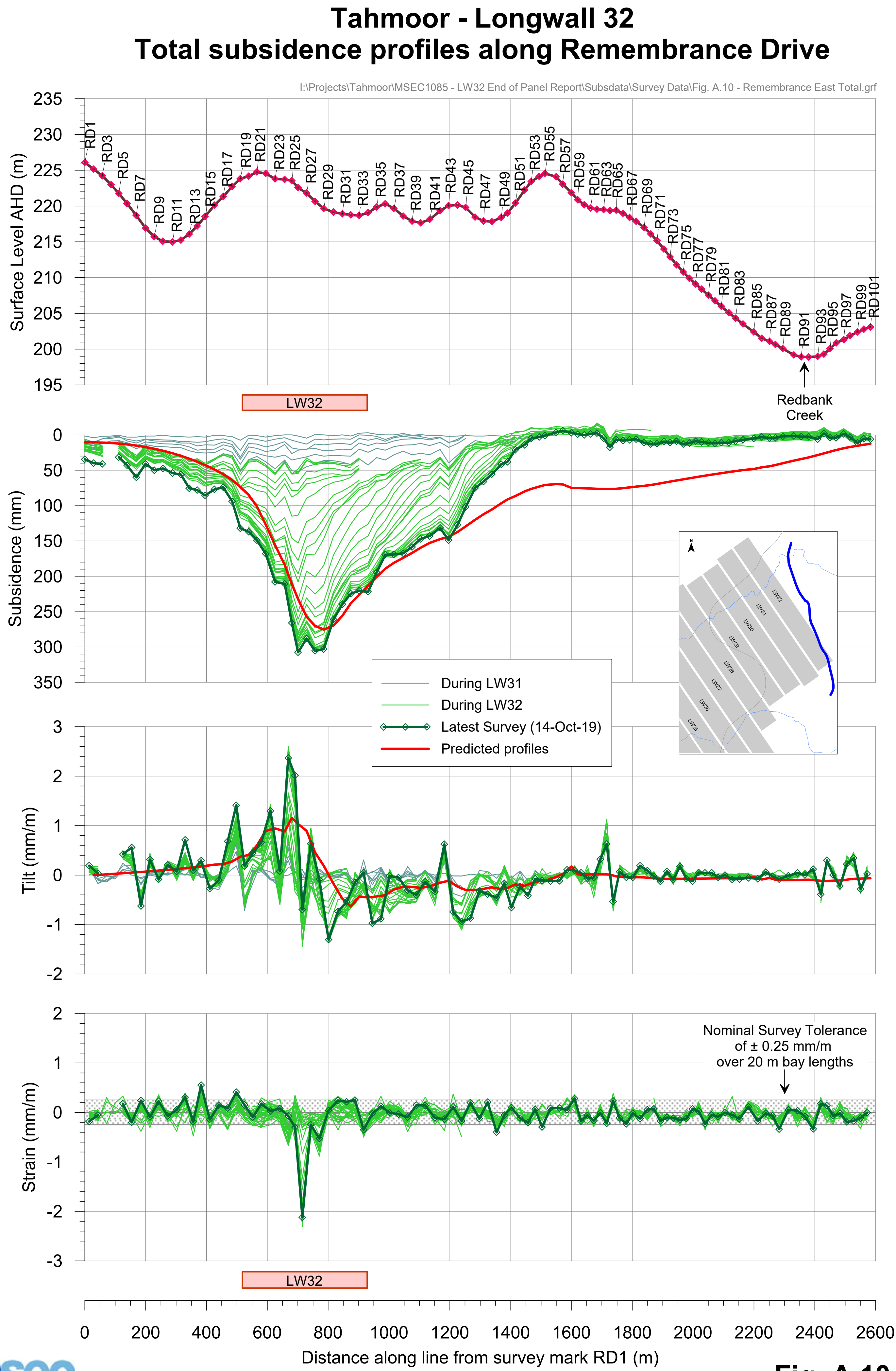


Fig. A.08

Tahmoor - Longwall 32
Incremental subsidence profiles along Remembrance Drive

msec

Fig. A.09

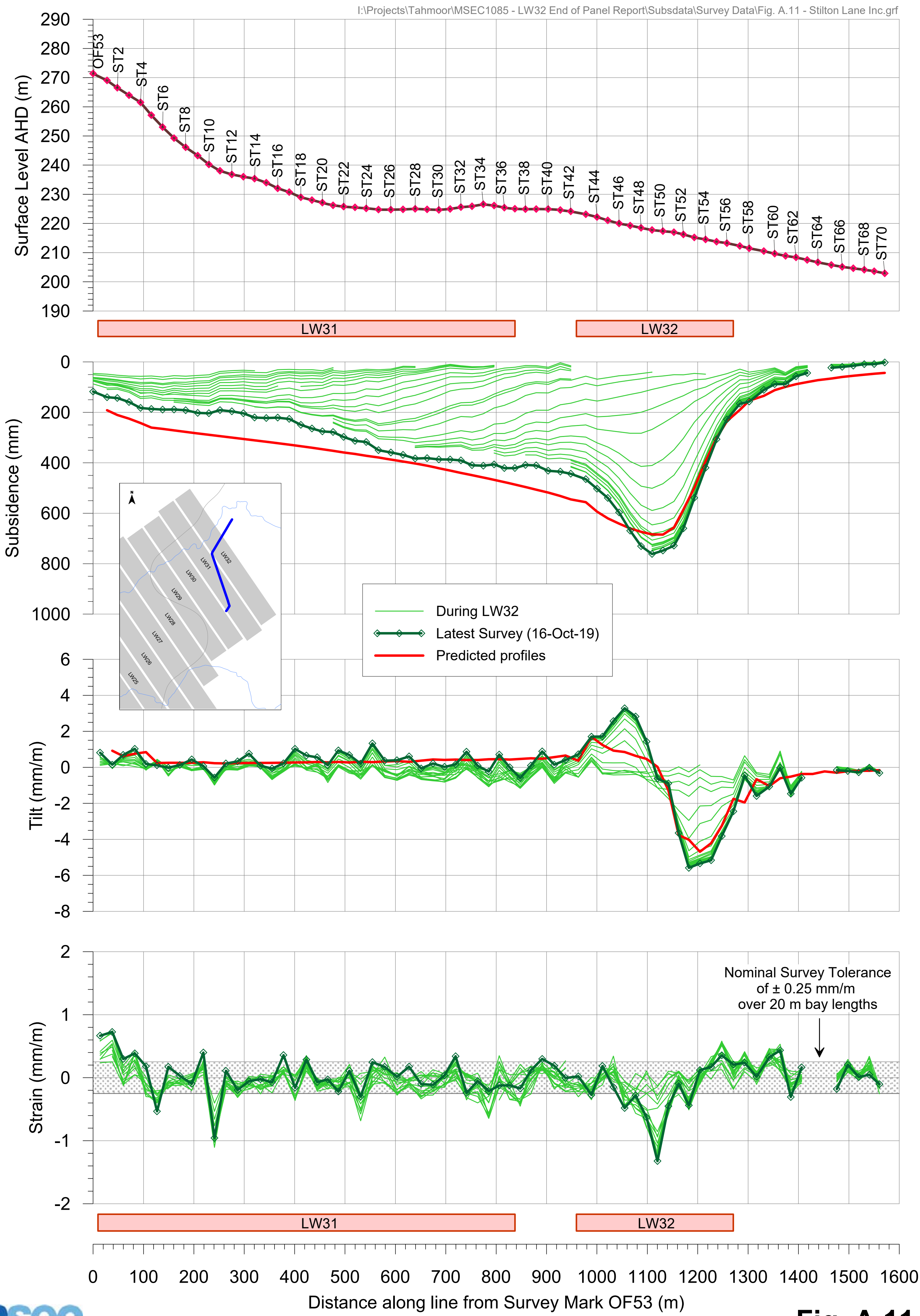


Tahmoor - Longwall 32
Total subsidence profiles along Remembrance Drive
I:\Projects\Tahmoor\MSEC1085 - LW32 End of Panel Report\Subsdata\Survey Data\Fig. A.10 - Remembrance East Total.grf
Surface Level AHD (m)
Redbank Creek
LW32
Subsidence (mm)
During LW31
During LW32
Latest Survey (14-Oct-19)
Predicted profiles
Tilt (mm/m)
Strain (mm/m)
Nominal Survey Tolerance
of ± 0.25 mm/m
over 20 m bay lengths
Distance along line from survey mark RD1 (m)

msec

Fig. A.10

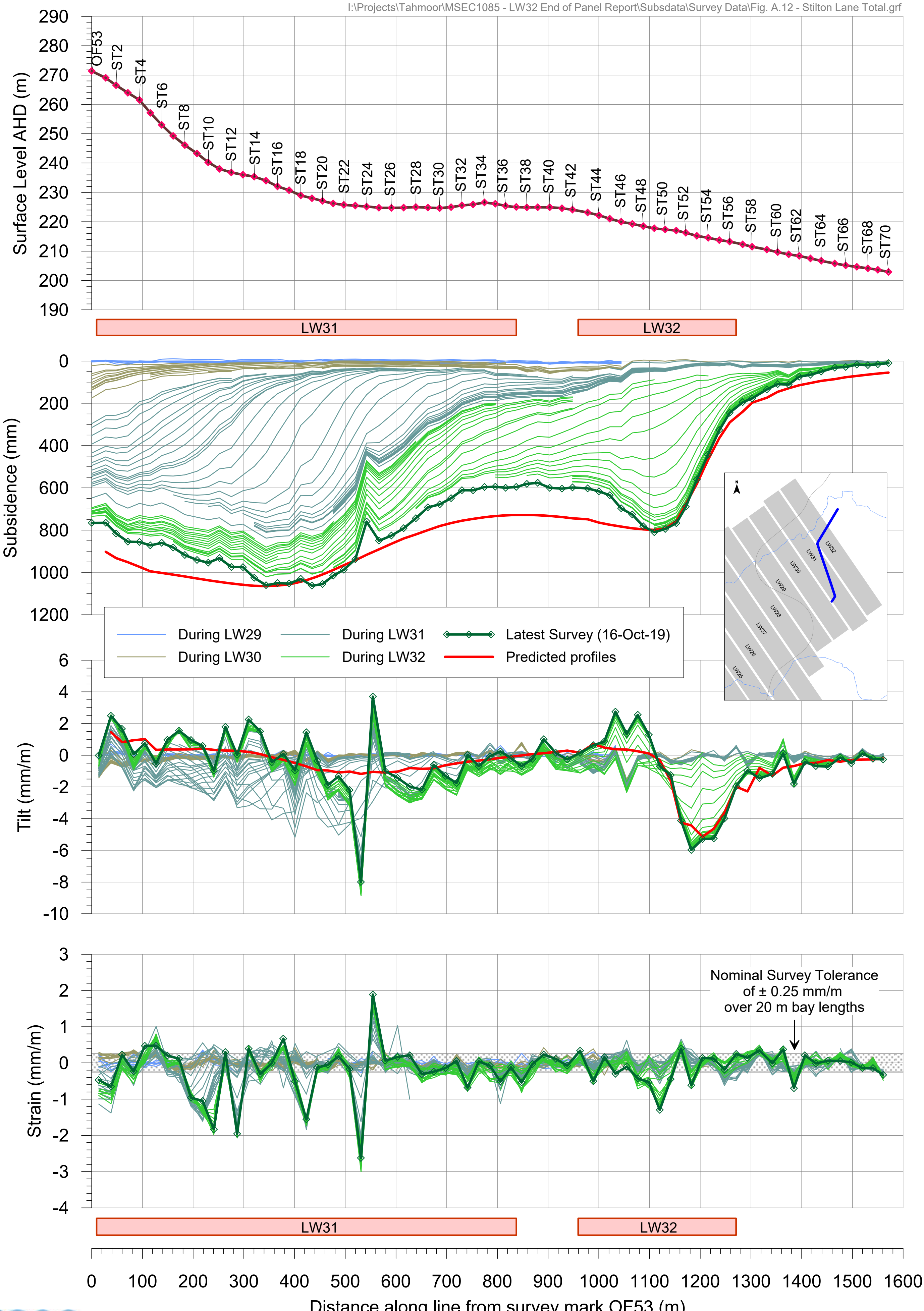
Tahmoor - Longwall 32
Incremental subsidence profiles along Stilton Lane / Henry Street



msec

Fig. A.11

Tahmoor - Longwall 32
Total subsidence profiles along Stilton Lane / Henry Street



msec

Fig. A.12

Tahmoor - Longwall 32
Incremental subsidence profiles along Bridge Street

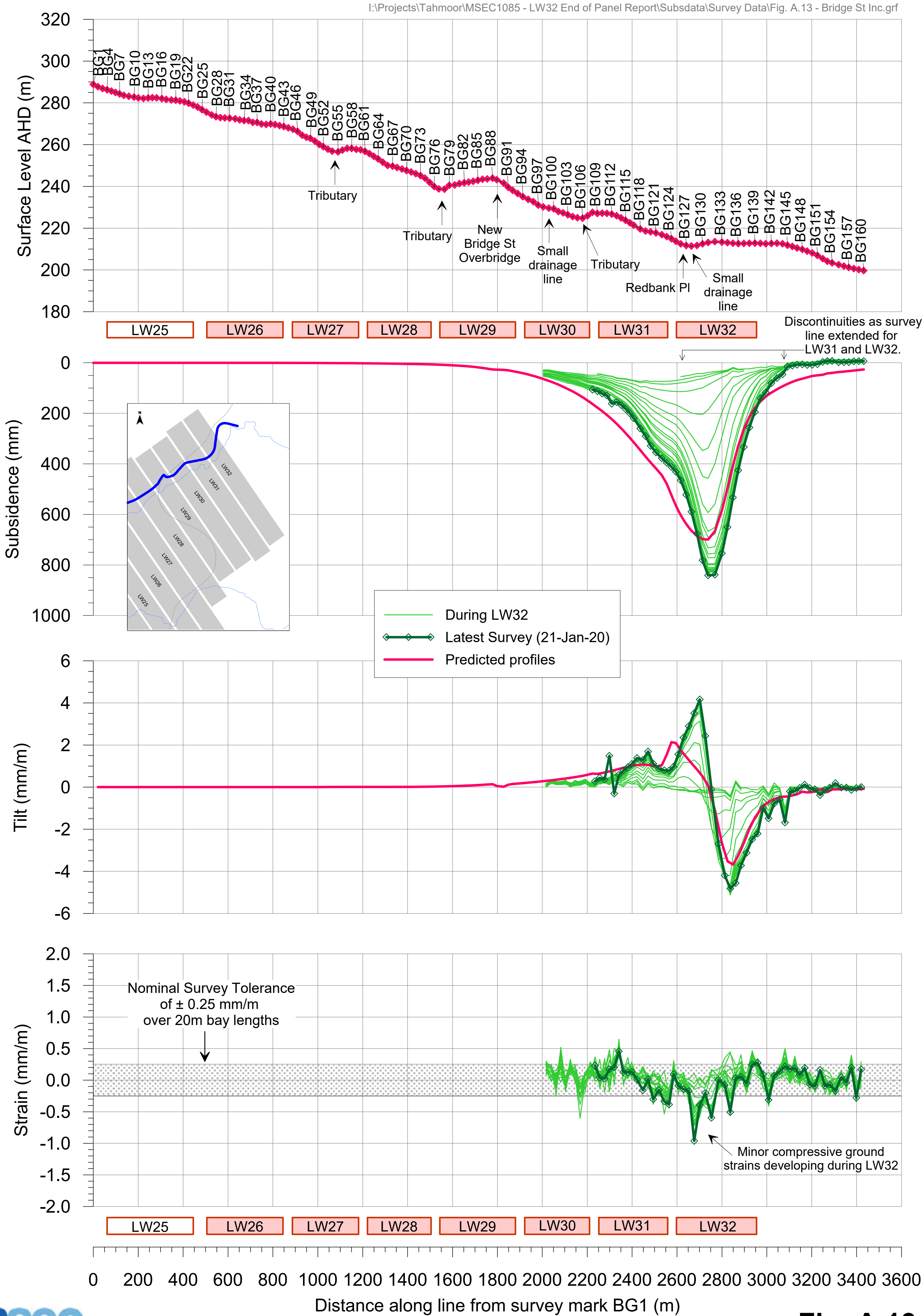


Fig. A.13

Tahmoor - Longwall 32
Total Subsidence Profiles along Bridge Street

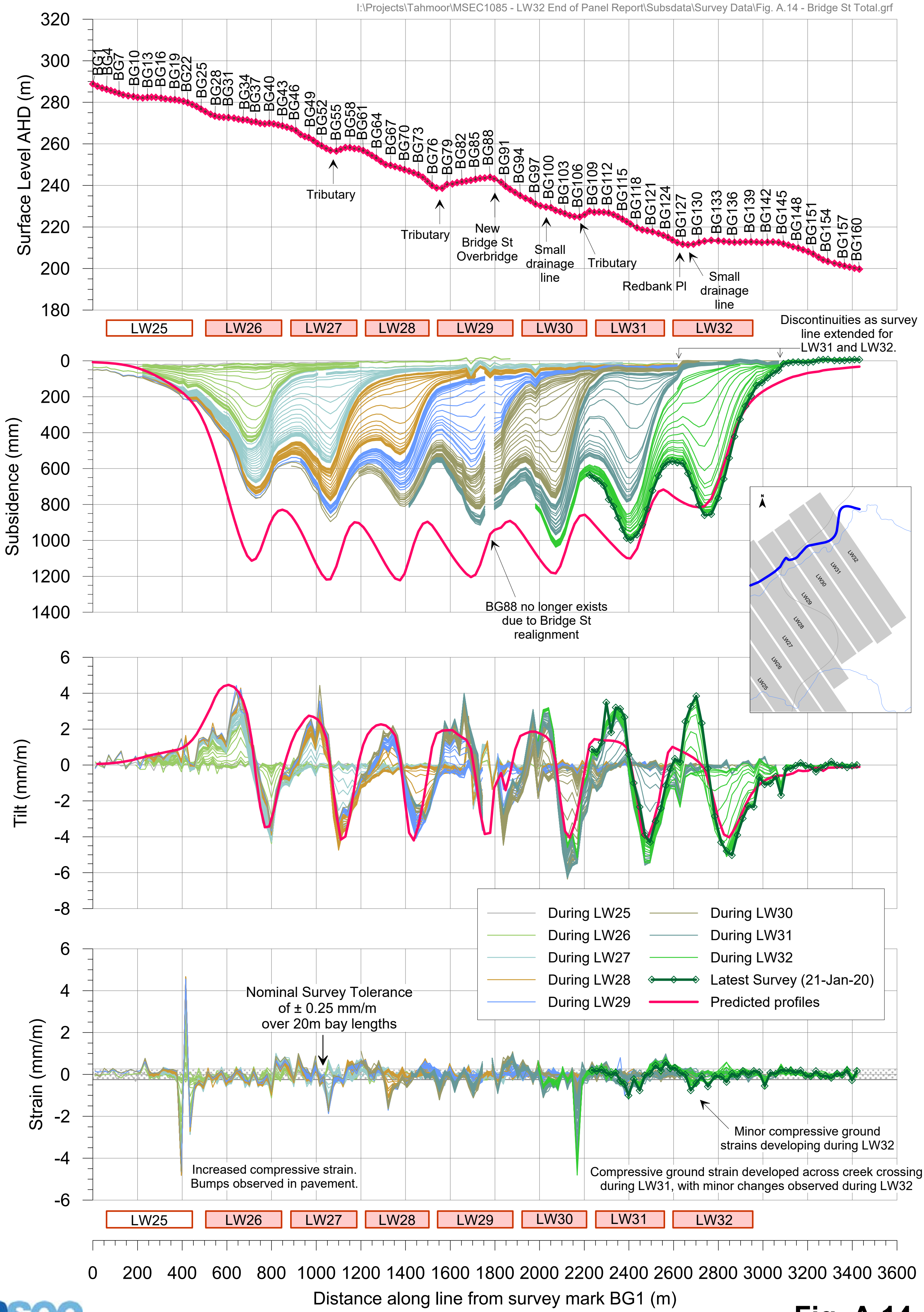
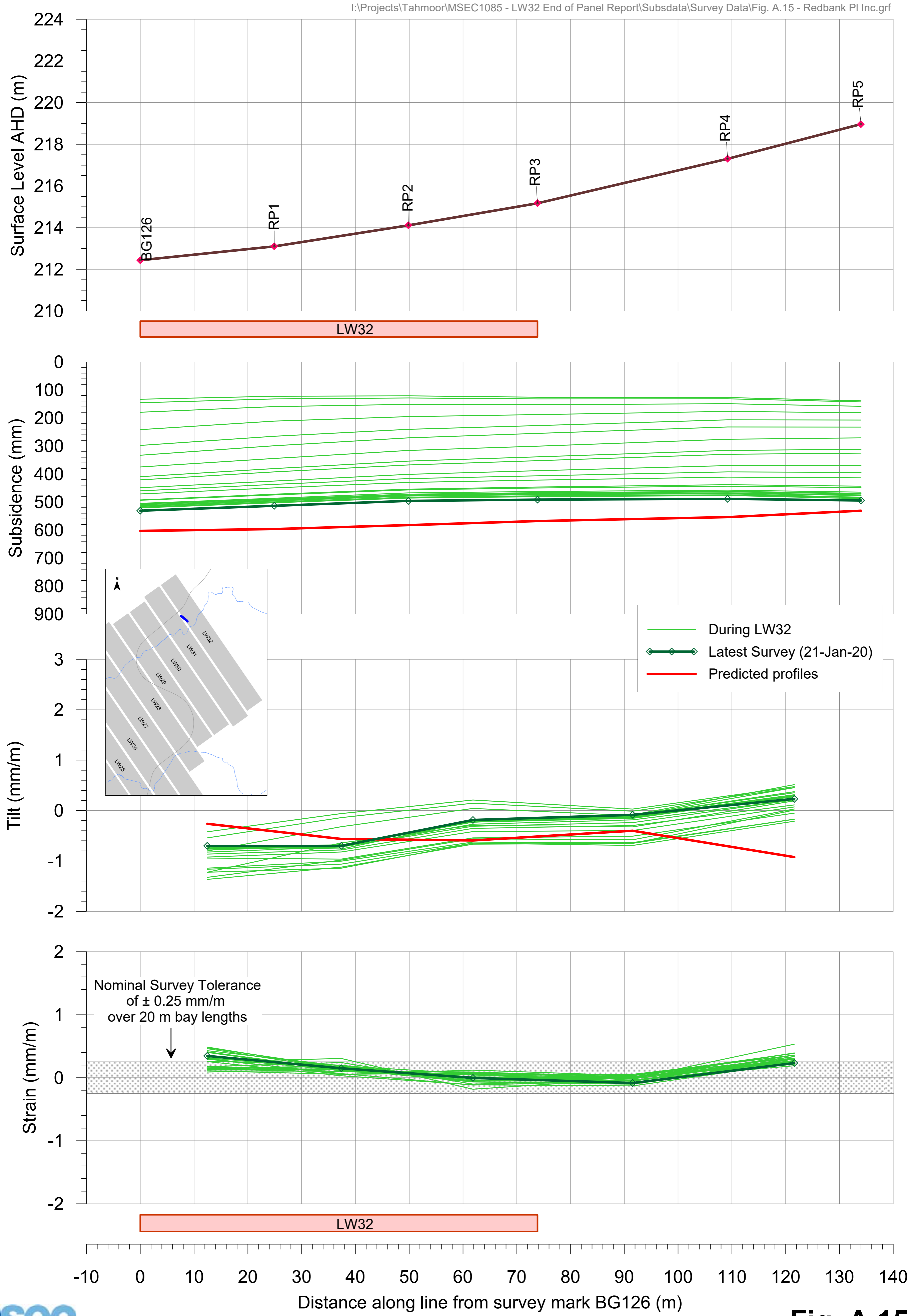


Fig. A.14

Tahmoor - Longwall 32
Incremental subsidence profiles along Redbank Place



msec

Fig. A.15

Tahmoor - Longwall 32
Total subsidence profiles along Redbank Place

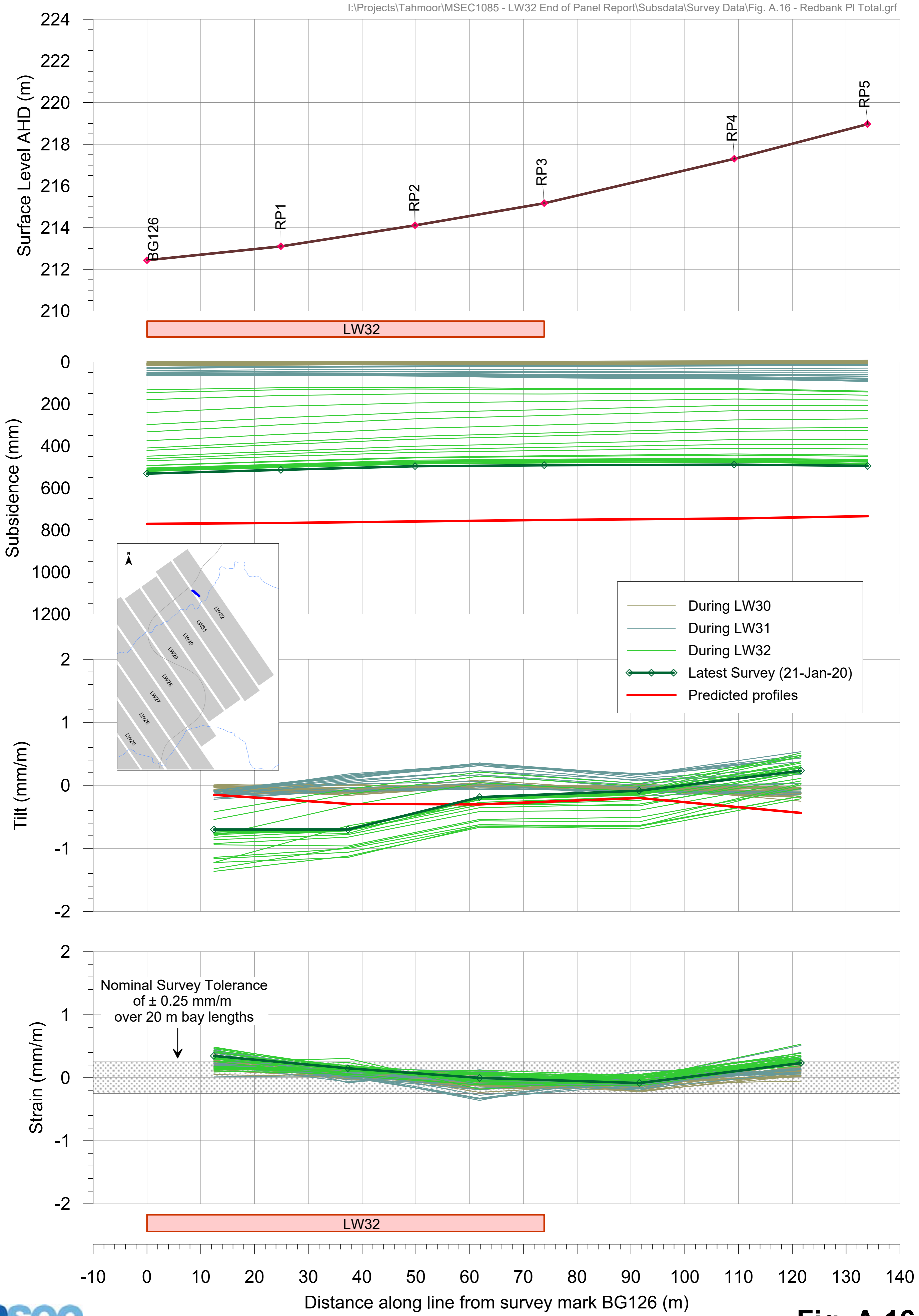


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Fig. A.16

Tahmoor - Longwall 32
Incremental subsidence profiles along Bollard Place

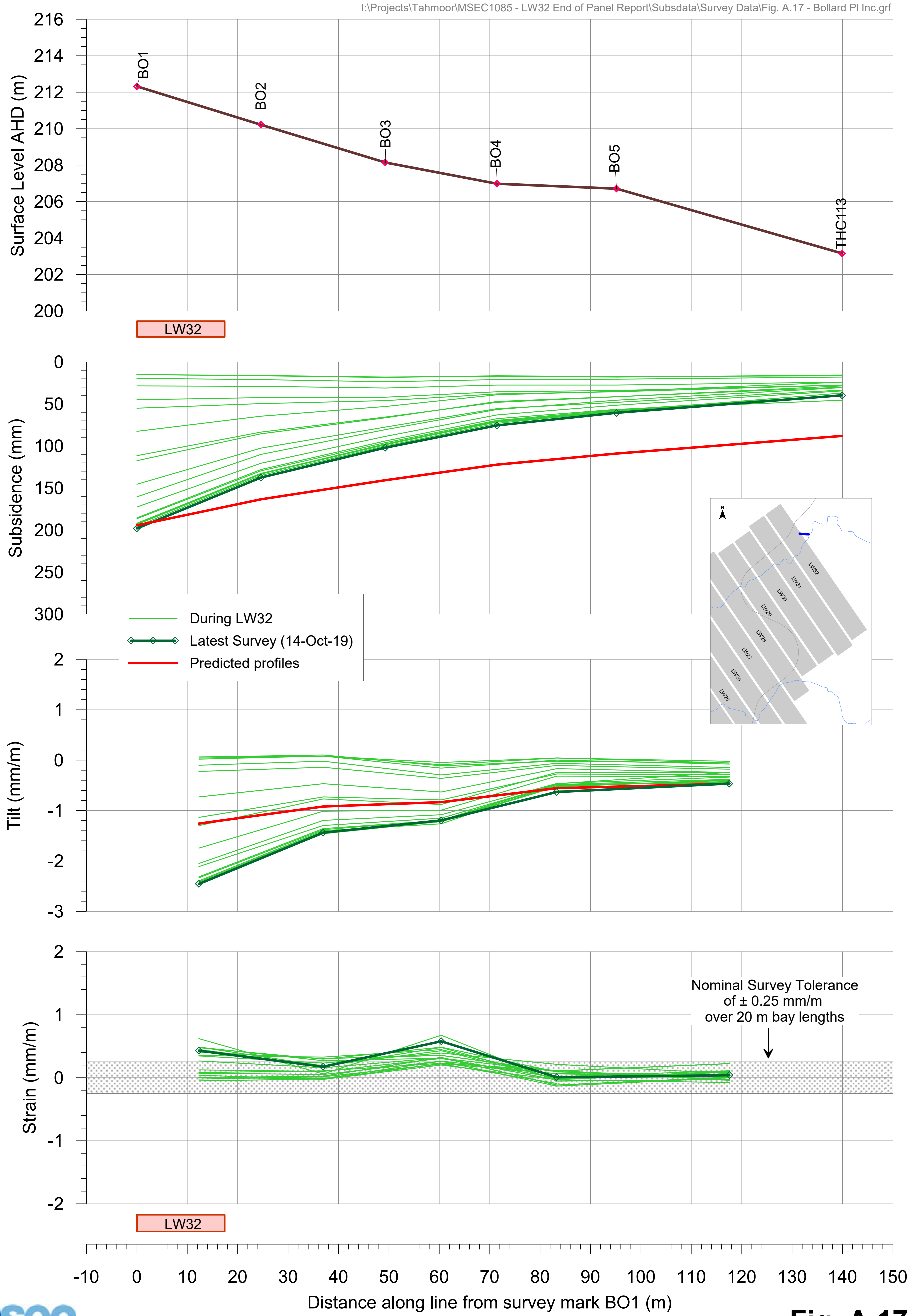

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Fig. A.17

Tahmoor Coal - Longwall 32
Total subsidence profiles along Bollard Place

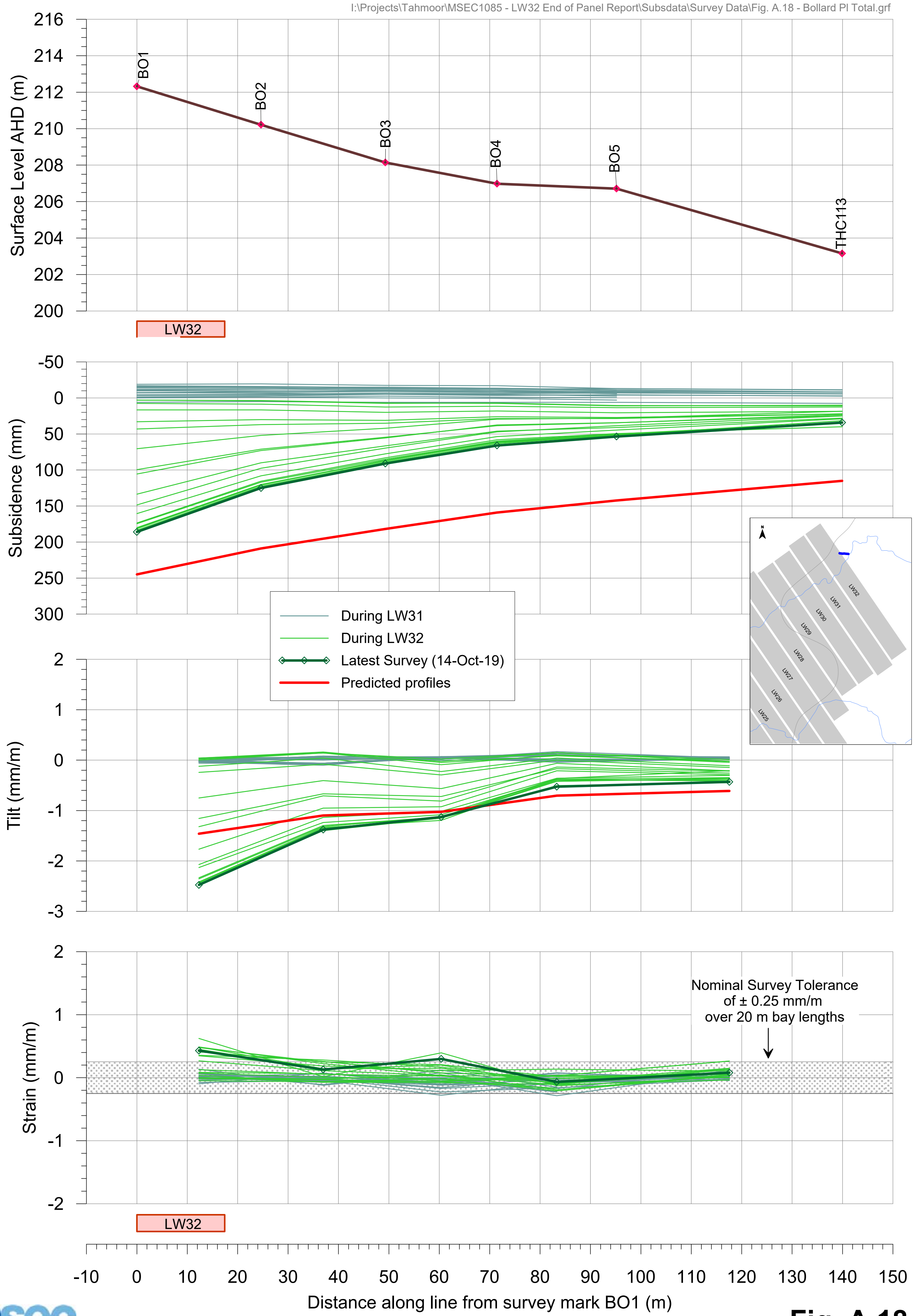

Fig. A.18

Tahmoor - Longwall 32
Incremental subsidence profiles along Thirlmere Way

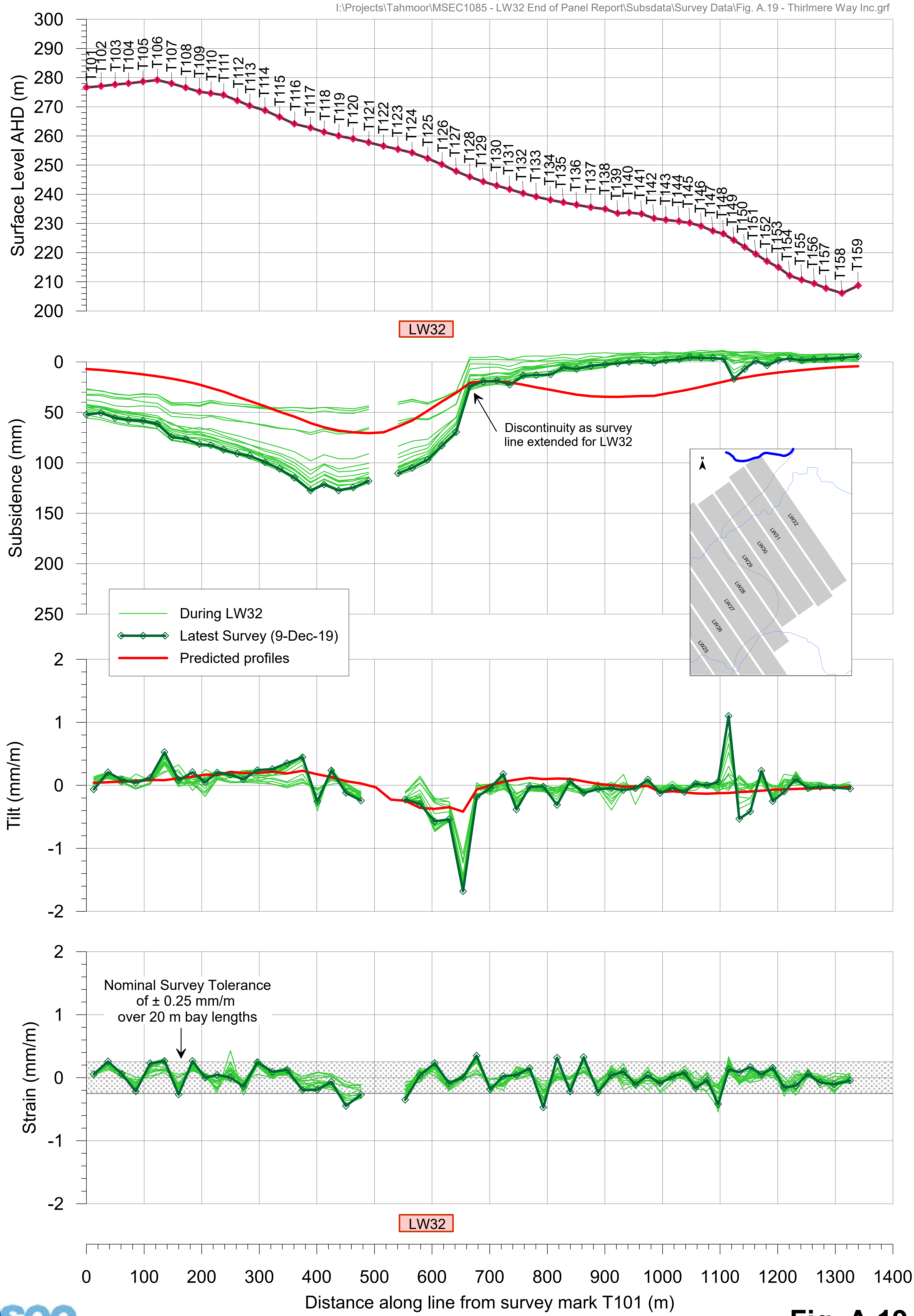

Fig. A.19

Tahmoor - Longwall 32
Total subsidence profiles along Thirlmere Way

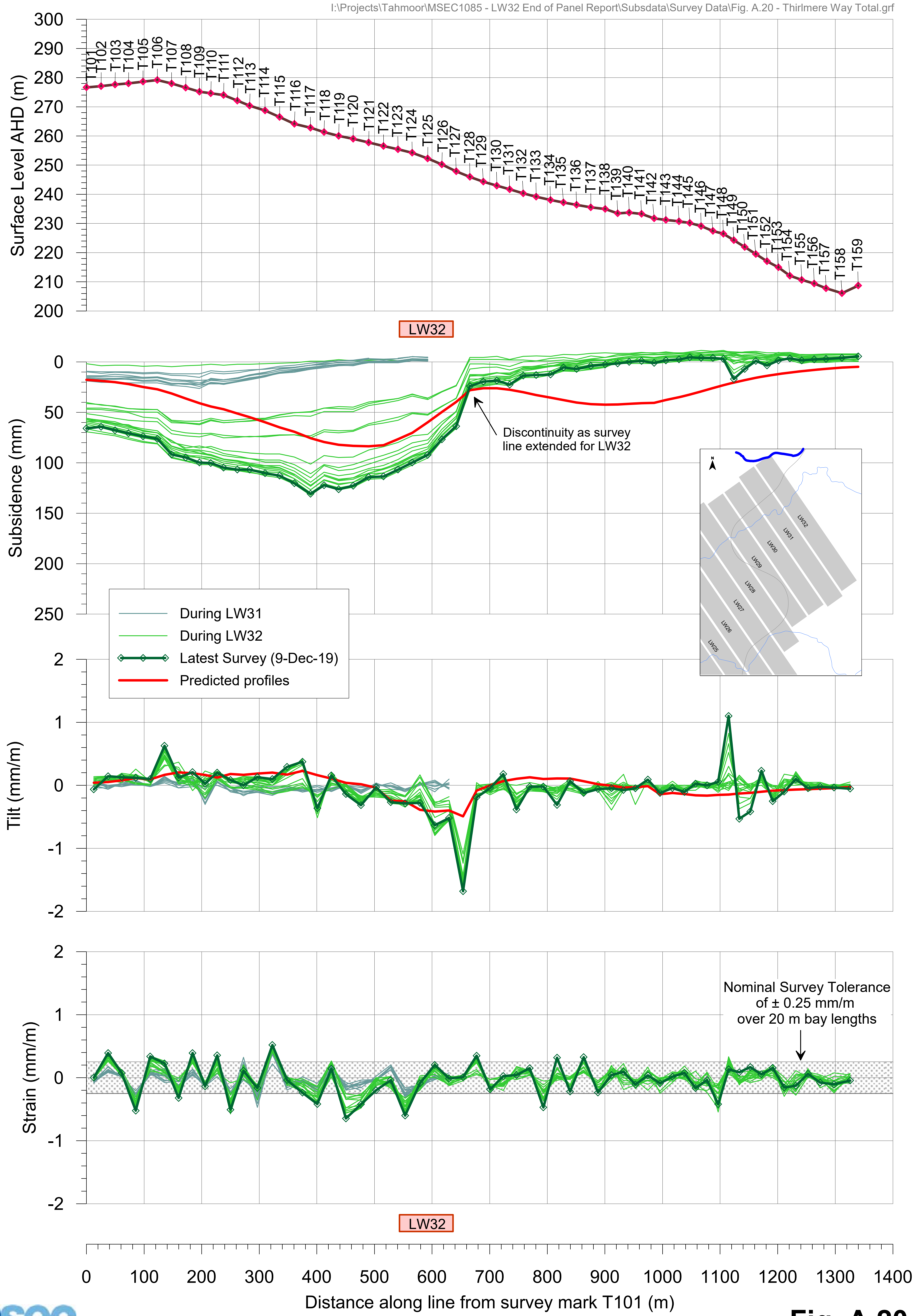

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Fig. A.20

Tahmoor - Longwall 32
Incremental subsidence profiles along the Optical Fibre Line

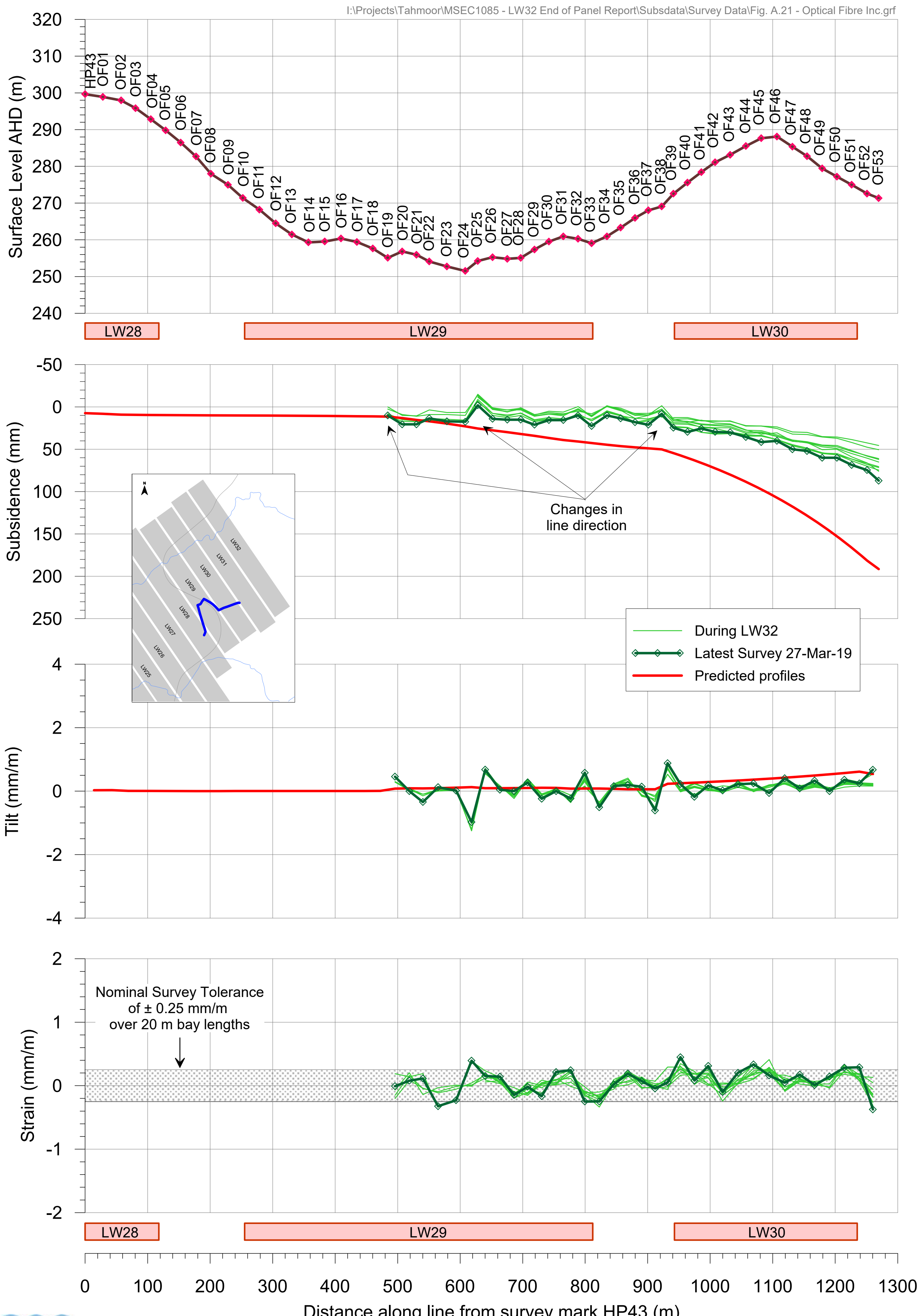

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Fig. A.21

Tahmoor - Longwall 32
Total subsidence profiles along the Optical Fibre Line

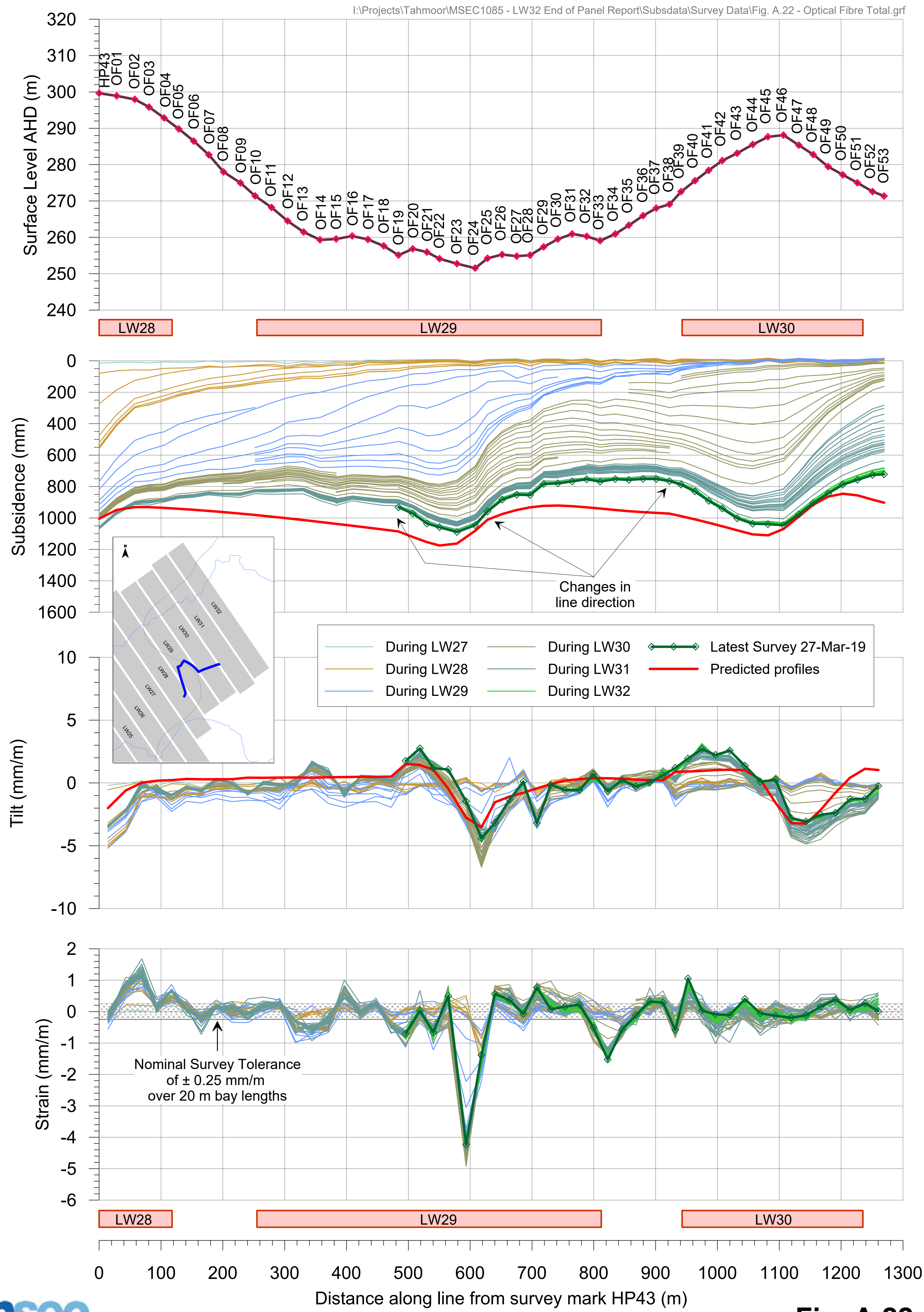

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Fig. A.22

Tahmoor Coal - Longwall 32
Incremental subsidence profiles along Thirlmere Carrier (east)

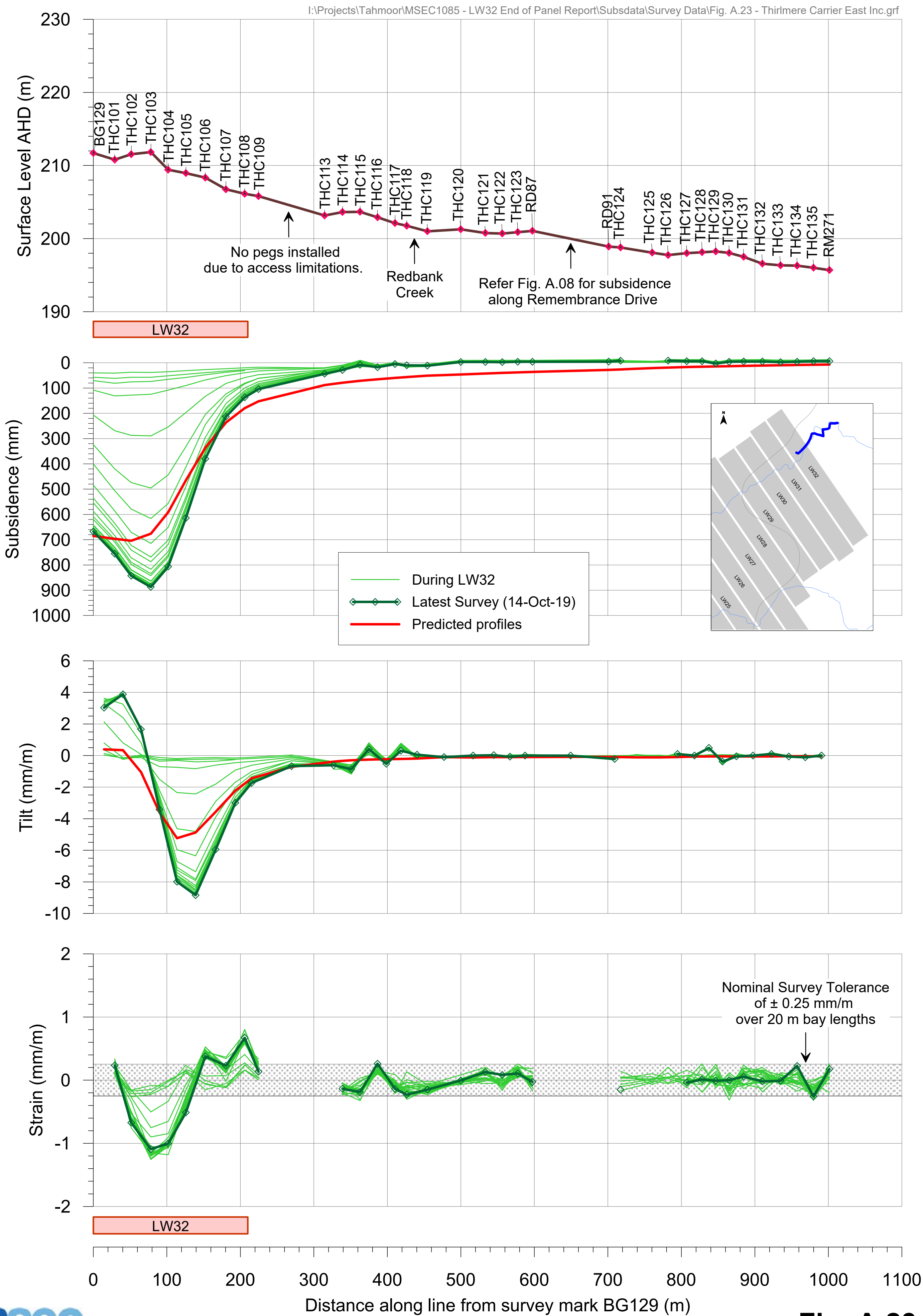

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Fig. A.23

Tahmoor Coal - Longwall 32
Total subsidence profiles along Thirlmere Carrier (east)

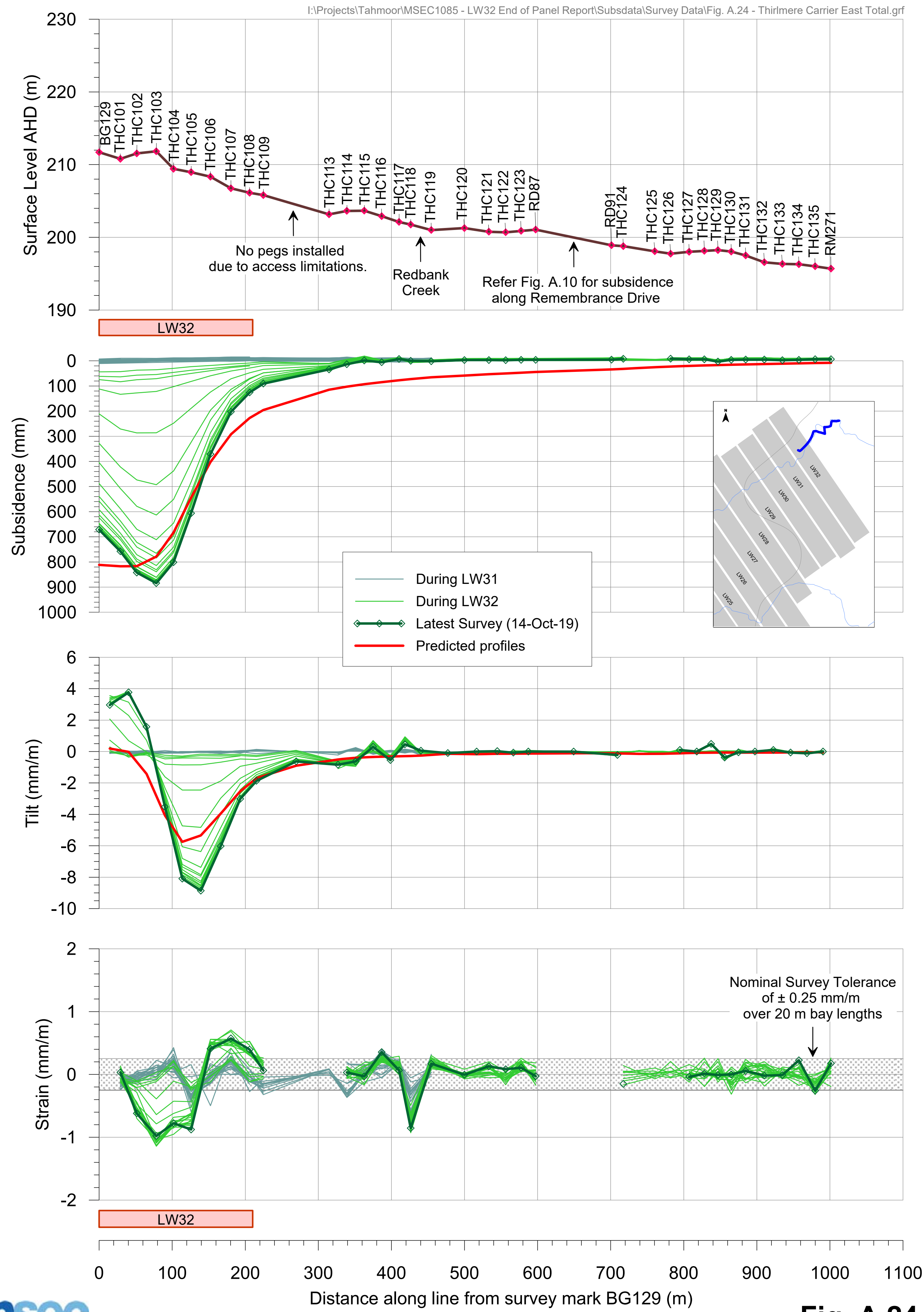

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Fig. A.24

Tahmoor Coal - Longwall 32
Incremental subsidence profiles along Thirlmere Carrier

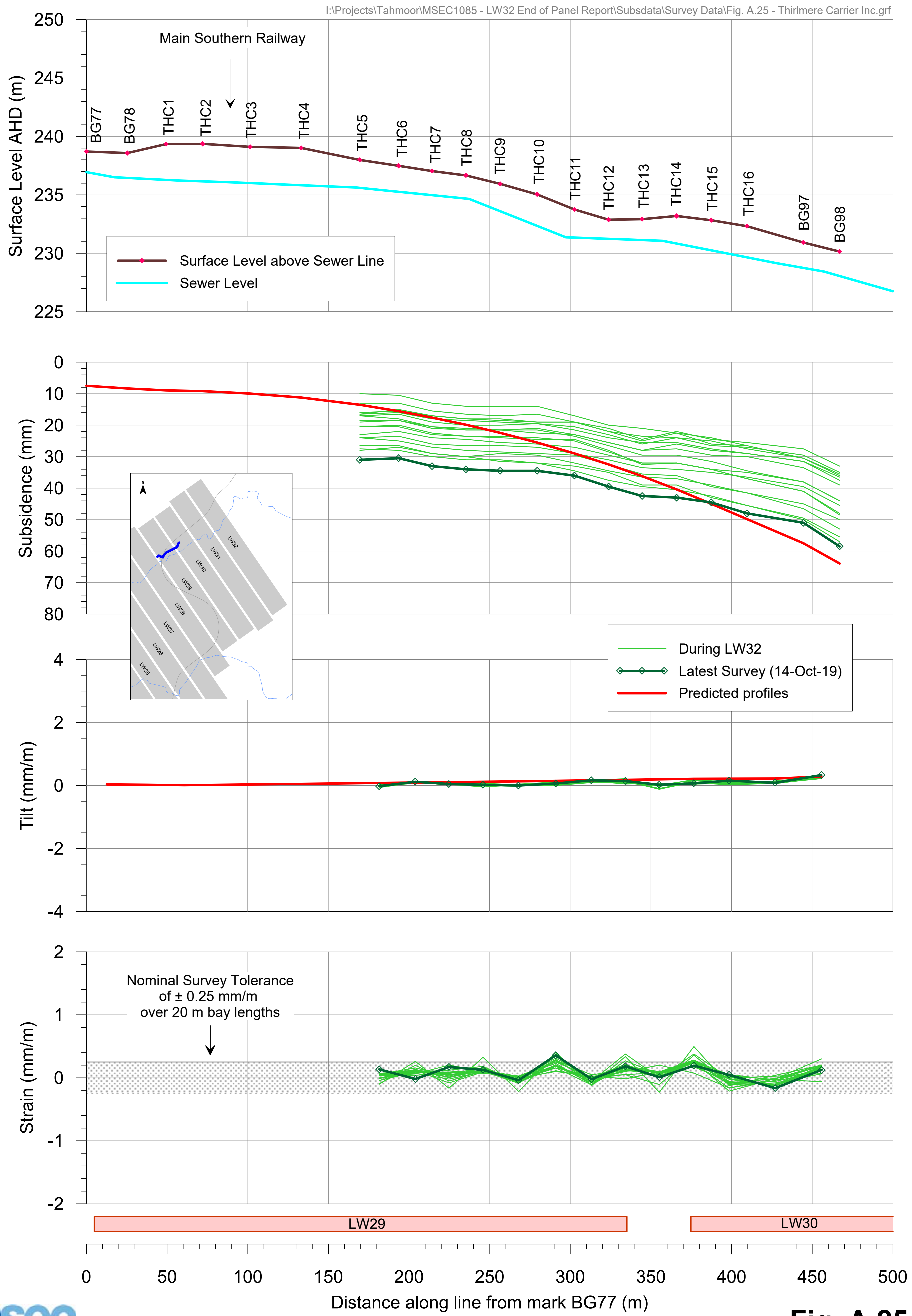

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Fig. A.25

Tahmoor Coal - Longwall 32
Total subsidence profiles along Thirlmere Carrier

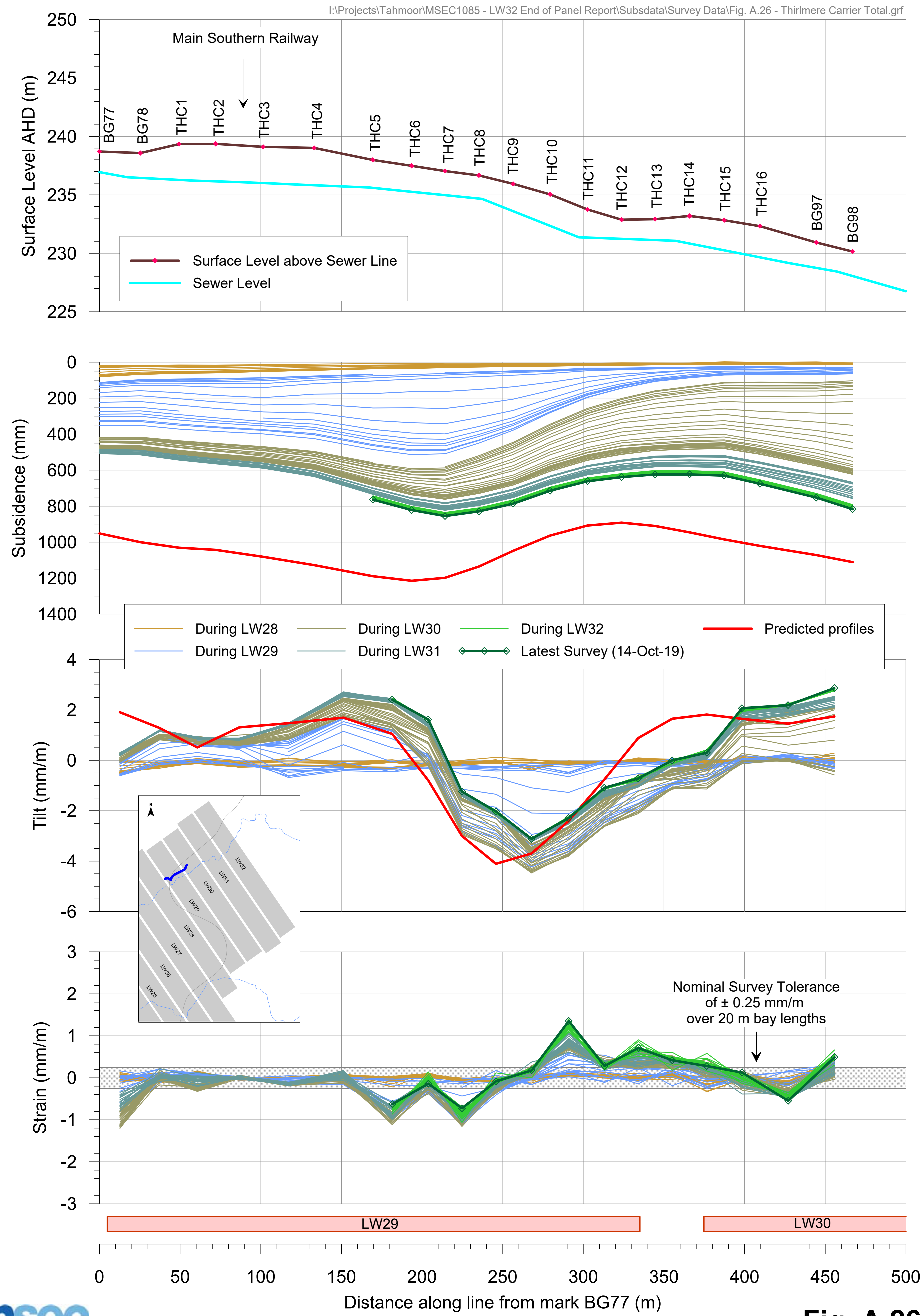

Fig. A.26

Tahmoor Coal - Longwall 32
Incremental subsidence profiles along Redbank Creek RK Line

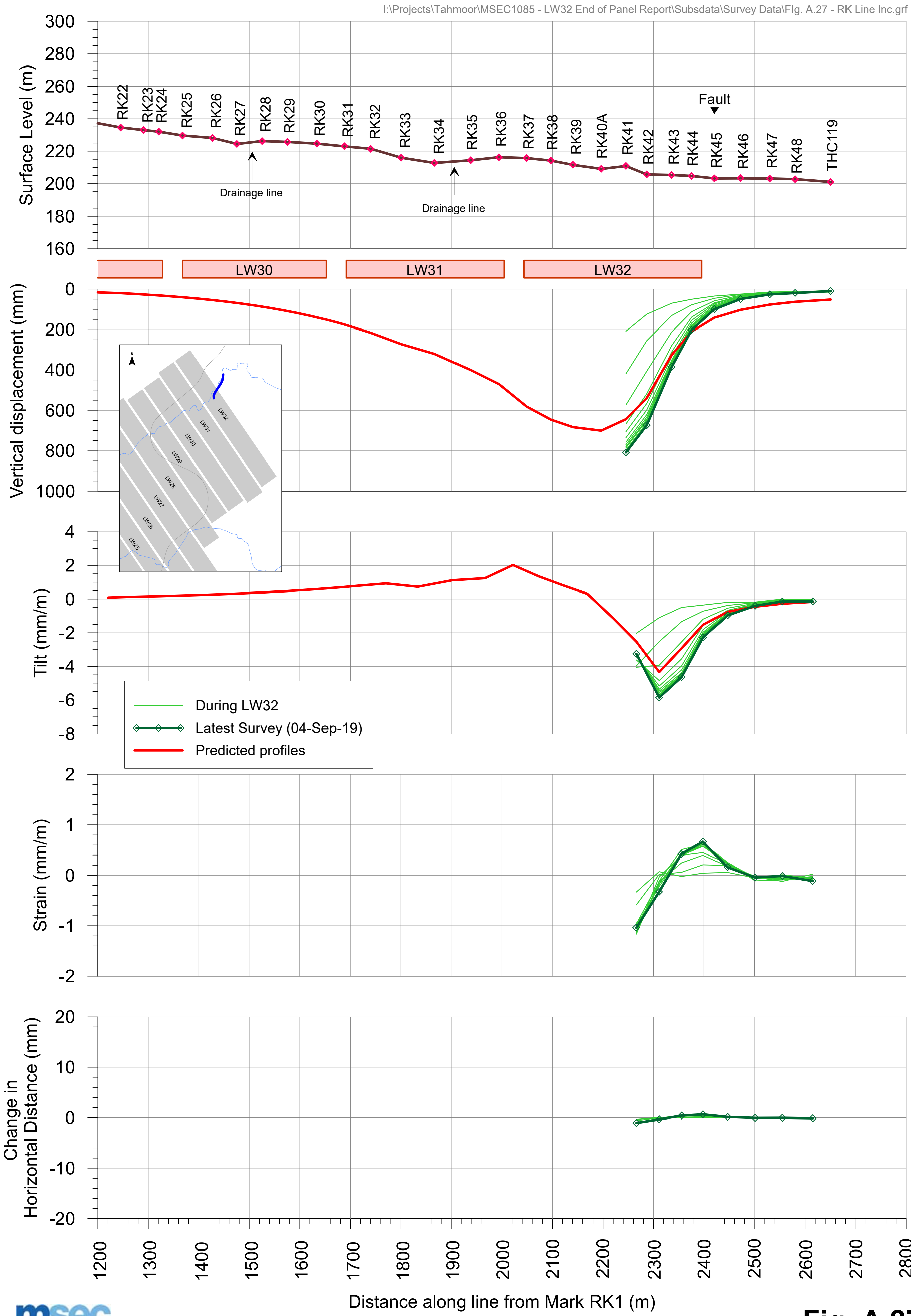

Fig. A.27

Tahmoor Coal - Longwall 32
Total subsidence profiles along Redbank Creek RK Line

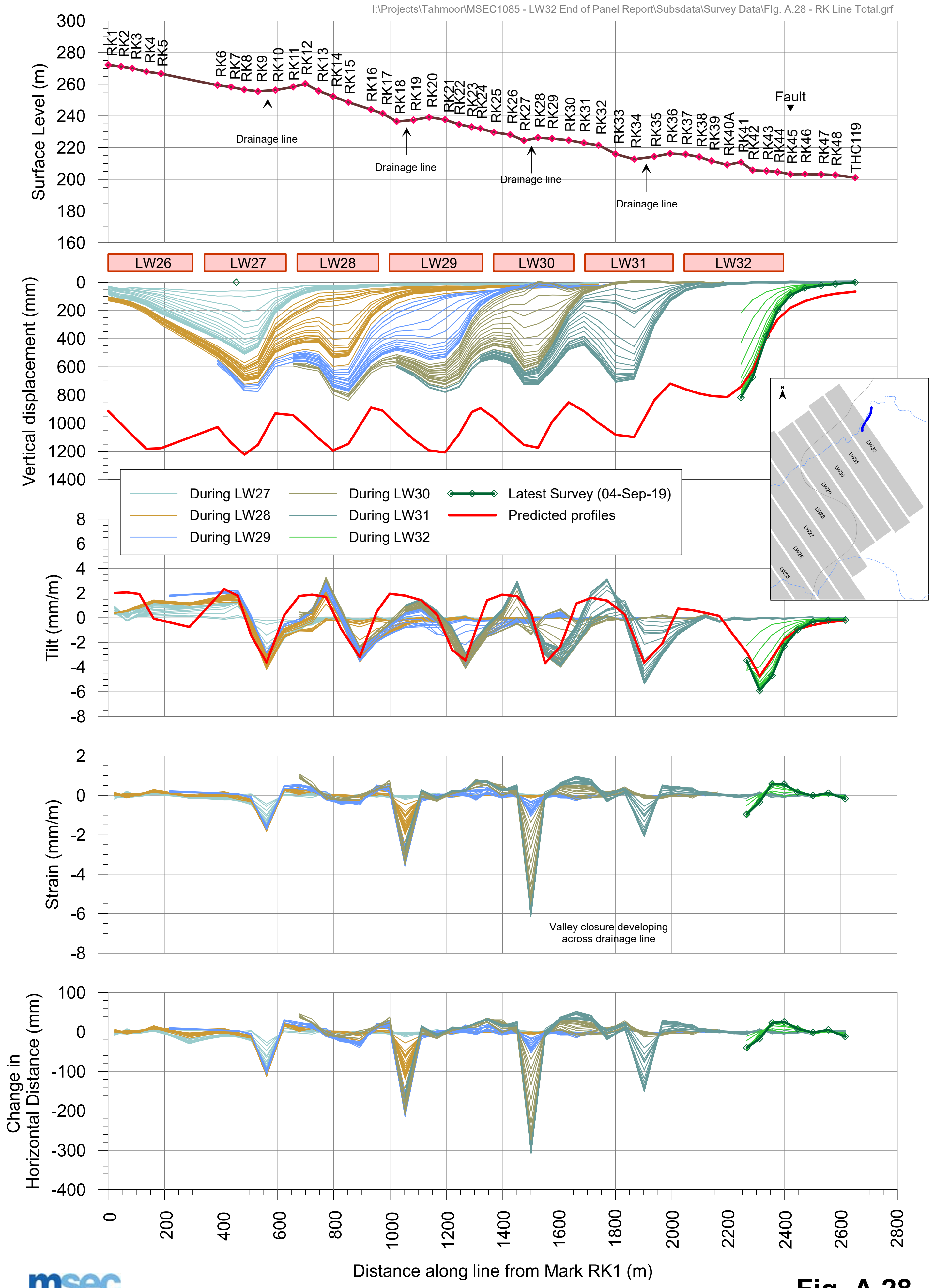

Fig. A.28

Tahmoor Coal - Longwall 32
Incremental subsidence profiles along Main Southern Railway Corridor

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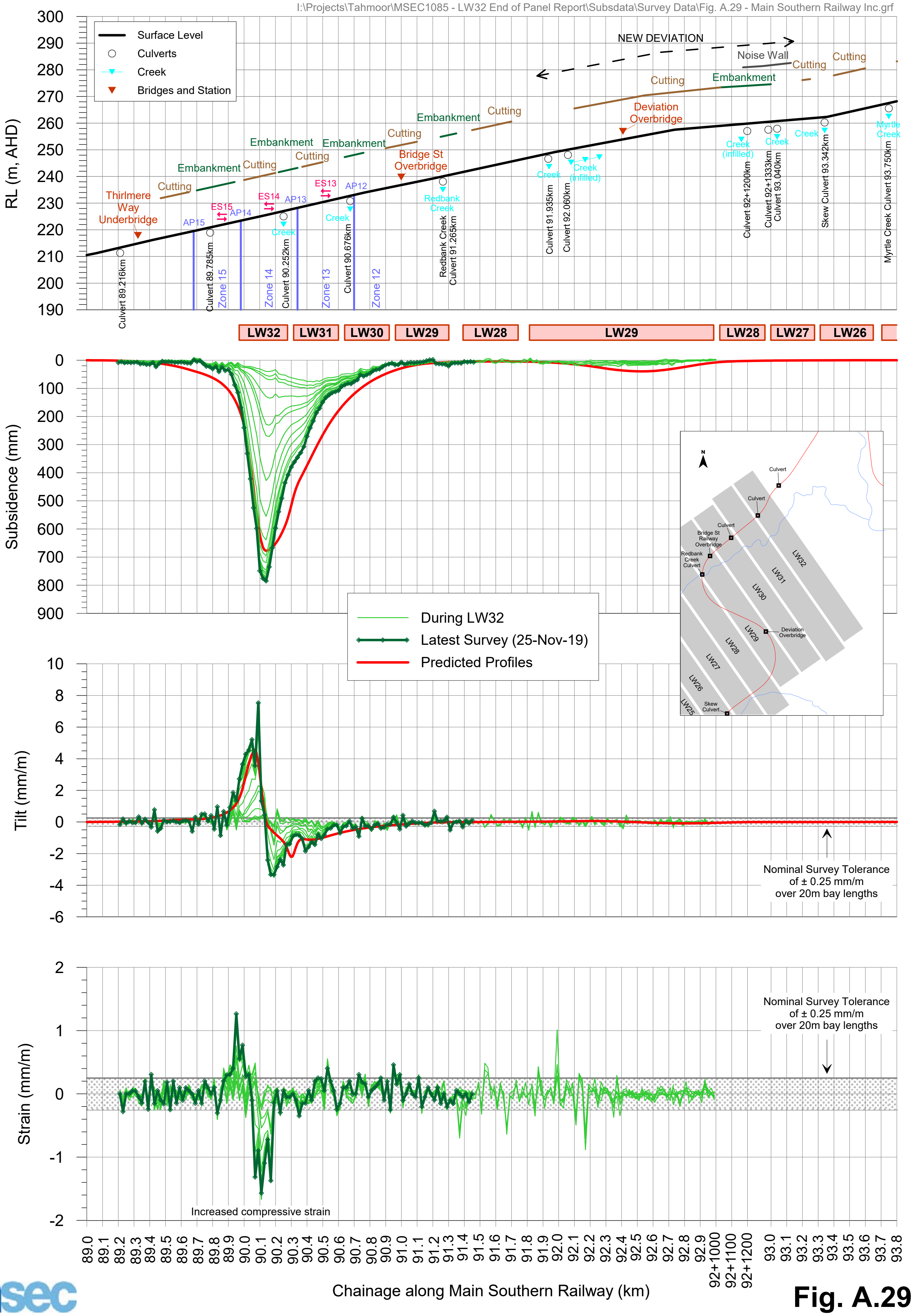

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Fig. A.29

Tahmoor Coal - Longwall 32
Total subsidence profiles
along Main Southern Railway Corridor

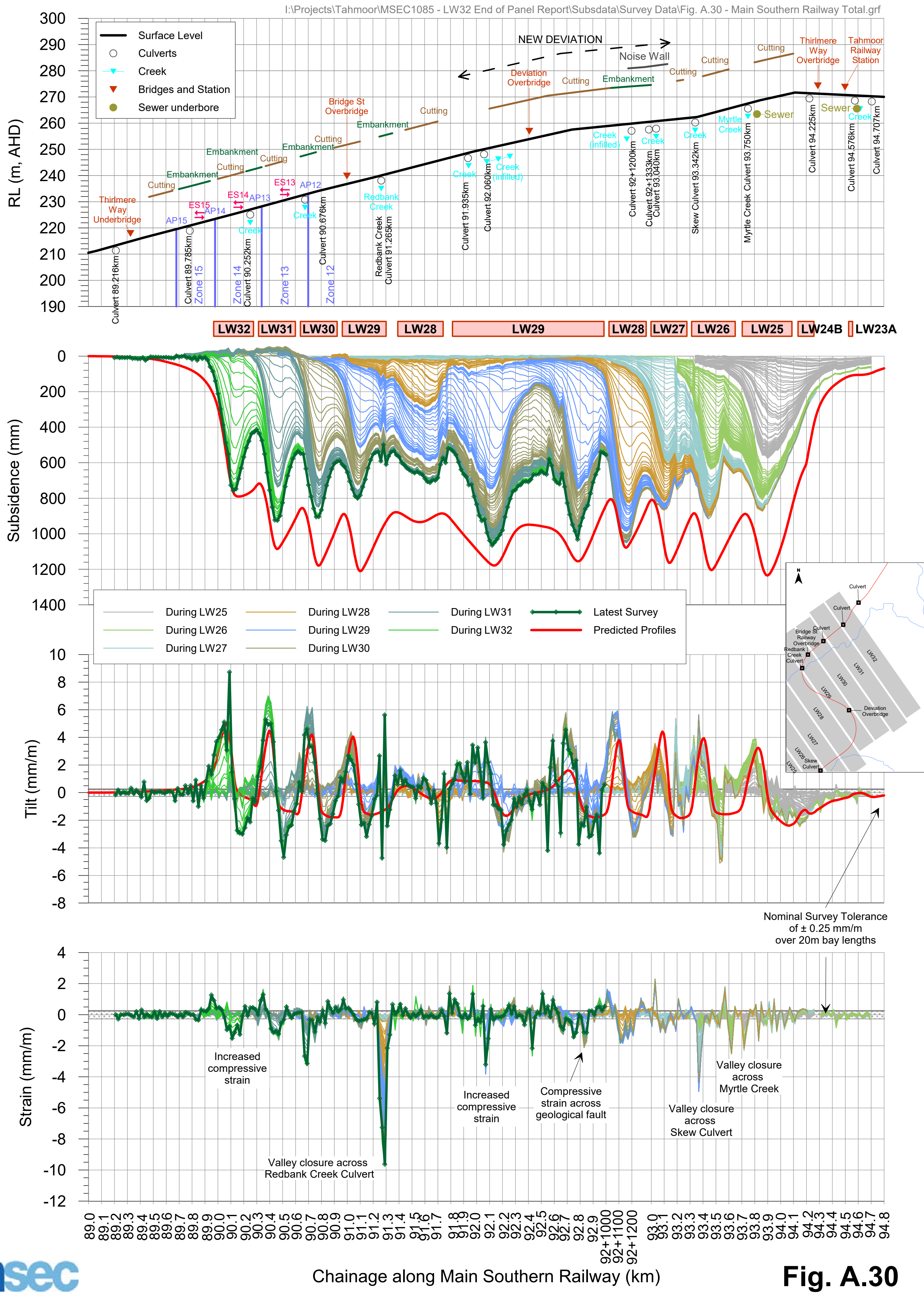

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Fig. A.30

APPENDIX B. DRAWINGS

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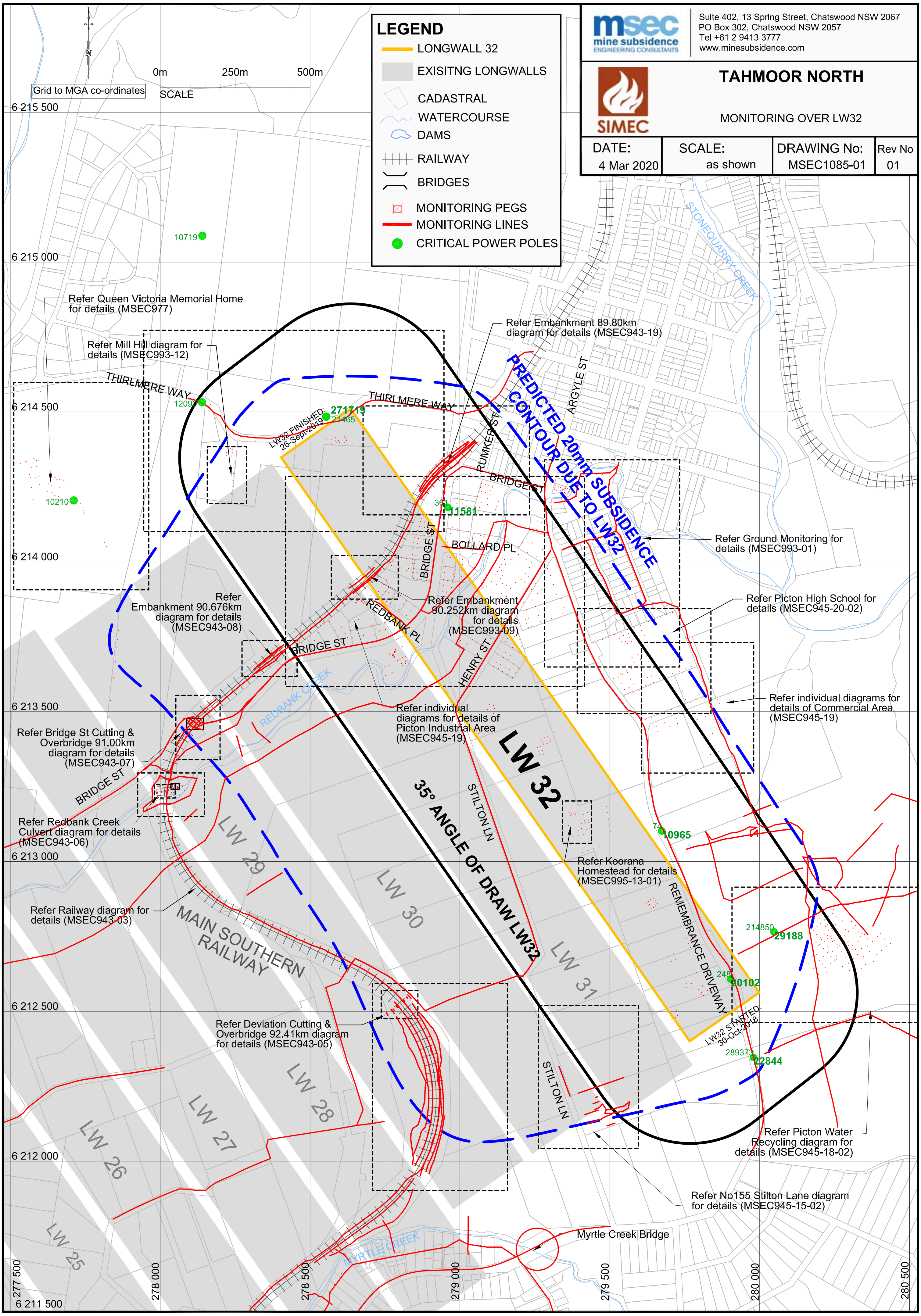

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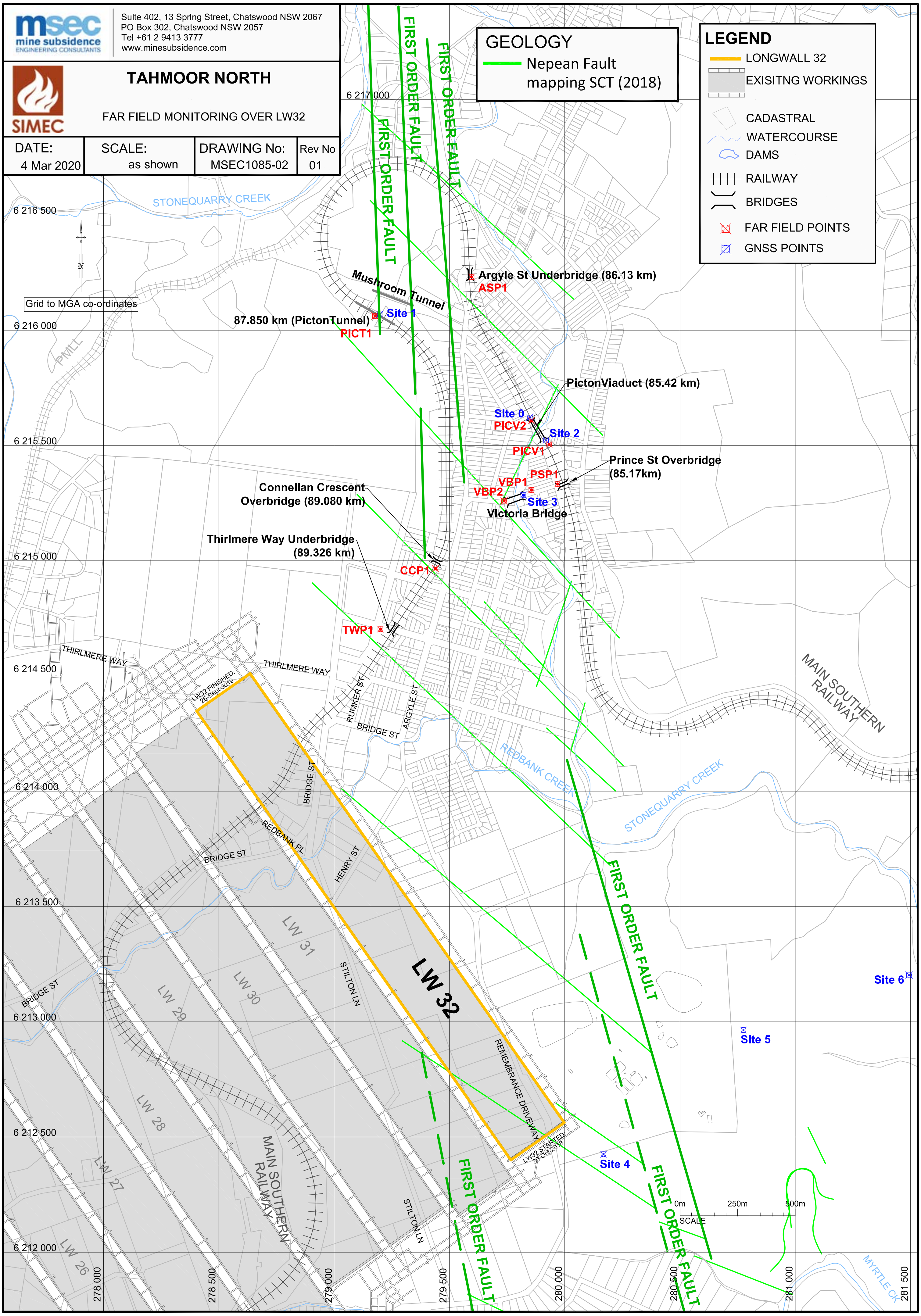

Tahmoor Colliery

Longwall 32
Surface Water, Dams and Groundwater
End of Panel Monitoring Report

TA35-R1A

27 March, 2020

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: Fiona Robinson

Fiona,

RE: Tahmoor Coking Coal Operations End of Longwall 32 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

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

Date	Rev	Comments
05/02/2020		Initial Draft
27/03/2020	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 groundwater systems within the Longwall 32, 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 32
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 Longwalls 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 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	Previously depressurised groundwater monitoring boreholes have gradually re-pressurised in areas outside of the active subsidence region. Interconnection between aquifers and aquitards was observed within 20m of the surface in the subsidence zone along Redbank Creek. No impacts on privately owned bores in regard to yield and serviceability occurred as a result of Longwall 32 extraction.
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	Temporary lowering of the shallow and deeper water levels in Piezometers P9 and P10 greater than 10m occurred due to Longwall 32 extraction, which partially recovered following the January / February 2020 rain events. The deeper water level recovery in P9 was not able to be measured as the casing sheared, whilst the P10 deeper water level recovered to above the pre-undermining level between late June and early August 2019.

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	The previously depressurised open standpipe piezometers P1, 3, 4, 7 and 8 gradually re-pressurised to similar, albeit lower pre-mining level compared to their original maximum depressurisation level.
The yield and serviceability in 1 registered bore (P4) may be affected by subsidence	No private bores have been reportedly adversely affected by subsidence associated with Longwall 32.
Horizontal displacement may make the private bore inaccessible	No private bores were reported to have been horizontally displaced as a result of Longwall 32 extraction. However a water bore (GW109010) that was horizontally sheared by Longwall 25 in 2009 was subsequently re-drilled by SA NSW in November 2019.
Potential Impacts	**Observed Impacts Due to Extraction of Longwall 32**
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 32.
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 32.
Interface drainage, ferruginous, brackish seeps may be generated in streams on the plateau	Increased ferruginous and salinity levels have been observed over and downstream of the Longwall 29 - 32 reach 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 was observed.

1. INTRODUCTION

Tahmoor Coal Pty Ltd (Tahmoor Coal) has extracted the Bulli Seam in Longwalls 22, 23A, 23B, 24A, 24B and 25 to 32 by retreat mining within the Tahmoor North Lease Area since June 2004.

The previous and last longwall in the Tahmoor North mining domain (Longwall 32) are located underneath Tahmoor, Thirlmere and Picton 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 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 32.

Surface water and groundwater features within the Longwall 32, 20mm subsidence zone include:

- Main channel and tributaries of Redbank Creek, which flows ENE into Stonequarry Creek and subsequently the Nepean River;
- 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;
- 12 generally small earthen wall dams that directly overly Longwall 32; and
- Four vibrating wire piezometer (VWP) arrays in bores TNC28 and TNC29 (now decommissioned) as well as TNC43 and P9 (VWP), two multi depth open standpipe piezometers (P9 and P10) and one licensed private bore (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 following:

- 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 completed 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 Pty Ltd (GeoTerra) (2009).

Surface water and groundwater monitoring End of Panel reports have been prepared for Longwalls 22, 23A, 23B, 24A, 24B and 25 to 31 by GeoTerra.

Ongoing monitoring of water level, flow and water quality in the plateau streams and groundwater bores is being conducted throughout extraction of LW 32 by Tahmoor Coal staff, GeoTerra 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 Coal has extracted coal by longwalls 1 to 32 in the Tahmoor North mining domain.

Longwall 32 commenced on 1 November 2018 and was completed on 29 October 2018 as outlined in **Table 1**. Longwall extraction in all panels occurred up-dip 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	29/10/18	26/09/2019	2500	450 - 500

Extraction of Longwall 32 occurred from 450 - 500m below surface with a seam thickness of approximately 2.1m.

Longwall 32 was 283m wide rib to rib, with a 39m wide chain pillar and is approximately 2,380m 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 32 20mm subsidence area also contains the main channel and tributaries of Myrtle and Redbank Creeks, which flow both to the Nepean River. These creeks are located approximately 1,100m south east of Longwall 32.

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 Myrtle Creek

Myrtle Creek is located approximately 830m south-west of Longwall 32.

The headwaters of the creek 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. Longwalls 29 to 32 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.

Water NSW registered water extraction does not occur within the creek, however an unlicensed pump was previously present over the middle of Longwall 25, off Castlereagh Street.

Myrtle Creek is outside the Longwall 32 20mm subsidence zone and is not discussed further in this report.

3.2.2 Redbank Creek

Redbank Creek drains into Stonequarry Creek approximately 1.06km downstream of the monitoring area, and Stonequarry Creek subsequently flowing into the Nepean River.

Redbank Creek has been undermined by Longwalls 25 to 32.

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 32.

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 32, 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 38 (also referred to as RC2 and R6) and downstream to RR30 over Longwall 32.

3.2.3 Dams

Surface runoff into the local streams and subsequently, the Nepean River, is regulated by 12 dams that directly overly Longwall 32 and associated chain pillars.

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

3.2.4 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).

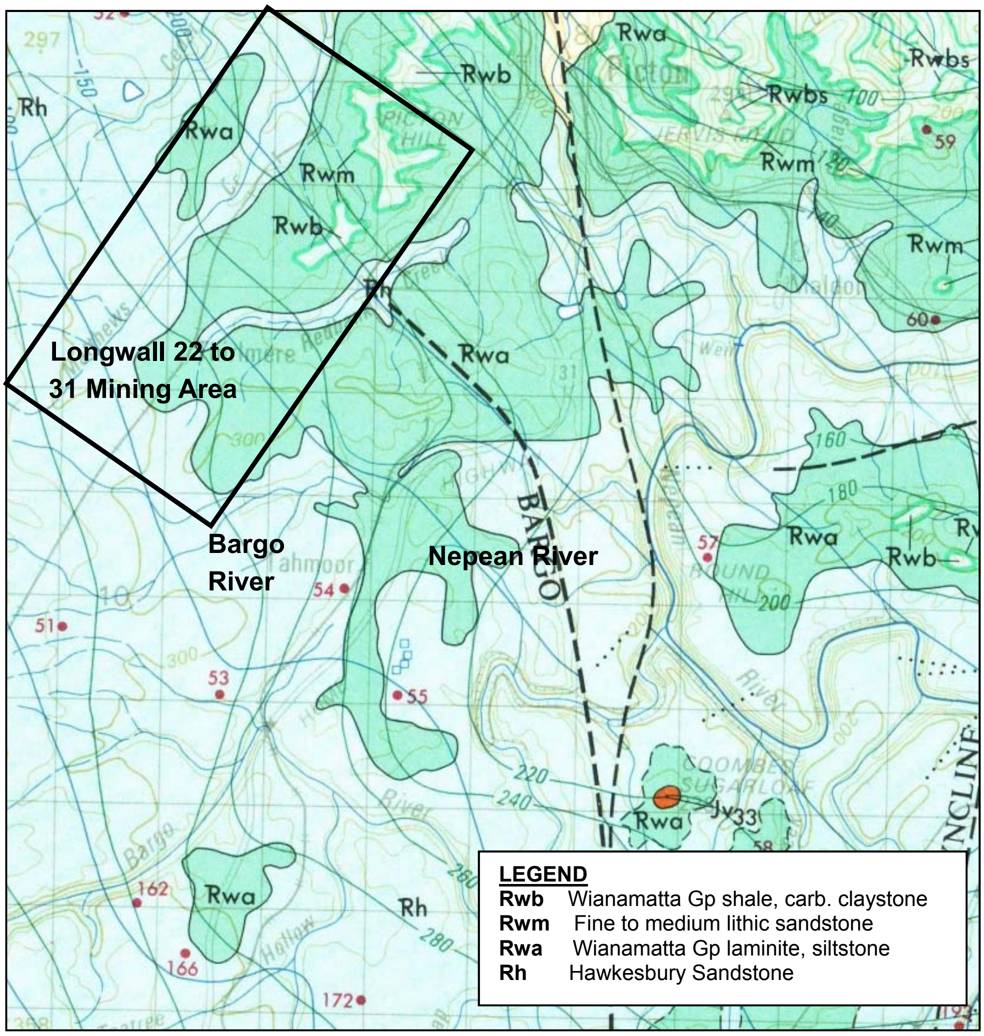


Figure 1 Surficial Geology

3.3 Hydrogeology

The Bargo River is a ‘gaining’ system, where groundwater flows from the plateau under a regional hydraulic gradient to the river. In this river, groundwater flow is predominantly 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.

Five Water NSW registered private bores, two uncased coal exploration bores and fifteen registered piezometers are located within the Longwall 22 to 32 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, over the Longwall 32 maingate chain pillar.

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.

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.

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

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 (68 mbgl) monitoring was discontinued due to shearing on 29th May 2019.

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			

4. RESULTS

4.1 Subsidence

The maximum monitored subsidence, tilt and strain following the completion of extraction of Longwall 32 is shown in **Table 4**.

Table 4 Maximum Subsidence at the Completion of Longwall 32

Component	Observed Total Movement
Vertical subsidence	1089 mm
Tilt	8.9 mm/m
Tensile / Compressive Strain	1.9 / -4.5 mm/m

Source: MSEC, 2020

4.1.1 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, 2020), with the available survey data (accurate to approximately 20 – 30mm.

4.2 Redbank Creek Monitoring

4.2.1 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 5** and shown in **Drawing 1**.

Table 5 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 Windeyer 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 31, 32 and downstream of Longwall 32 commenced on 12 December 2018 and continued until 16 July 2019, after which time, approximately monthly surveys have been conducted to date as shown in **Table 6**.

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

Redbank Creek was first undermined by Longwall 32 on approximately 28 May 2019.

Table 6 LW32 Redbank Creek Weekly Monitoring Sites

Site	Description	Additional Sites
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
RT34	Creek reach under cross creek pipe	
RW35	Small height waterfall / rock bar constrained pool	R11
RB36	Rock bar constrained pool	
RR37	Rock bar constrained pool	
RR38	Tree root / sediment / rock bar constrained pool	RC5
RR39	Rock bar constrained pool	

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

4.2.2 Pre Longwall 32 Creek Subsidence Observations

Subsidence effects observed due to extraction of Longwall 31 (i.e. prior to late May 2019, when Longwall 32 first undermined Redbank Creek) at the following sites included:

Over Longwall 25

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

Over Longwall 26

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

Over Longwall 27

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

Over Longwall 28

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

Over Longwall 29

- Sites 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;
- Site RRS12 - partial drying up (without obvious cracking); and
- Site RW13 - partial drying up.

Over Longwall 31

- Site RR23 and RR24 - new cracking, without flow impacts;
- Site RB25 - new cracking and reduced flow impacts;
- Weir 26 - new cracking downstream of the Weir 26 concrete weir, without flow impacts; and
- Sites RR27 and RB28 - new cracking, without flow impacts.

Over Longwall 32

- Site RR29 - rock bar delamination and uplift with pool level reduction; and
- Sires RR30, RR31, RB32 and RB33 / RC4 - pool level reduction, without obvious cracking.

4.2.3 Post Longwall 32 Creek Subsidence Observations

After being undermined by Longwall 32 in late May 2019, Redbank Creek was observed to have undergone subsidence effects as summarised in **Table 7**.

In addition to the sites over and downstream of Longwall 32 that had previously been affected by Longwall 31, subsidence (or additional subsidence) effects were observed as a result of Longwall 32 extraction included:

- Site RR29 - Additional rock bar delamination and uplift, with pool desiccation;
- Site RR30 - pool level desiccation, with limited observed cracking where the underlying sandstone is exposed in the sandy / clayey sediments; and
- Sites RR31, RB32 and RB33 / RC4 - pool desiccation.

It should also be noted that pools between RB33 and RB38 also dried up, however no direct subsidence impact was observed. It is most likely that the drying up of these pools was a result from the extended and significant drought that eventually broke in January 2020.

Table 7 Redbank Creek Subsidence Effects During and After LW31 Extraction

Site	Relative Location	Effect	Date Initially Observed	TARP First Triggered
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
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	Significant pool level decline plus new cracking	Pool medium depth, no cracks 18/4/18	30/09/19
RR31	Centre / maingate	Significant pool level decline plus new cracking	pool dry, no obvious cracks 27/4/18	16/10/19
RB32	Chain pillar	Significant pool level decline, with no obvious cracking	pool dry, no obvious cracks 18/4/18	31/10/19
RB33 / RC4	Dwnstm of chain pillar	Significant pool level decline, with no obvious cracking	pool dry, no obvious cracks 18/4/18	TARP not triggered

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 32 are shown in **Appendix A**.

As shown in **Table 7**, 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;

- 7/6/18 RR29
- 30/9/19 RR30
- 25/10/19 RR31
- 29/11/19 RB32

4.2.4 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 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 Site R2 is located at north eastern upstream corner of Longwall 25, and upstream of Longwall 26.

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

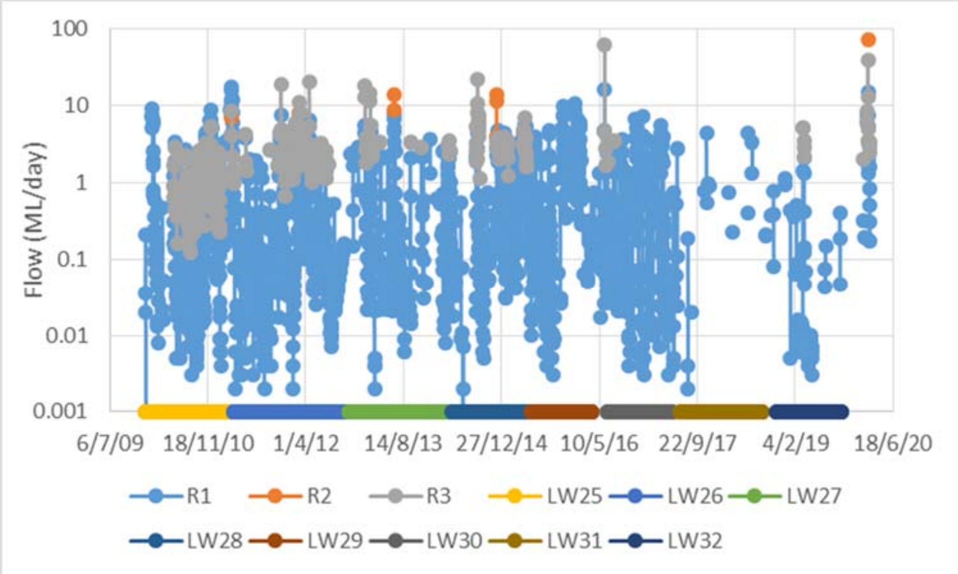
Site R5 is located downstream of Longwall 27, whilst Site R6 is situated over the middle of Longwall 29 and contains the permanently ferruginous Pool RC2.

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

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

The majority of pools over and downstream of Longwalls 25 to 32 showed evidence of subsidence related pool holding capacity impacts. Site R11 also showed drying out of the pool, however this was considered to be primarily due to the extended drought in the catchment, rather than purely subsidence impacts, as shown in **Figure 2**.

Note: missing data is due to loss of logger data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10
1
0.1
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18/11/10
1/4/12
14/8/13
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10/5/16
22/9/17
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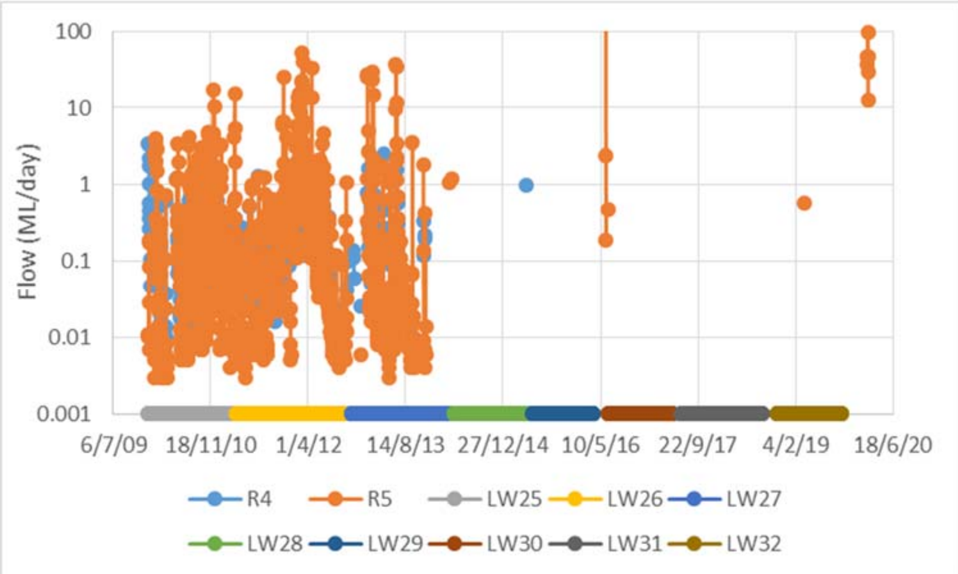
LW30
LW31
LW32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10/5/16
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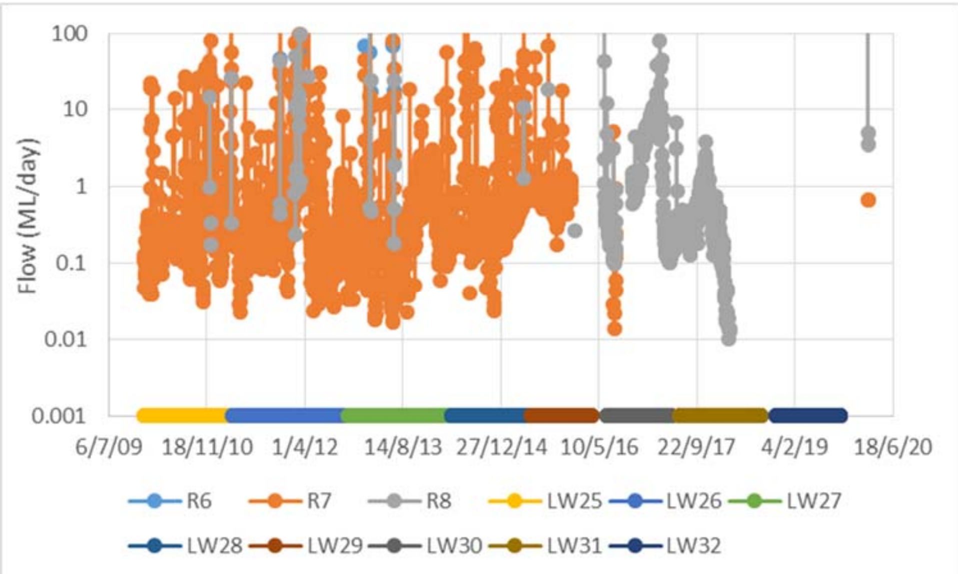
LW30
LW31
LW32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Flow (ML/day)
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1/4/12
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10/5/16
22/9/17
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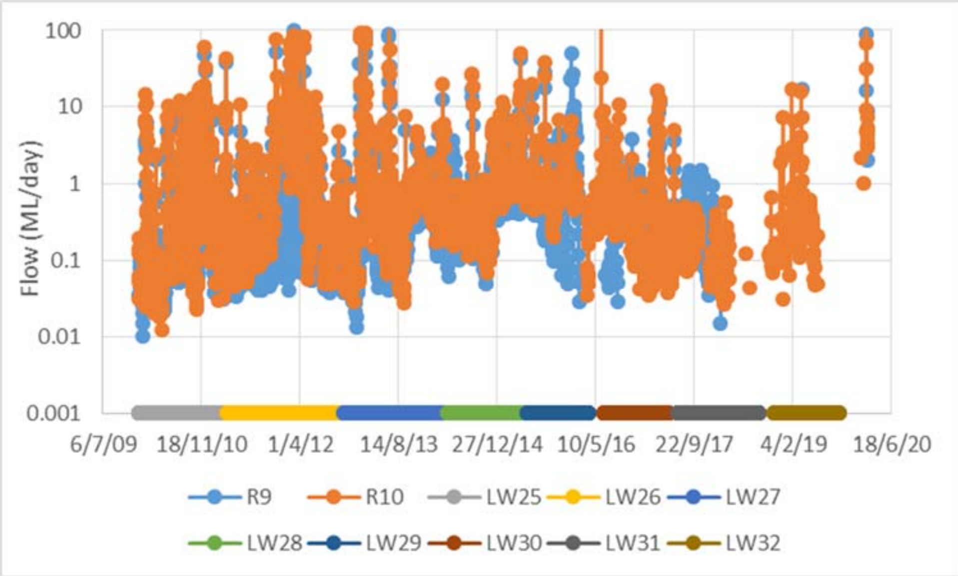
LW32



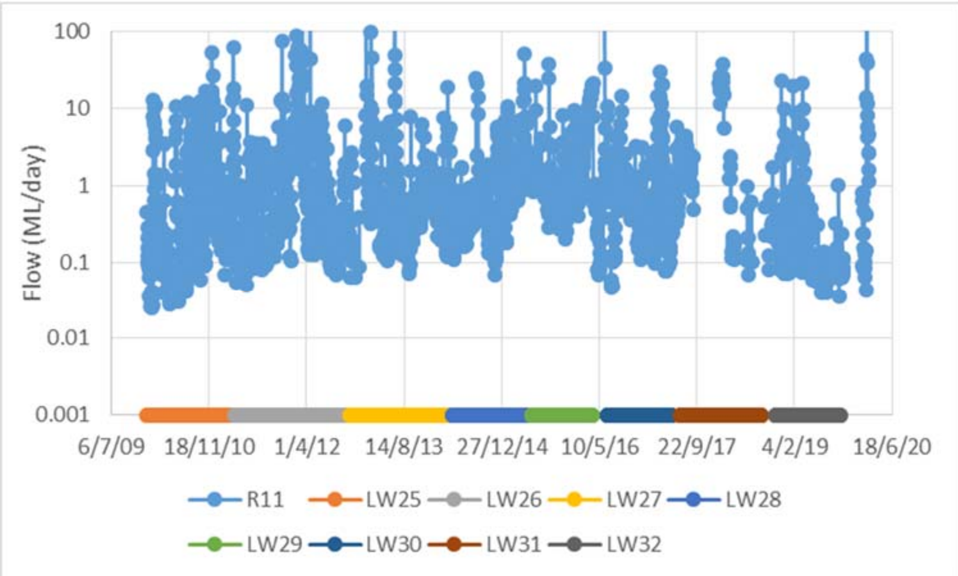


Figure 2 Redbank Creek Flow

4.2.5 Redbank Creek Water Quality

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

During extraction of Longwall 32, 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 / drought periods.

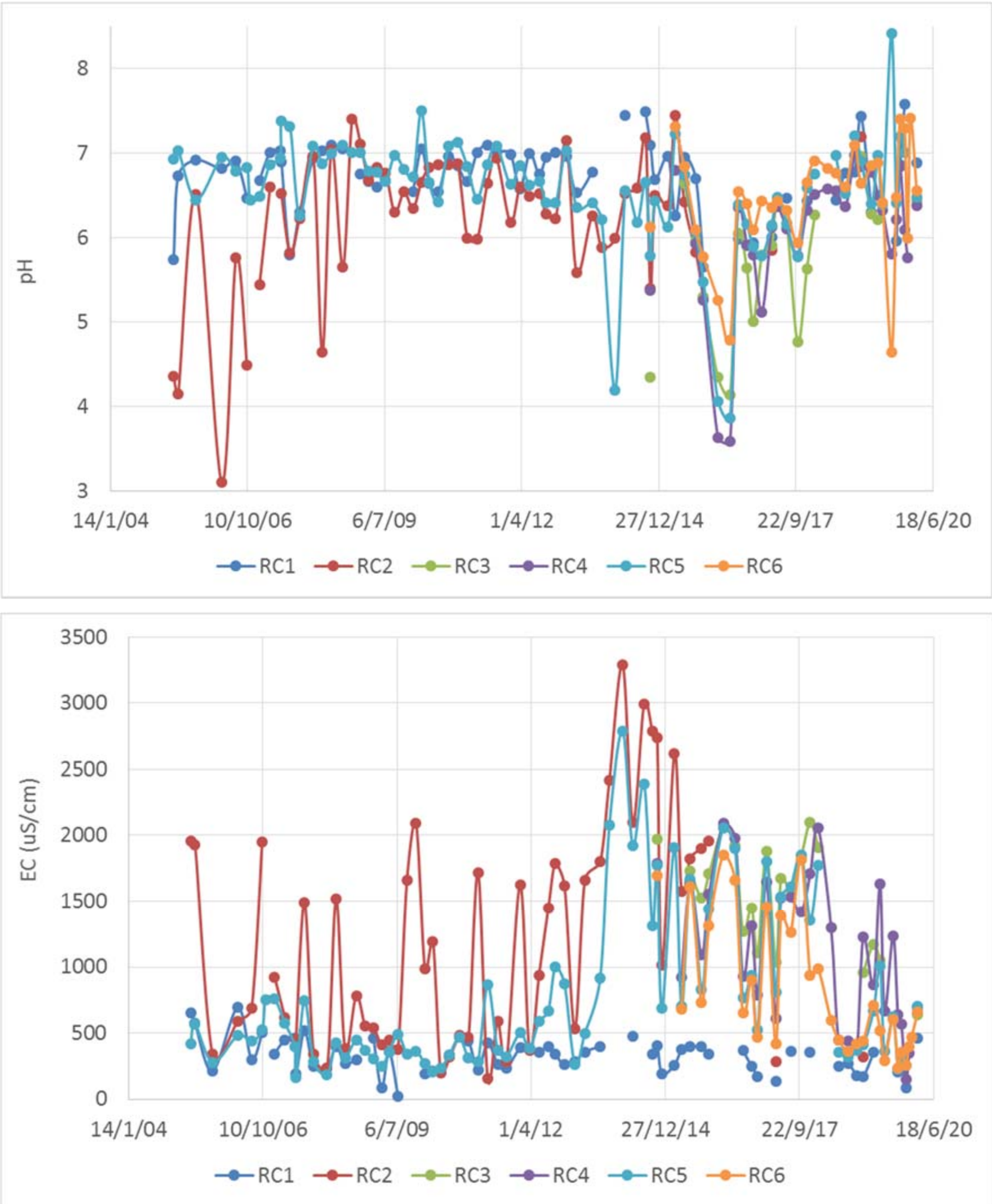


Figure 3 Redbank Creek Field Water Quality

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

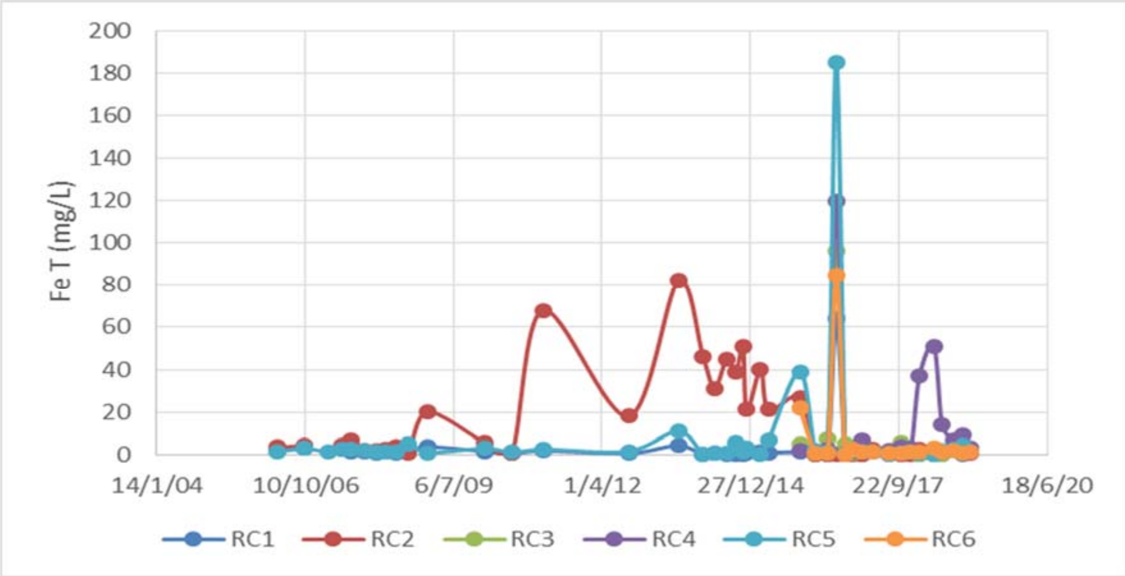
Redbank Creek generally contained elevated iron and, occasionally, manganese results were above ANZECC 2000 Protection of 95% of Freshwater Aquatic Species trigger level at Site RC2 in association with the upstream tributary seepage as shown in **Figure 4**.

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

Ferruginous seeps were 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 - 30.

The iron and manganese levels varied with rainfall in the catchment, with lower concentrations noted after wetter periods. However a definitive rise in iron was observed at Site RC2, and a rise in manganese at Sites 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 Sites RC1 and RC2 were dry).



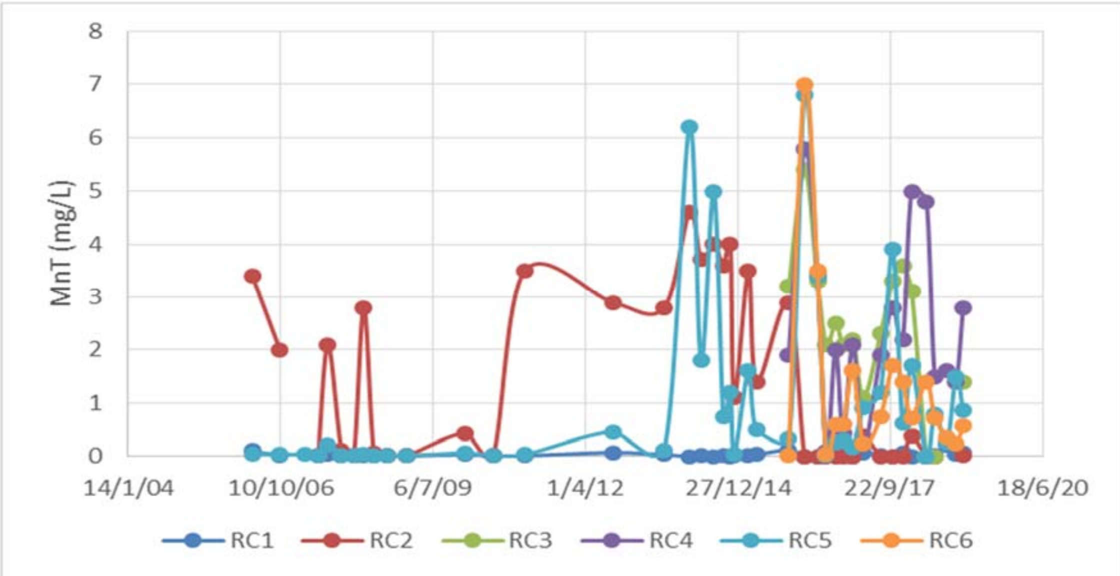


Figure 4 Redbank Creek Iron and Manganese

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

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

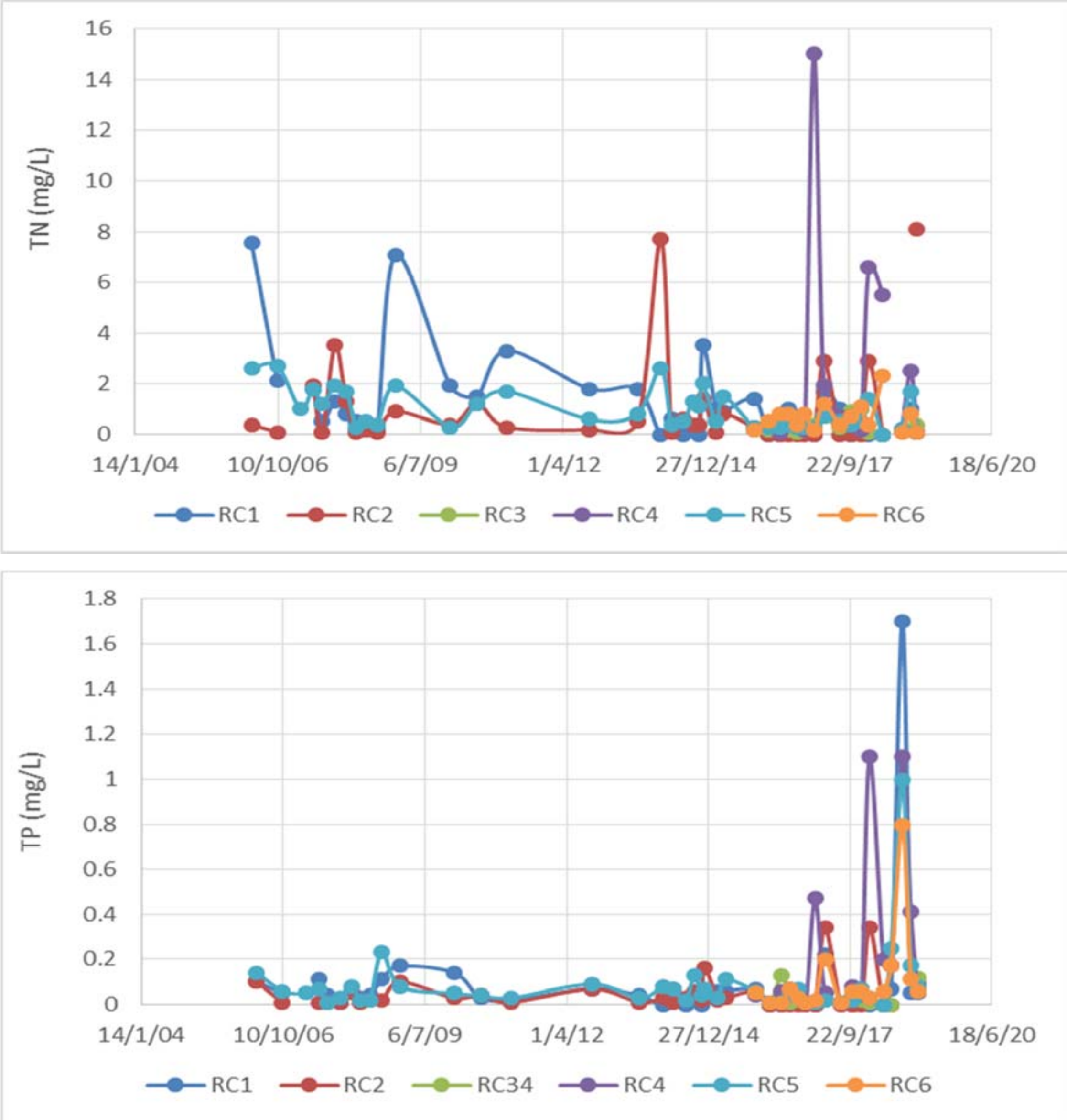


Figure 5 Redbank Creek Nutrients

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

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

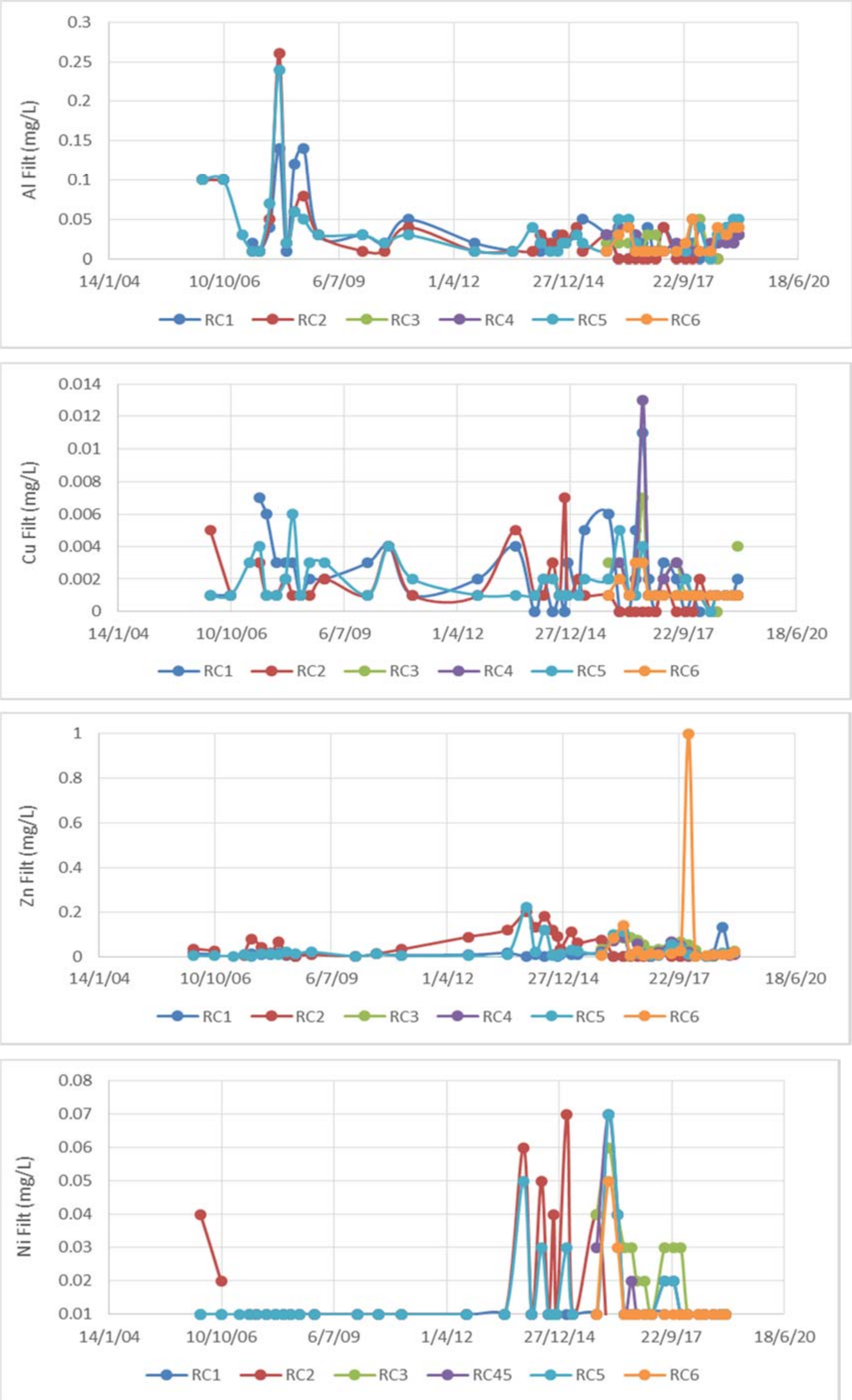


Figure 6 Redbank Creek Metals

Zinc concentrations were noted to reach up to 1.0mg/L as shown in **Figure 6**, with a rise in concentration observed at Site RC2 since late 2010, and since August 2013 at RC3. An erratic, although generalised reduction, was also observed since February 2014 and subsequent rise after extraction of Longwall 29 and after Longwall 31.

Nickel concentrations were 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 32 and the associated enhanced through flow of waters through freshly cracked sandstone.

4.3 Dams

Twelve generally small dams directly overlie Longwall 32 as shown in **Drawing 1**.

All of the dams are located within rural residential properties, with 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 32.

4.4 Groundwater

4.4.1 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;
- 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; and
- 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 Tahmoor Coal in December 2015.

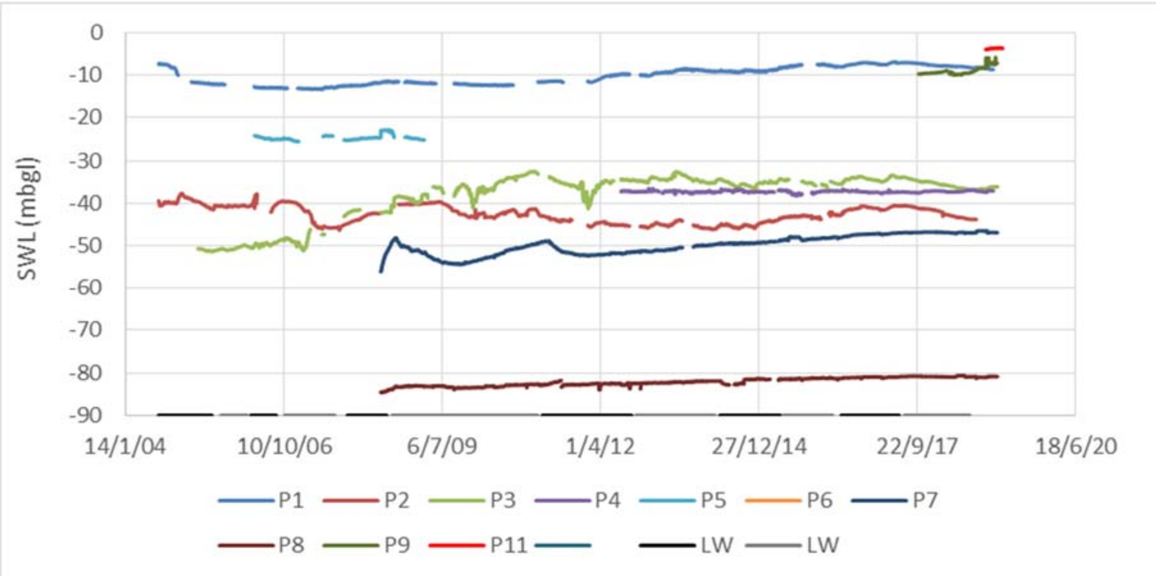


Figure 7 Standing Water Levels and Panel Extraction

4.4.2 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 a 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 Longwall 30.

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 was 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 did 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 relevant TARP trigger during the Longwall 32 extraction period.

VWP array intakes were also 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 VWP monitoring results are discussed further in **Section 3.7.5**.

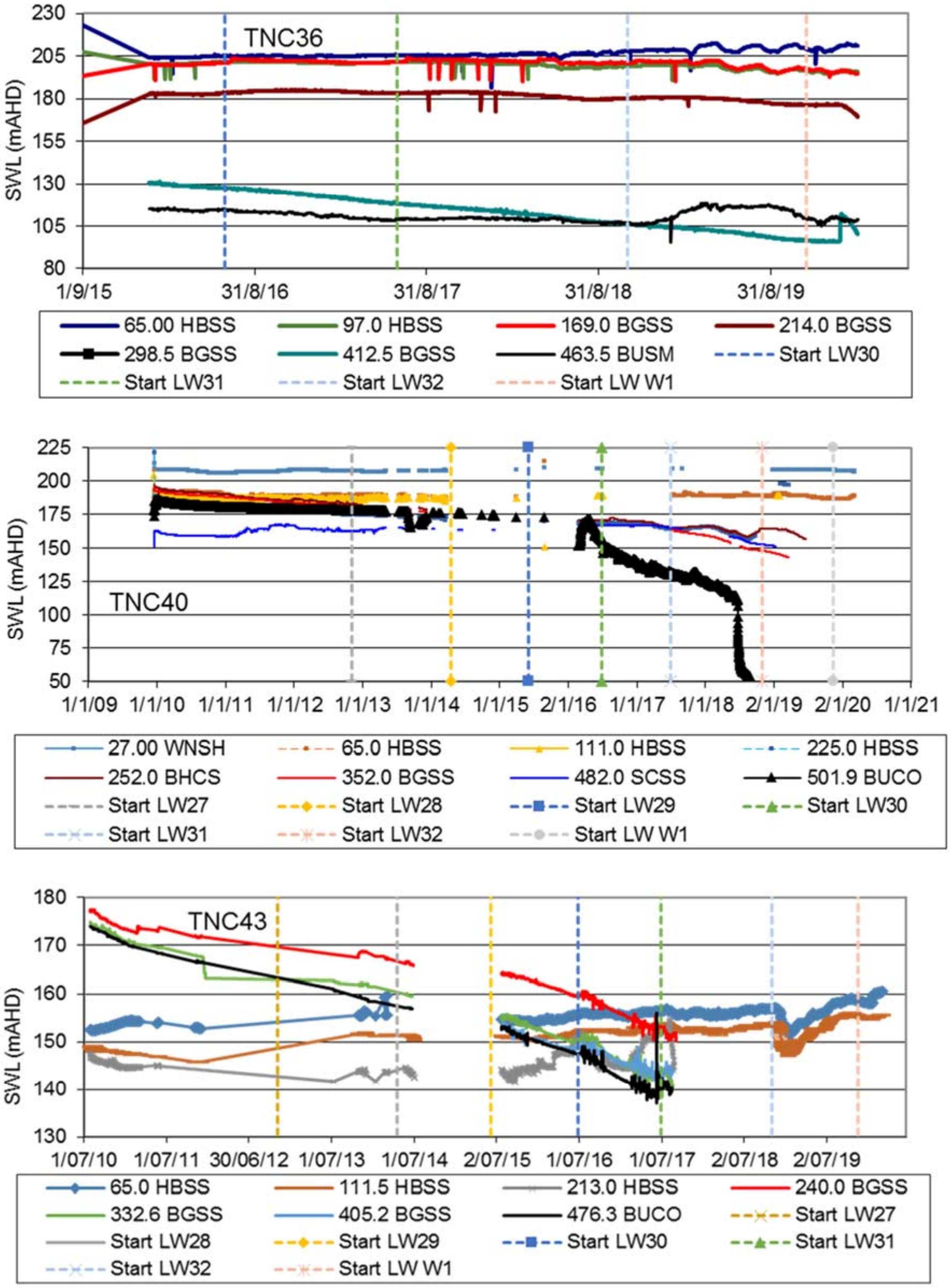


Figure 8 Vibrating Wire Piezometer TNC36, 40 and 43 Groundwater Levels

4.4.3 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.

4.4.4 Groundwater Seepage To The Underground Workings

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

Mine water pumped out of the workings is shown in **Figure 9**.

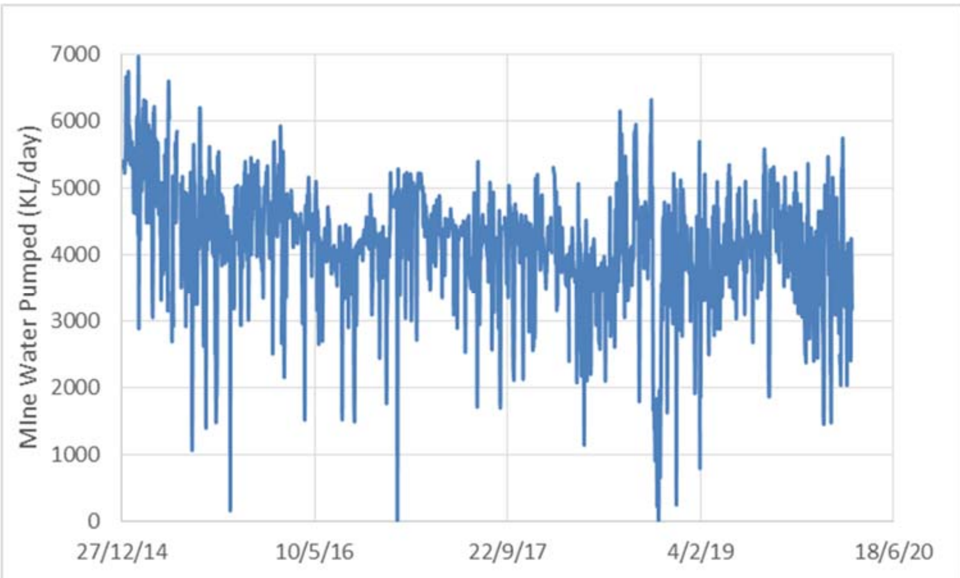


Figure 9 Mine Water Pumped out of Tahmoor Colliery Workings

4.4.5 Interconnection of Redbank Creek and the Adjacent Shallow Groundwater (P9)

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 10,** when Longwall 31 was approximately 140m south of the creek bed.

The Site 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 Site 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 21 to 23 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 10 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 P9C) failed to record any further readings after 19 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 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.

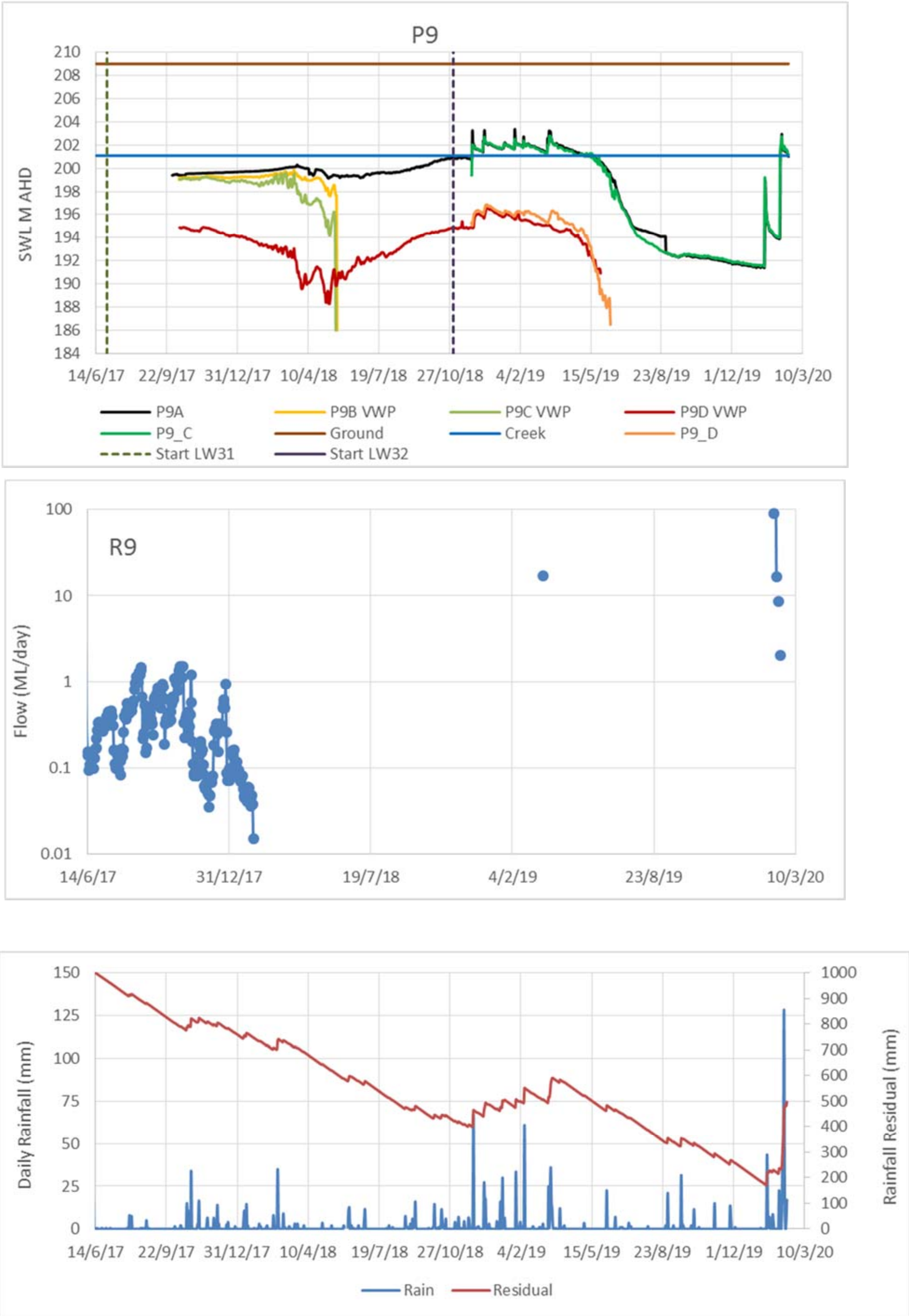


Figure 10 P9 Series Groundwater Levels, Pool R9 Water Level and Rainfall

4.4.6 Interconnection of Redbank Creek and the Adjacent Shallow Groundwater (P10)

As shown in **Figure 11**, the P10 piezometers showed a definitive water level reduction in all three open standpipe piezometer intakes before the piezometer was undermined in late May 2019.

The two upper piezometers at 5m and 20m below the groundwater intersection depth showed an 8m and a 10.7m initially rapid and subsequently slower depressurisation between late May 2019 and early January 2020, at the which time the drought broke and the groundwater levels rose to above the stream bed (for P10A) and to 3m below the creek bed in P10B.

The P10C intake at 50m below the first groundwater intersection began to depressurise before the piezometer was undermined and had a maximum depressurisation of 16.1m in late June 2019, after which it recovered to 4m higher than its pre undermined level.

Following significant rain in January and early February the deepest intake rose a further 5.5m.

Observation of the P10 piezometers, pool levels in Redbank Creek and rainfall indicates undermining of the creek and P10 by Longwall 32 increased the fracture connection with the creek and now enables a heightened recharge / discharge response after rain events within the shallow strata.

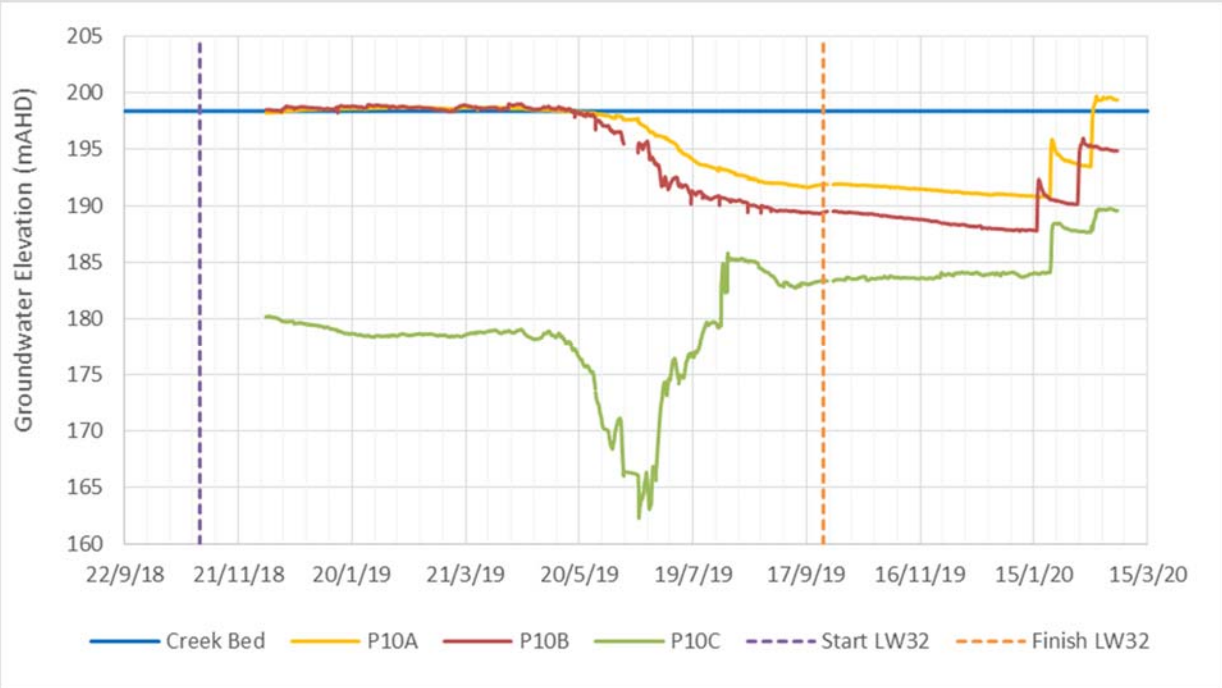


Figure 11 P10 Groundwater Levels and Rainfall

4.4.7 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 **Figures 12** and **13**.

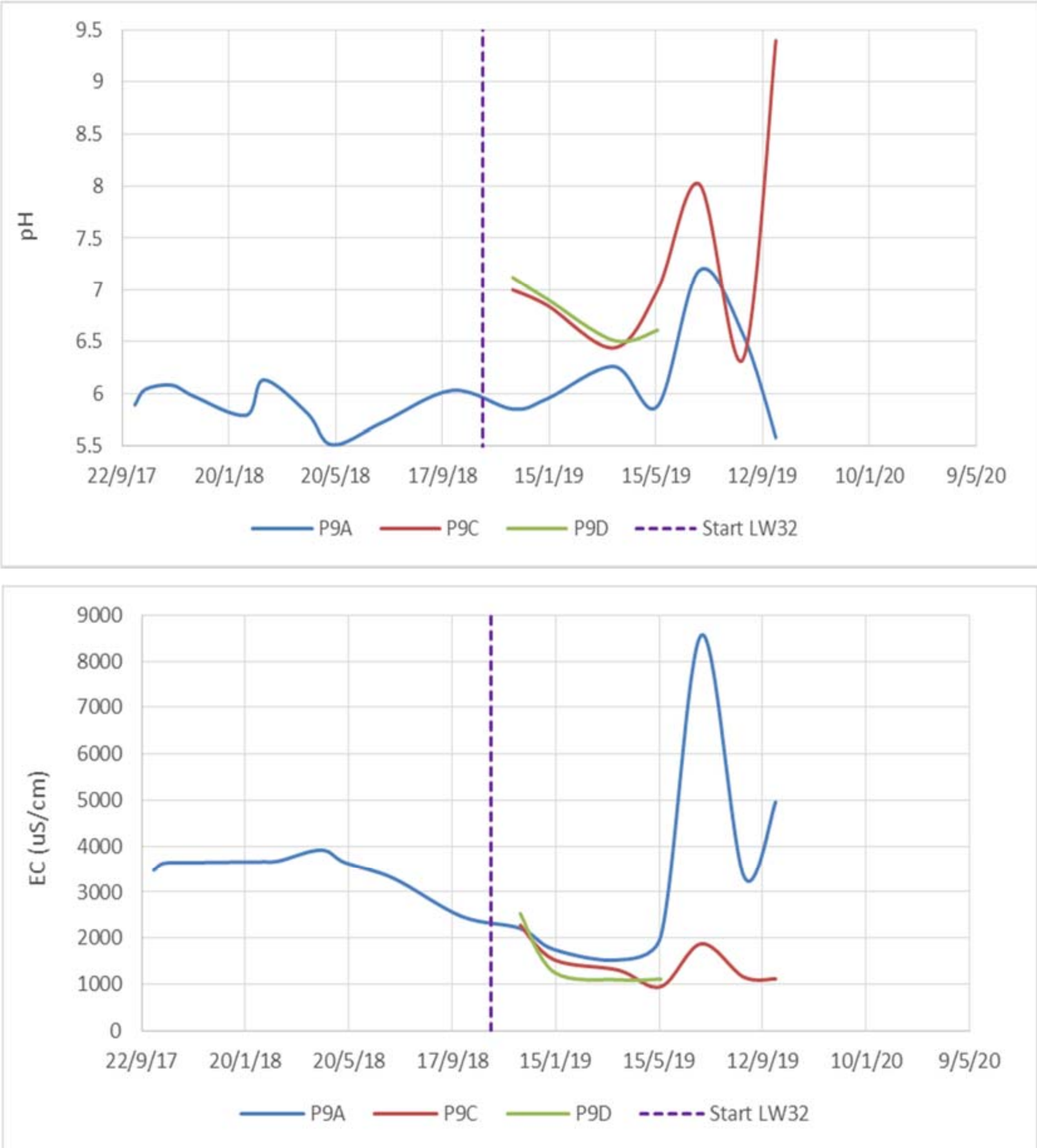


Figure 12 Field Groundwater Quality

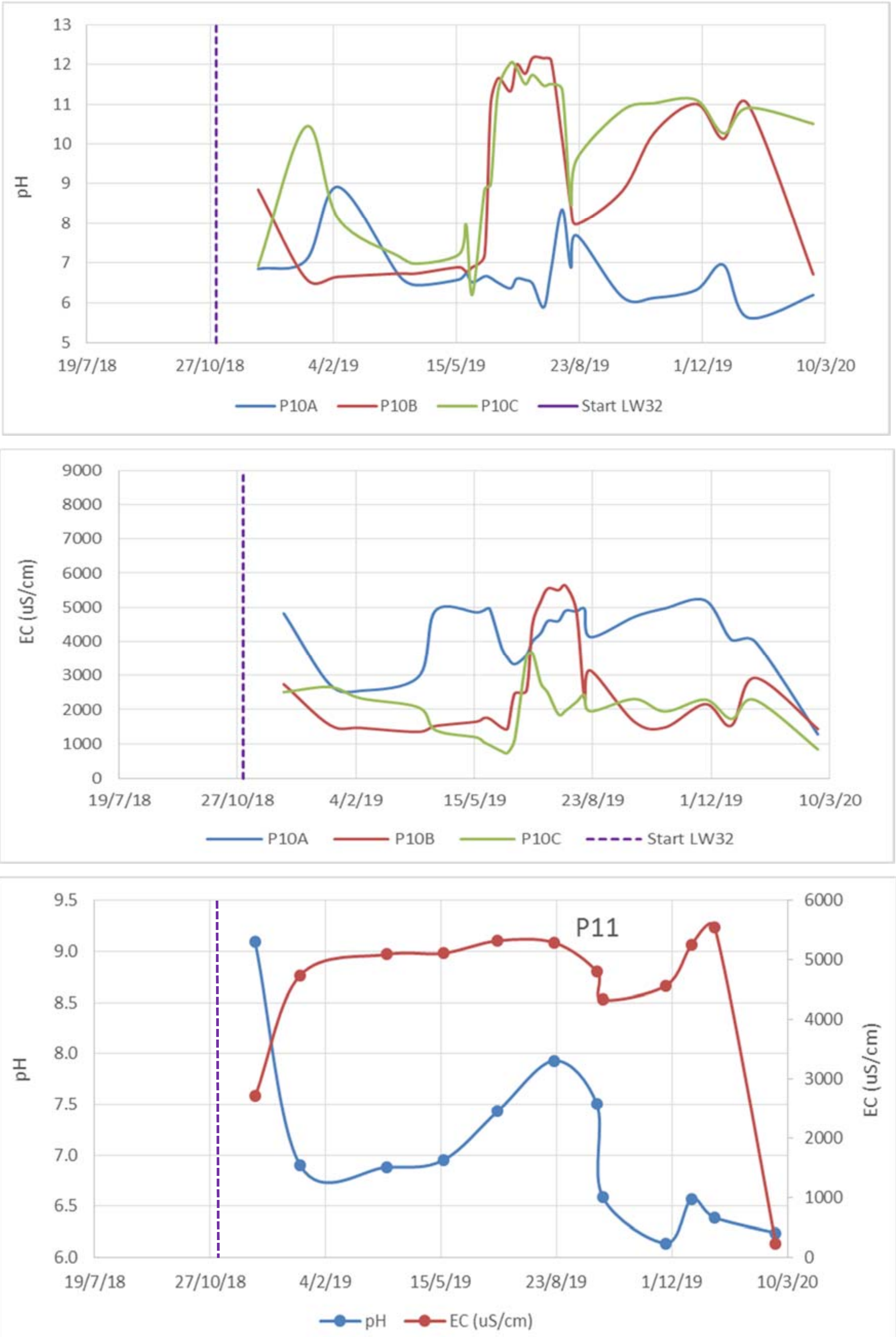


Figure 13 Field Groundwater Quality

Laboratory analyses obtained to date indicated that the bore water generally is outside the 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; and
- Filterable manganese, copper, zinc, nickel, aluminium and, to a small degree, lead.

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

Groundwater in the Longwall 22 to 32 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.

5. ADDITIONAL REDBANK CREEK STUDIES

5.1 CMAP Piezometer Installation

As part of the Redbank Creek Corrective Action Plan (CMAP), a series of up to 30m deep piezometers were installed along Redbank Creek at nine locations (in addition to P9 and P10) as shown in **Drawing 1**.

The piezometers were drilled to characterise the relationship between Redbank Creek and the adjacent groundwater system.

The program established that, except for short periods after significant rain, this section of Redbank Creek is a “losing” system, where the adjacent groundwater levels are located beneath the creek bed level.

In other words, except after major rain events, the creek drains into the groundwater system over Longwalls 28 to 32, rather than the groundwater system providing baseflow to Redbank Creek.

5.2 Groundwater Model

In accordance with the conditions of consent for Longwall 32, a two-dimensional cross sectional MODFLOW groundwater model was constructed to represent the interaction of Longwalls 31 and 32 between the groundwater and Redbank Creek stream systems, as detailed in **Appendix B**.

6. SUBSIDENCE IMPACT MANAGEMENT

During and after extraction of Longwall 32, the relevant TARP 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:

- 7/6/18 RR29
- 18/9/19 RR30
- 16/10/19 RR31
- 31/10/19 RB32

Accordingly, Tahmoor Coal prepared and submitted the Redbank CMAP (SIMEC, 2018) on 31/12/2018 to address the ongoing monitoring, management and subsequent remediation of Redbank Creek.

7. CONCLUSIONS

Based on monitoring of streams, dams and groundwater conducted prior to, during and after extraction of Longwall 32, 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 32 (and preceding longwalls) to Site RR33, 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) re-commencing at Site RT34;
- 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 4 sites between Sites RR29 and RB32 for the period of 07/06/18 to 31/10/19;
- Significant depressurisation of the Bulli Seam was observed in the vibrating wire piezometer bores TNC40 and TNC43 along with partial depressurisation in the upper and middle Hawkesbury Sandstone in TNC43 during the Longwall 32 extraction period;
- During the Longwall 32 extraction period, at least 10m of depressurisation was observed in the 68mbgl piezometer intake at P9, adjacent to Redbank Creek (over Longwall 31/21 chain pillar). The full depressurisation is not known as the piezometer sheared and locked the water level logger in the bore, and a dip meter could not go past the blockage;
- During the Longwall 32 extraction period, up to 16.2m of depressurisation was observed in the piezometer intake set at 50m below the groundwater intersection depth, adjacent to Redbank Creek (over Longwall 32 main-gate chain pillar), which subsequently recovered to approximately 9.5 m above its pre-subsided water level; and
- No adverse effects on private bore yield or water quality have been reported during or after Longwall 32 extraction.

8. 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

GeoTerra, 2018 End of Longwall 31 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 2020 End of Panel Subsidence Monitoring Report for Tahmoor Longwall 32

SIMEC, 2018 Redbank Creek Corrective Management Action Plan

Tahmoor Underground, 2017 Tahmoor Colliery Longwall 31 Environmental Management Plan

LIMITATIONS

This report was prepared in accordance with the scope of services set out in the contract between GeoTerra Pty Ltd (GeoTerra) and the client, or where no contract has been finalised, the proposal agreed to by the client. To the best of our knowledge the report presented herein accurately reflects the clients requirements when it was printed. However, the application of conditions of approval or impacts of unanticipated future events could modify the outcomes described in this document.

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APPENDIX A

REDBANK CREEK END OF LONGWALL 32
SELECTED PHOTOGRAPHS

RR19 / R8

RR22

RR24

Weir 26 (upstream)

Weir 26/ RC3 / R9

RB28

RR29

RR30 / R10

RB32

RB36

RB38

Excellence in your environment

Ecology End of Panel Report
Tahmoor Longwall 32

Prepared for Tahmoor Colliery | 31 March 2020

niche-eh.com

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Document control

Project number	Client	Project manager	LGA
5511	Tahmoor Colliery	Sarah Hart	Wollondilly Shire

Version	Author	Review	Status	Date
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Table of Contents

1. Introduction

1.1 Background

Tahmoor Coal Pty Ltd (Tahmoor Coal) has completed extraction of Longwall 32. Tahmoor Coal is required to develop an End of Panel (EoP) Report for Longwall 32, to comply with the Subsidence Management Plan in accordance with approval dated 14 September 2018

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 32 (Study Area) (Figure 1).

This report reviews the predicted and observed impacts on terrestrial and aquatic ecology within the Study Area in order to assess the impacts against the relevant Trigger Action Response Plans (TARPs) associated with the Tahmoor Coal Longwall 32 Environmental Management Plan (SIMEC 2019). In particular, this assessment has utilised monitoring data collected as part of the following monitoring campaigns and specialist studies:

- Niche (2019a) Tahmoor North, Redbank Creek Aquatic Monitoring, Prepared for Tahmoor Coal.
- Niche (2019b) Tahmoor Mine Redbank Creek, Riparian and Amphibian Monitoring, Prepared for Tahmoor Coal.
- Niche (2020a) Tahmoor North, Redbank Creek Aquatic Monitoring, Prepared for Tahmoor Coal.
- Niche (2020b) Tahmoor Mine Redbank Creek, 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) (2020) End of Panel Subsidence Monitoring Report for Tahmoor Coal Longwall 32. An unpublished Management Plan for Tahmoor Colliery.
- GeoTerra (2020) Longwall 32 Surface Water, Dams and Groundwater End of Panel Monitoring Report, Tahmoor, NSW. Report No. TA35-R1.
- SIMEC (2019) Tahmoor Colliery Longwall 32 Environment Management Plan. An unpublished report for Tahmoor Colliery.

2. Subsidence monitoring results

2.1 Subsidence Monitoring Results Summary (MSEC)

The EoP Subsidence Report for Longwall 32 prepared by MSEC (2020) is a comprehensive report which addresses all aspects of the recorded subsidence parameters resulting from the extraction of Longwall 32.

Subsidence has the potential to impact aquatic and terrestrial ecological values. Table 1 outlines the observed subsidence impacts and the potential consequences for aquatic and terrestrial ecological values relevant to Longwall 32. As indicated in Table 1, overall the recorded subsidence on natural landscape features resulting from the extraction of Longwall 32 was similar to those predicted.

Table 1. Observed impacts from Longwall 32 due to subsidence and the potential consequential impact to terrestrial and aquatic ecology

Natural feature	Summary of predicted impacts (MSEC 2020)	Subsidence monitoring results (MSEC 2020)	Potential consequence to terrestrial and aquatic ecology
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 32 and is considered to be a result of extraction of Longwall 32 and previous longwalls (GeoTerra 2020).Approximately half of the pools have been observed to be dry during the mining of Longwall 32, however this was also over a period of generally low l flows. During extraction of Longwall 32, 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/drought periods. Enhanced salinity and lower pH is predominantly associated with the more ferruginous seeps in the stream. (GeoTerra 2020).	Change in water levels due to ponding, flooding and inundation or desiccation has the potential to alter the distribution of water and vegetative habitat for amphibians and drown or dessicate riparian vegetation removing foraging habitat for any fauna dependant on pools. Potential localised reduction in aquatic macroinvertebrate biomass, possible loss of sensitive species, and change in community composition.
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 32.	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 the mining of Longwall 32.	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 broader current and on-going Tahmoor North monitoring campaign. This includes seasonal aquatic, riparian vegetation and amphibian monitoring (variously conducted in spring, summer and autumn) since 2017. Monitoring sites include areas of Redbank Creek which occur within the Study Area. This assessment includes review of these previous monitoring results which have been reported on in the following documents:

- Niche (2019a) Tahmoor North, Redbank Creek Aquatic Monitoring, Prepared for Tahmoor Coal.
- Niche (2019b) Tahmoor Mine Redbank Creek, Riparian and Amphibian Monitoring, Prepared for Tahmoor Coal.
- Niche (2020a) Tahmoor North, Redbank Creek Aquatic Monitoring, Prepared for Tahmoor Coal.
- Niche (2020b) Tahmoor Mine Redbank Creek, 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.

3.1.1 Amphibian and riparian monitoring

The Longwall 32 Study Area includes monitoring sites associated with the biodiversity (amphibian and riparian) monitoring program (Niche 2019b; 2020b). The riparian vegetation monitoring along Redbank Creek entailed traverses of the creek, and collection of floristic data along marked plots/transects. The amphibian monitoring included targeted surveys along transects at permanent monitoring locations along Redbank Creek. Further monitoring sites are located along Stonequarry Creek, Cedar Creek, Newlands Gully and Matthews Creek. The detailed survey and assessment methodology is provided in Niche (2020b).

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

Riparian vegetation monitoring:

- Spring 2017: 7, 13 and 14 December 2017
- Autumn 2018: 13, 19 and 20h April 2018
- Spring 2018: 26, 29 and 30 November 2018
- Autumn 2019: 8 and 9 April 2019
- Spring 2019: 28 and 29 November 2018.

Amphibian monitoring:

- Summer 2017: 4, 5 and 7h of December 2017.
- Autumn 2017: 3, 8h 17 of May 2018.
- Summer 2018: 4, 5 and 6 of December 2018.
- Autumn 2018: 19, 20 and 21 March 2019
- Summer 2019: 15, 16, 17, 21 October 2019.

3.1.2 Aquatic ecology monitoring

The Longwall 32 Study Area includes monitoring sites associated with the aquatic ecology monitoring program (Niche 2014), and Tahmoor North, Redbank Creek Aquatic Monitoring (Niche 2019a; 2020a).

Aquatic ecological monitoring of Longwall 32 started in spring (November) 2017 before the Redbank Creek was undermined by Longwall 31. Three sites were monitored at of Longwall 31 and 32 and one site downstream. These locations were surveyed again in April and November 2018 and again in May and September 2019 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, dam and groundwater monitoring program for Longwall 32 has been conducted by GeoTerra since June 2004. The monitoring by GeoTerra has assessed the following features:

- 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 (2020) have been incorporated throughout this assessment where applicable.

4. Monitoring results

4.1.1 Riparian vegetation monitoring results

During the Niche (2014) biodiversity impact assessment and as detailed in the results of the most recent round of monitoring Niche (2020b), 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 in a degraded condition, which integrated with areas of Grey Myrtle Dry Rainforest closer to the Creek.

No areas of vegetation dieback or significant changes to vegetation floristic diversity or abundance have been recorded across the monitoring periods to date.

4.1.2 Amphibian monitoring results

During the Niche (2014) biodiversity impact assessment and as detailed in Niche (2020b), it was confirmed that Redbank Creek is unlikely to support habitat for any threatened amphibian species. To date, the Niche (2020b) monitoring has not recorded any threatened amphibian species within the Study Area. The amphibian diversity and abundance at the monitoring sites is relatively low and this has been largely attributed to the absence of water and pools within Redbank Creek within the Longwall 32 Study Area.

4.1.3 Aquatic ecology monitoring

Details of the monitoring results are provided in Niche (2020a). In summary, the most-recent monitoring (spring 2019) revealed similar results to surveys conducted in previous years and 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.

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) and generally consisted of pollution-tolerant macroinvertebrate families. Overall, it was considered that natural environmental stressors (predominantly low flow) were likely to be driving these observations with local anthropogenic influences exacerbating these conditions. These natural stressors and previous impacts from mining have made it difficult to determine the aquatic ecological responses from Longwall 32 specifically, as the site already consisted of pollution-tolerant fauna. However the site directly above Longwall 32 (Site 2) was dry in the Spring 2019 monitoring, which had always held water in all previous monitoring periods This indicates that mining beneath Redbank Creek was the likely cause of the poor stream health i.e. no aquatic habitat available at this location.

In November 2019, the quantitative sampling of macroinvertebrate communities showed higher abundances of pollution-tolerant taxa including: true fly (Chironominae) and worm (Oligochaeta/Lumbricidae); and lower abundances of phantom midge Choaboridae and Tanypodinae compared to previous monitoring. The results indicated that there was no significant difference between autumn 2019 and spring 2019 monitoring for Sites 1 and 3. This may indicate that Sites 1 and 3 ecology have not deteriorated further since Longwall 32 was mined. However, Site 2 which is directly above Longwall 32, has shown obvious impacts including the lack of water and no viable aquatic habitat. This has resulted in the absence of aquatic fauna at this location. To reiterate, there has been no change ecologically at sites above and below the Longwall, however at the site directly above Longwall 32 the stream was completely dry resulting in no viable aquatic habitat.

It was concluded that mining has had impacts to the waterway with the loss of water and has likely contributed to low family richness, densities, Observed /Expected and SIGNAL scores that have been observed since aquatic monitoring commenced. There are cumulative impacts from previous longwalls, urbanisation, and low flows that have resulted in pervasive poor stream health in Redbank Creek.

4.1.4 Surface water, dam and groundwater monitoring

GeoTerra (2020) details the results from the on-going monitoring of environmental values within the limit of subsidence of Longwall 32.

Impacts from mining of Longwall 32 identified by GeoTerra (2020) include the following:

- 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 32 (and preceding longwalls).
    - The majority of pools over and downstream of Longwalls 25 to 32 show evidence of subsidence related pool holding capacity impacts. Site R11 also shows drying out of the pool, however this is considered to be primarily due to the extended drought in the catchment, rather than purely subsidence impacts.
- During extraction of Longwall 32, 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/drought periods.
    - Enhanced salinity and lower pH is predominantly associated with the more ferruginous seeps in the stream.
- To date, no loss of stream flow from Redbank Creek into the Tahmoor mine workings has occurred.
- 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

1.1 Field survey

A one-day field inspection was undertaken by Sarah Hart (Niche Ecologist) on the 06 March 2020 along Redbank Creek within the predicted subsidence zone, to observe any areas of vegetation die-back that may be attributed to subsidence.

During the field survey, no signs of vegetation die back were observed along the riparian zones within the limits of subsidence for Longwall 32. Furthermore, no threatened flora or fauna were recorded whilst traversing the area during the field survey.

5.1 Threatened ecological communities

Niche (2014) and Biosis (2009) recorded three Threatened Ecological Communities (TECs) within the vicinity of Longwall 32: Cumberland Plain Woodland, Shale Sandstone Transition Forest, and Moist Shale Woodland. These communities are listed as TECs under the NSW *Biodiversity Conservation Act 2016* (BC Act) and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Both Niche (2014) and Biosis (2009) concluded mining within the vicinity of Longwall 32 would be unlikely to have a significant impact on any of these TEC's.

Subsidence impacts associated with the extraction of Longwall 32 are consistent with the subsidence impact assumptions/predictions stated in Niche (2014) and Biosis (2009).No changes in any of these vegetation communities has been reported (Niche 2020b; GeoTerra 2020) or observed during the Niche surveyor monitoring undertaken to date. It should be noted that whilst Niche and GeoTerra were not able to inspect all areas of the TECs (the location of some of the TEC patches occurs within private properties), it is considered highly unlikely that subsidence would significantly 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.

5.2 Threatened flora

No threatened terrestrial or aquatic flora species have been recorded in the Study Area during the Niche assessment (2014) or subsequent monitoring events, or survey conducted by Biosis (2009). However, within the vicinity of Longwall 32, potential habitat was determined for two threatened flora species that may potentially be impacted by subsidence: *Epacris purpurascens* var. *purpurascens* and *Pomaderris brunnea.* Niche (2014) concluded that mining of Longwalls 31-37 was unlikely to have a significant impact on any threatened flora. A similar conclusion was reached in Biosis (2009) in relation to Longwalls 27-30.

Subsidence impacts associated with the extraction of Longwall 32 are consistent with the subsidence impact assumptions/predictions stated 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 targeted survey or monitoring (Niche 2020b) and Biosis (2009).

As such it is considered unlikely that the extraction of coal from Longwall 32 has led to any impacts on these two threatened plant species.

5.3 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 32 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 32. The Red-crowned Toadlet has not been recorded within the Study Area during initial surveys (Biosis 2009, Niche 2014) and subsequent monitoring and thus is considered unlikely to occur and/or be significantly impacted by potential subsidence related impacts of Longwall 32.

Subsidence impacts associated with the extraction of Longwall 32 are consistent with the subsidence impact assumptions/predictions stated in Niche (2014) and Biosis (2009), namely the extraction of coal from the Longwall is not likely to have 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 terrestrial TEC's and threatened species (and their habitats) resulting from coal extraction within Longwall 32 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 32

Ecological value	Predicted impact Niche (2014)	Observed impact (Niche 2020a, 2020b; GeoTerra 2020 and MSEC (2020)	Observed impacts align with predicted impacts? (yes/no)
Threatened 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 (dieback or substantial changes in floristic composition/distribution) have been observed or reported. No significant impacts to TECs or vegetation have been observed or are considered 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 (dieback or substantial changes in floristic composition/distribution) have been observed or reported. No significant impacts to flora and flora habitat are considered to have occurred	Yes
Threatened fauna and fauna habitat	• Changed surface water conditions, such as effects to pools and streams. • Potential impacts to steep slopes and cliffs. • Potential impacts of gas emissions on water quality and riparian vegetation. • No threatened amphibians were regarded as having potential habitat in the watercourses of Longwall 32 • No significant impacts to any threatened fauna.	No vegetation impacts (dieback or substantial changes in floristic composition/distribution) have been observed or reported. No threatened fauna, including the Red-crowned Toadlet, have been recorded within the Study Area over the five monitoring periods from 2017-2019. No significant impacts to fauna and fauna habitat are considered to have occurred.	Yes
Aquatic habitat	• Potential localised reduction in biomass, possible loss of sensitive species, and change in community composition.	Localised loss of aquatic habitat and biomass in reaches directly above Longwall 32.	Yes

7. Trigger Action Response Plan

Each of the measures within the Trigger Action Response Plan (TARP) related to riparian, amphibian and aquatic ecology are addressed in Appendix A.

In summary, based on the field observations and monitoring completed by Niche to date, and GeoTerra (2020), 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 those predicted in the Niche (2014) Biodiversity Impact Assessment.
- No threatened amphibians were recorded during five seasonal monitoring periods undertaken from 2017 to 2019(Niche 2020a, 2020b).
- The amphibian diversity and abundance along Redbank Creek has been consistently, relatively low. This is likely due to lack of water along the Creek over the entire monitoring period. No significant decline in amphibian populations has been observed over the course of the monitoring.
- No vegetation die back has been observed during the monitoring or field survey.
- The riparian monitoring has not detected any significant changes in floristic diversity or abundance within the Redbank Creek monitoring sites over the monitoring periods.

Impacts to aquatic habitat and surface water have been observed and have triggered a response in accordance with the TARP. A Corrective Action Management Plan (SIMEC 2019) has been prepared in relation to this (see Appendix A). In summary, the aquatic ecology monitoring concluded the following:

- Redbank Creek is in a relatively poor condition and likely was prior to Longwall 32 mining (due to weed invasion and human disturbance/landuse influences).
- The drying of sections of Redbank Creek (Site 2) and loss of aquatic habitat in this area is considered likely to be a result of underground mining of Longwall 31 and Longwall 32. Prior to spring 2019, Site 2 consistently held water and there was no significant change in aquatic habitat at any of the other monitoring sites. Aquatic habitat was lost immediately following the undermining of Redbank Creek from Longwall 32.
- AUSRIVAS and SIGNAL completed as part of Niche (2020a) indicated that the poor health of Redbank Creek within the Longwall 32 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 longwall mining of Longwall 31 and Longwall 32.
- The aquatic ecology trigger exceeded because:
  - Surface flow trigger was exceeded (GeoTerra 2020).
  - Habitat was lost immediately following the undermining of Redbank Creek from LW 32 and was significantly different to baseline conditions.
- Continuation of macroinvertebrate and steam health monitoring along Redbank Creek is recommended to provide further data for analysis in regards to the impacts, remediation and recovery post longwall mining operations.

8. Conclusion

This report compares the observed impacts of subsidence associated with the extraction of Longwall 32 at Tahmoor Mine with the impacts predicted to occur prior to extraction of coal from the Longwall in relation to biodiversity values. This assessment is based on review of survey and monitoring results undertaken by Niche (2014; 2019a, 2019b; 2020a, 2020b), MSEC (2020), and GeoTerra (2020).

The impacts which have occurred within the limit of subsidence for Longwall 32 are within the parameters of the predicted impacts outlined in the terrestrial ecological assessment for Longwalls 31 to 37 (Niche 2014).

The trigger associated with aquatic ecology that was exceeded was based on the surface water trigger and significant changes in habitat quality compared to baseline conditions.

It is recommended that the monitoring should continue along Redbank Creek in order to assist in the rehabilitation of the Creek with the future longwall activities as well as assessment of recovery of pool holding capacity, aquatic habitat and ecosystem function.

References

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

GeoTerra (2020). Longwall 32 Surface Water, Dams and Groundwater End of Panel Monitoring Report, Tahmoor, NSW. Report No. TA35-R1.

Mine Subsidence Engineering Consultants (MSEC_1085 RevA) (2020). End of Panel Subsidence Monitoring Report for Tahmoor Coal Longwall 32. An unpublished Management Plan for Tahmoor Colliery.

Niche (2019a). Tahmoor North, Redbank Creek Aquatic Monitoring, Prepared for Tahmoor Coal.

Niche (2019b). Tahmoor Mine Redbank Creek, Riparian and Amphibian Monitoring, Prepared for Tahmoor Coal.

Niche (2020a). Tahmoor North, Redbank Creek Aquatic Monitoring, Prepared for Tahmoor Coal.

Niche (2020b). Tahmoor Mine Redbank Creek, 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.

SIMEC (2019). Tahmoor Colliery Longwall 32 Environment Management Plan. An unpublished report for Tahmoor Colliery.

Appendix A: TARP trigger observations and impacts associated with Longwall 32

Natural feature	Trigger	Actions required	Summary results	Response
Aquatic habitat and surface water	Water flow and quality results exceed predictions. Observational monitoring shows significant change observed in aquatic habitat compared to baseline observed	• Notify within 48 hours NSW Resources Regulator – Director Compliance Operations and Principal Subsidence Engineer, Observational monitoring Advisory NSW, Wollondilly Shire Council, DI-Water and observed OEH of exceedance. • Site visit within 1 week. • Record photographically within 1 week. • Provide written Status Report to NSW Resources Regulator –Director Compliance Operations within 4 weeks of notification reviewing requirement, need and potential cost/benefit of preparation and implementation of a corrective action management plan. • Investigate the potential source/s of any water quality trigger exceedance. • Report notification in EOP report and AEMR.	Riparian and amphibian monitoring found no impact to riparian vegetation, amphibians, EEC, or threatened species. Redbank Creek was and is in relatively poor condition prior to Longwall 32 mining. AUSRIVAS and SIGNAL completed as part of Niche (2020a) indicated that the poor health of Redbank Creek within the Longwall32 Study Area is likely due to a number of factors including natural environmental stresses, local pollution from the urban catchment and likely due to undermining of the Redbank Creek. However, this result exceeded prediction as surface flow as per the following *“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”* which was triggered at 4 sites between RR29 and RB32. (GeoTerra 2020). These triggers were reported to the Resources Regulator as required. Additionally, the aquatic monitoring site above Longwall32 (Site 2) was dry compared to previous pre – Longwall 32 mining. Additional monitoring is required to assist in interpreting this TARP. Monitoring was conducted in 2020 however data for review was not available at the time of this	Monitoring was conducted in 2020 however data for review was not available at the time of this report. A Corrective Management Action Plan has been prepared for Redbank Creek (SIMEC 2019). Niche recommend further monitoring of surface water quality and aquatic habitat including the riparian vegetation and amphibian habitat.

Natural feature	Trigger	Actions required	Summary results	Response
			report. A Corrective Management Action Plan has been prepared for Redbank Creek (SIMEC 2019).	

Contact Us

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Our services

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Aboriginal heritage
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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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18 March 2020

Ms Fiona Robinson
Environment Co-ordinator
Tahmoor Coal
Remembrance Drive
TAHMOOR NSW 2573

Via email: Fiona.Robinson@simecgfg.com

Dear Ms Robinson,

Re: Tahmoor Coal Longwall 32 End of Panel: Cultural Heritage Review and Reporting (Niche Ref: #5511)

Niche Environment and Heritage (Niche) has undertaken a further site inspection of Redbank Creek-4 (AHIMS ID #52-2-2082) to assess any observable impacts may have occurred to the site during the extraction of Longwall 32 with representatives from the following Registered Aboriginal Parties (RAPs):

- Cubbitch Barta Native Title Claimants.

The inspection found that no new impacts have occurred at Redbank Creek-4 (AHIMS ID #52-2-2082) from the extraction process.

The following recommendations have been made:

- Tahmoor Colliery should continue their consultation with the Aboriginal community in regards to Redbank Creek-4 (AHIMS ID #52-2-2082); and
- Redbank Creek-4 (AHIMS ID #52-2-2082) should continue to be monitored during any future program of works.

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

Yours sincerely,

MAlow

Marika Low
Heritage Consultant
Niche Environment and Heritage

Statement of management objective

The management objective of Redbank Creek-4 (AHIMS ID #52-2-2082) is to ensure that any impacts to the site resulting from the extraction of Longwall 32 are reduced and minimised over the long term. The impacts to be minimised include potential fracturing within the vicinity of the grinding groove due to subsidence related cracking.

Background and introduction

Niche Environment and Heritage Pty Ltd (Niche) was commissioned by Tahmoor Coal Pty Ltd (Tahmoor Cooal) to conduct an End of Panel assessment of the Aboriginal cultural heritage within the limit of subsidence of Longwall 32.

The site inspections for this End of Panel assessment were carried out by Renée Regal (Team Leader-Aboriginal Heritage -Niche), Sarah Hart (Ecologist - Niche) and Glenda Chalker (RAP - Cubbitch Barta Native Title Claimants) on 6 March 2020.

During this assessment no observable impacts as a result of mining were identified at the Aboriginal archaeological site of Redbank Creek-4 (AHIMS ID #52-2-2082).

Subsidence results summary (MSEC)

The End of Panel Subsidence Report for Longwall 32 prepared by MSEC (MSEC1085_Revision A; 2020) is a comprehensive report which addresses all aspects of the recorded subsidence parameters resulting from the extraction of Longwall 32.

In relation to matters that may affect Aboriginal cultural heritage values, MSEC notes the following (MSEC1085_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 32;
- No impacts were observed during the extraction of Longwall 32 to the steep slopes and cliffs; and
- There were no impacts observed on archaeological sites during Longwall 32.

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 2020 to organise a site inspection and sent a copy of the Longwall 32 End of Panel report:

- Cubbitch Barta Native Title Claimants.
- Tharawal Local Aboriginal Land Council.
- Duncan Falk- Duncan Falk Consulting.

The following RAPs registered their interest to attend:

- Mrs Glenda Chalker, Cubbitch Barta Native Title Claimants.

A draft copy of this report was sent to the RAPs on 18 March 2020. Comments will be incorporated once they have been received.

Previous site assessment summaries

Aboriginal Heritage

Redbank Creek-4 (AHIMS ID #52-2-2082) was recorded with AHIMS in 1999. This Aboriginal archaeological site consists of one axe grinding groove that was identified by Caryll Sefton in 1998 during an archaeological survey of Tahmoor North Lease Area, Urban Areas and Railway Infrastructure for mining application for longwall mining. The Aboriginal site is situated on an outcrop located in the bed of the Redbank Creek near old Thirlmere Road. It is at the eastern end of the quarry and 50 m from the Amaroo Factory. The Aboriginal site is described as: "*One grinding groove 290x70x15 mm located at the side of a pothole in the centre of a large sandstone outcrop in the middle of the creek. Water flows S-N across the longitudinal axis. Outcrop is 25 mm x 11 m.*" (AHIMS site card ID#52-2-2082).

Plate 1 General location of Redbank Creek – 4, grinding groove as recorded in 1998 and taken from AHIMS site card ID #52-2-2082 (OEH 2019)

Plate 2 Photo of Redbank Creek – 4, grinding groove as recorded in 1998 and taken from AHIMS site card ID #52-2-2082 (OEH 2019)

Subsidence summary

As stated in the Tahmoor Coal Longwall 32 Environmental Management Plan (EMP) (SIMEC 2019), two archaeological sites are located above Longwall 32 including an open camp site (AHIMS ID #52-23870) and a grinding groove site (Redbank Creek 4; AHIMS ID #52-2-2082). The Longwall 32 EMP concluded that, while the open camp site would unlikely experience adverse subsidence impacts resulting from the proposed extraction of Longwall 32 (and was thus not included in this assessment), it was possible that fracturing could occur in the vicinity of the grinding groove site (SIMEC 2019: 39). The recommendation included obtaining a S90 Consent to Disturb from the NSW Office of Environment and Heritage (OEH) and preparing an Aboriginal Cultural Heritage Management Plan (ACHMP) which details monitoring of the site by an archaeologist and Aboriginal Stakeholders. This End of Panel report has been written in accordance with the Longwall EMP's recommendation for Redbank Creek –4 (AHIMS ID#52-2-2082).

Site inspection and results

A site inspection and assessment was carried out on 6 March 2020 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.

The purpose of the assessment was to observe and document the current conditions of Redbank Creek-4 so that any changes since the previous recordings could be documented. A summary of the findings is outlined in Table 1.

Table 1: Site inspection results

AHIMS Site #	Site Name	Results of Inspection	Photos
52-2-2082	Redbank Creek-4	The condition of the site has not changed due to mining related impacts since the original recording in 1998.	 **Plate 3 General location of the site showing the large sandstone outcrop associated with Redbank Creek**

AHIMS Site #	Site Name	Results of Inspection	Photos
			 Plate 4 General location of the site showing the large sandstone outcrop associated with Redbank Creek.  Plate 5 Photo showing grinding groove to the right of the water-filled pothole.

			 **Plate 6. General location of the site showing the large sandstone outcrop associated with Redbank Creek.**

AHIMS Site #	Site Name	Results of Inspection	Photos
			 **Plate 7 Close up photo of the grinding groove currently filled with water.**

Discussion and Conclusion

There were no observable changes as a result of the extraction of Longwall 32 to Redbank Creek-4 (AHIMS ID #52-2-2082).

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 EMP.

The recommendations made below are designed to allow Tahmoor Coal to discharge its obligations under the EMP.

Table 2: Trigger Action Response Plan

Feature	Monitoring			Management	
	Prior to Mining	During Mining	Post Mining	Trigger	Action
Aboriginal Archaeology Sites (Including Redbank Creek-4 AHIMS ID #52-2-2082)	Baseline archival recording at least two months prior to mining.	Observations weekly during active subsidence period.	EOP observations and report by Heritage Consultant.	**NORMAL** No observable mining induced change NO MAJOR TRIGGERS OBSERVED, CONTINUE WITH APPROVED ACTIONS. **WITHIN PREDICTION** No observable mining induced change. Rock fracturing within 2 meters of Aboriginal Archaeology site. NO TRIGGERS WITHIN PREDICTION OBSERVED, NO ACTION REQUIRED. **EXCEEDS PREDICTION** Rock fracturing of Aboriginal archaeology site. NO TRIGGERS EXCEEDING PREDICTIONS OBSERVED, NO ACTION REQUIRED.	**NORMAL** Continue with monitoring program, report in EOP report and AEMR. COMPLETED BY THIS REPORT. **WITHIN PREDICTION** Continue with monitoring program, report in EOP report and AEMR. COMPLETED BY THIS REPORT. **EXCEEDS PREDICTION** Notify within 48 hours NSW Resources Regulator – Director Compliance Operations and Principal Subsidence Engineer, Subsidence Advisory NSW, Wollondilly Shire Council, DI-Water and OEH of exceedance. Site visit within 1 week. Record photographically within 1 week. Provide written Status Report to NSW Resources Regulator – Director Compliance Operations within 4 weeks of notification reviewing requirement, need and potential cost/benefit of preparation and implementation of a corrective action management plan. Report notification in EOP report and AEMR. COMPLETED BY THIS REPORT

Recommendations

Based on community consultation with Aboriginal Stakeholders, geotechnical assessments by Daryl Kay from MSEC and visual inspection undertaken of the site on 6 March 2020, the following recommendations have been made for Redbank Creek-4 (AHIMS ID #52-2-2082).

Recommendation 1:

Tahmoor Coal should continue their consultation with the Aboriginal Community with regards to Redbank Creek-4 (AHIMS ID #52-2-2082).

Recommendation 2:

Redbank Creek-4 (AHIMS ID #52-2-2082) should continue to be monitored during the any future program of works.

References

MSEC_1085 RevA (2020) *End of Panel Subsidence Monitoring Report for Tahmoor Coal Longwall 32.* An unpublished Management Plan for Tahmoor Coal.

SIMEC (2019) *Tahmoor Colliery Longwall 32 Environment Management Plan*. An unpublished report for Tahmoor Coal.