SIMEC Mining:

Tahmoor South Longwalls S1A to S7A

Management Plan for potential impacts to Jemena Gas Infrastructure

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Jan-23	MSEC1193-06	A	Final for LWs S1A to S2A
Mar-24	MSEC1193-06	B	Draft for LWs S1A to S7A

References:-

	AS/NZS ISO 31000:2009 Risk Management – Principles and guidelines
Advisian (2022)	Mine Subsidence Impact – Jemena DN150 Steel Gas Pipe, Advisian, Project No. 311023-40903, Rev. 3, March 2022.
Advisian (2023)	Mine Subsidence Impact – Jemena DN150 Steel Gas Pipe, Advisian, Project No. 311023-40903, Rev. 0, August 2023.
Axys (2023)	Longwall LWS3A to LWS7A Subsidence Impacts to Jemena 150mm MP Gas Main – Risk Assessment Report No. AR3793, Revision 2, 27 October 2023.
HMS (2022)	*Risk Assessment on the Tahmoor South Longwall LW1A & LW2A Subsidence Impacts on the Jemena 150mm High Pressure Steel Gas Pipeline*. Report No. HMS1482, Draft Report, HMS Consultants, April 2022.
McGill (2007).	*Mitigating the Effects of Mine Subsidence Due to Coal Mining on Major Infrastructure Assets Critical to Sydney*. Proceedings of the MSTS Mine Subsidence Technological Society 7th Triennial Conference on Mine Subsidence, 26th to 27th November 2007.
MSO (2017)	*Managing risks of subsidence – Guide | WHS (Mines and Petroleum Sites) Legislation*, NSW Department of Planning & Environment, Resources Regulator, Mine Safety Operations, February 2017.
MSEC (2022)	*Tahmoor South- Longwalls S1A to S6A - Subsidence ground movement predictions and subsidence impact assessments for natural features and surface infrastructure in support of the Extraction Plan Application. (Report No. MSEC1192, Revision A, May 2022)*, prepared by Mine Subsidence Engineering Consultants.
MSEC (2024)	*Tahmoor South – Modification 3 - Longwall S7A - The effects of the proposed addition of LW S7A on previous subsidence predictions and impact assessments. (Report No. MSEC1348, Revision B, March 2024)*, prepared by Mine Subsidence Engineering Consultants.
Robinson, M. (2007).	*West Wallsend Colliery - A Coordinated Approach to Managing Subsidence Impacts on Multiple High Risk Sensitive Surface Features: LW27 Case Study*. Robinson, M. Proceedings of the MSTS Mine Subsidence Technological Society 7th Triennial Conference on Mine Subsidence, Nov 2007 (pp. 11-22).
Tahmoor Coal (2024)	*Contingency Plan to uncouple the 150 mm Jemena Gas pipeline along Remembrance Drive, Bargo, from the ground in the event of a triggered response from longwall mining*, Tahmoor Coal, Rev. 8, March 2024.

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Drawings

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

Drawing No.	*Description*	*Revision*
MSEC1193-01-01	Monitoring plan	B
MSEC1193-06-01	Jemena Gas Pipelines	B
MSEC1193-03-02	MSR Rail Viaduct & Remembrance Drive Bridge over Bargo River	B
MSEC1193-03-07	Remembrance Drive Embankment over Teatree Hollow over LW S3A (RE4)	B
MSEC1193-03-08	Remembrance Drive Cutting and Embankment north of Yarran Road over LWs S4A and S5A (RE3)	B
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1.1. Background

Tahmoor Coal Pty Ltd (Tahmoor Coal), owns and operates Tahmoor Mine, an existing underground coal mine located approximately 80 km southwest of Sydney in the Southern Coalfields of New South Wales (NSW). Tahmoor Coal is a wholly owned entity within the SIMEC Mining division of the GFG Alliance group. Tahmoor Coal has extracted 36 longwalls to the north and west of the mine's surface facilities.

Tahmoor Coal received development consent in April 2021 for the Tahmoor South Project, which is an extension of the current Tahmoor Mine underground coal mining within the Bulli seam towards the south of the existing Tahmoor Mine.

Tahmoor Coal received approval for an Extraction Plan for Longwalls S1A to S6A (LW S1A-S6A), which are the first longwall panels to be extracted in the Tahmoor South domain. The proposed longwalls are located between Tahmoor's surface facilities to the north and the township of Bargo to the south. Infrastructure owned by Jemena is located within this area.

Tahmoor Coal has almost completed extraction of LW S2A. In March 2024, Tahmoor Coal submitted an application to shorten the commencing (i.e. southern) end of LW S3A by 104 m from the position that was approved. The shortened commencement position is located away from Jemena infrastructure and results in negligible changes to predictions of subsidence along Jemena infrastructure.

Tahmoor Coal will soon submit a Modification to the development consent to extract LW S7A to the side of LW S6A. The proposed LW S7A will not extract directly beneath Jemena infrastructure and result in very minor additional subsidence along Remembrance Drive, where Jemena's infrastructure is located.

In January 2023, Jemena and Tahmoor Coal developed and agreed Revision A of the Management Plan for the mining of LWs S1A and S2A beneath Jemena's infrastructure.

This Management Plan provides detailed information about how the risks associated with mining beneath Jemena's infrastructure will be managed by Tahmoor Coal and Jemena during the mining of LWs S1A to S7A. Previously extracted LWs S1A and S2A remain part of this Management Plan even though the two longwalls have been extracted because the risk control procedures in this Management Plan include managing the residual effects of the mining of these two longwalls. Whilst LW S7A has been included in this Management Plan, Tahmoor Coal cannot extract the longwall until the Department of Planning, Housing and Infrastructure approves the proposed modification to Tahmoor Coal's development consent.

A summary of the dimensions of LW S1A-S7A are provided in Table 1.1.

Table 1.1 Longwall dimensions

Longwall	Overall void length including the installation heading (m)	Overall void width including the first workings (m)	Overall tailgate chain pillar width (m)
LW S1A	1,711	283	-
LW S2A	1,768	285	38
LW S3A	1,704	285	36
LW S4A	1,860	285	36
LW S5A	1,949	285	36
LW S6A	1,999	285	36
LW S7A	1,918	285	36

The Management Plan is a live document that can be amended at any stage of mining, to meet the changing needs of Tahmoor Coal and Jemena.

1.2. Jemena assets potentially affected by LW S1A-S7A

The locations of Jemena infrastructure in relation to LW S1A-S7A are shown in Drawing No. MSEC1193-06-01.

The gas infrastructure comprises a 150 mm diameter steel main which runs along the eastern side of Remembrance Driveway. The gas main was constructed in 1994 and was designed and constructed in accordance with the requirements of SA NSW. The gas main distributes gas to the townships north of

Bargo, including Tahmoor, Thirlmere and Picton, and is located directly above LW S1A-S5A. A short length of 50 mm nylon pipe connects to the 150 mm diameter steel main approximately 175 m north of LW S1A.

A 32 mm nylon pipe is located within the Bargo township network alongside Wellers Road, to the southwest of LW S7A. The Bargo township network is not connected to the steel gas main.

1.3. Consultation

1.3.1. Consultation with Jemena

Tahmoor Coal regularly consults with Jemena in relation to mine subsidence effects. This includes consultation during the development of subsidence management plans for previous Longwalls 22 to 32 and LW W1-W4, and regular reporting of subsidence movements and impacts.

Details regarding consultation and engagement are outlined below:

- Risk assessment with Andrew Walker (Jemena), Muhammad Siddiqui (Jemena), Amanda Fitzgerald, Ross Barber (Tahmoor Coal), David Ho (Advisian), Daryl Kay (MSEC) and facilitators Chris Allanson and Andrew Whelan (HMS Consultants) in April 2022.
- Correspondence between Tahmoor Coal and Jemena confirming details of planned risk controls
- Provision of the draft Subsidence Management Plan for LW S1A-S2A to Andrew Walker (Jemena) in January 2023.
- Risk assessment with Andrew Walker (Jemena), Bruno Martino (Jemena), Ryan Juhyun Son (Zinfra), Nafizul Akash (Wollondilly Shire Council), Ross Barber, David Talbert (Tahmoor Coal), David Ho (Worley), Glen Dominish (Worley), Graeme Robinson (Robinson Rail), Daryl Kay (MSEC) and facilitator Shane Chiddy (Axys Consulting) on 18 October 2023.
- Correspondence between Tahmoor Coal, Jemena and Zinfra confirming details of planned risk controls, including selection of risk control for Remembrance Drive bend and Teatree Hollow creek crossing on 11 January 2024.
- Weekly monitoring meetings between Tahmoor Coal, Jemena, Sydney Water, Telstra and engineering specialists during the mining of LW S2A.
- Tahmoor Coal have engaged Zinfra (Jemena's maintenance and construction contractor) to provide support for two uncoupling works during the mining of LW S2A.

Tahmoor Coal will continue to consult regularly with Jemena during the extraction of LW S1A-S7A in relation to mine subsidence effects from mining.

1.3.2. Consultation with Government Agencies & Key Infrastructure Stakeholders

Government agencies including the NSW Department of Planning & Environment, Resources Regulator, Mine Safety Operations, Subsidence Advisory NSW and key infrastructure stakeholders including Wollondilly Shire Council, Endeavour Energy, Sydney Water and Telstra have also been consulted as part of the Extraction Plan approval process.

1.4. Limitations

This Management Plan is based on the predictions of the effects of mining on surface infrastructure as provided in Report No. MSEC1192 for LWs S1A to S6A by Mine Subsidence Engineering Consultants (MSEC, 2022) and Report No. MSEC1348 for LW S7A by Mine Subsidence Engineering Consultants (MSEC, 2024). Predictions are based on the planned configuration of LW S1A-S6A at Tahmoor South (as shown in Drawing No. MSEC1193-06-01), along with available geological information and data from numerous subsidence studies for longwalls previously mined in the area.

Infrastructure considered in this Management Plan has been identified from site visits and aerial photographs and from discussions between Tahmoor Coal representatives and Jemena.

The impacts of mining on surface and sub-surface features have been assessed in detail. It is recognised, however, that the prediction and assessment of subsidence can be relied upon only to a certain extent. The limitations of the prediction and assessment of mine subsidence are discussed in report MSEC1192 by Mine Subsidence Engineering Consultants.

As discussed in the report, there is a low probability that ground movements and their impacts could exceed the predictions and assessments. However, if these potentially higher impacts are considered prior to mining, they can be managed. This Management Plan will not necessarily prevent impacts from longwall mining, but will limit the impacts by establishing appropriate procedures that can be followed should evidence of increased impacts emerge.

1.5. Objectives

The objectives of this Management Plan are to establish procedures to measure, control, mitigate and repair potential impacts that might occur to Jemena gas infrastructure.

The objectives of the Management Plan have been developed to:

- Ensure the safe and serviceable operation of all surface infrastructure. Public and workplace safety is paramount. Ensure that the health and safety of people who may be present on public property are not put at risk due to mine subsidence;
- Avoid disruption and inconvenience, or, if unavoidable, keep to minimal levels;
- Monitor ground movements and the condition of infrastructure during mining;
- Initiate action to mitigate or remedy potential significant impacts that are expected to occur on the surface;
- Provide a plan of action in the event that the impacts of mine subsidence are greater than those that are predicted;
- Establish a clearly defined decision-making process to ensure timely implementation of risk control measures for high consequence but low likelihood mine subsidence induced hazards that involve potential serious injury or illness to a person or persons that may require emergency evacuation, entry or access restriction or suspension of work activities;
- Provide a forum to report, discuss and record impacts to the surface. This will involve Tahmoor Coal, Jemena, relevant government agencies as required, and consultants as required; and
- Establish lines of communication and emergency contacts.

1.6. Scope

The Management Plan is to be used to protect and monitor the condition of the items of Jemena infrastructure identified to be at risk due to mine subsidence and to ensure that the health and safety of people who may be present in the vicinity or on Jemena property are not put at risk due to mine subsidence. The major items at risk are:

- 150 mm diameter steel gas main;
- Local nylon gas mains; and
- Gas pipelines at minor creek crossings.

The gas pipelines are shown in Drawing No. MSEC1193-06-01 classified by pipe size and by pipe type.

The Management Plan only covers infrastructure that is located within the limit of subsidence, which defines the extent of land that may be affected by mine subsidence as a result of mining LW S1A-S7A only. The management plan does not include other gas infrastructure owned by Jemena which lies outside the extent of this area.

1.7. Proposed mining schedule

It is planned that LW S1A-S7A will extract coal working south from the northern end. This Management Plan covers longwall mining until completion of mining in LW S7A and for sufficient time thereafter to allow for completion of subsidence effects. The current schedule of mining is shown in Table 1.2.

Table 1.2 Schedule of mining

Longwall	Start Date	Completion Date
LW S1A	October 2022	July 2023
LW S2A	August 2023	March 2024
LW S3A	May 2024	December 2024
LW S4A	January 2025	August 2025
LW S5A	August 2025	April 2026
LW S6A	May 2026	December 2026
LW S7A	January 2027	July 2027

Please note the above schedule is subject to change due to unforeseen impacts on mining progress. Tahmoor Coal will keep Jemena informed of changes.

1.8. Definition of Active Subsidence Zone

As a longwall progresses, subsidence begins to develop at a point in front of the longwall face and continues to develop after the longwall passes. The majority of subsidence movement typically occurs within an area 150 metres in front of the longwall face to an area 450 metres behind the longwall face.

This is termed the "active subsidence zone" for the purposes of this Management Plan, where surface monitoring is generally conducted. The active subsidence zone for each longwall is defined by the area bounded by the predicted 20 mm subsidence contour for the active longwall and a distance of 150 metres in front and 450 metres behind the active longwall face, as shown by Fig. 1.1.

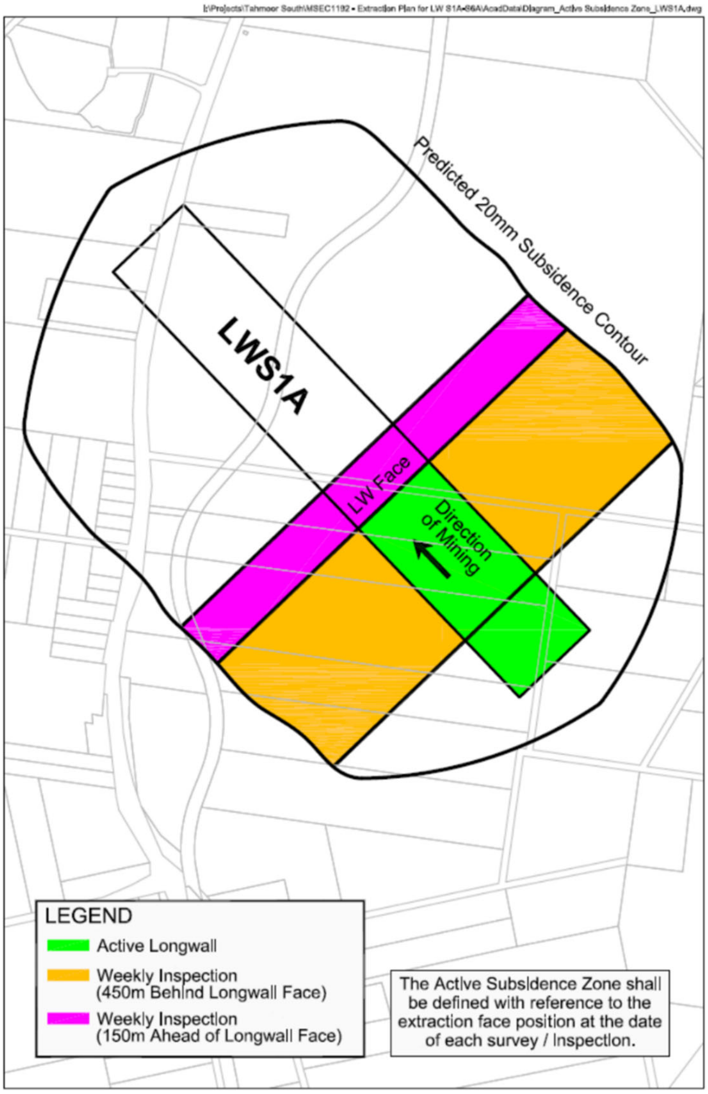


Fig. 1.1 Diagrammatic Representation of Active Subsidence Zone

1.9. Compensation

The *Coal Mine Subsidence Compensation Act 2017* (MSC Act) is administered by Subsidence Advisory NSW (Mine Subsidence Board).

Currently, under the *Coal Mine Subsidence Compensation Act 2017*, any claim for mine subsidence damage needs to be lodged with Subsidence Advisory NSW. Subsidence Advisory NSW staff will arrange for the damage to be assessed by an independent specialist assessor. If the damage is attributable to mine subsidence, a scope will be prepared and compensation will be determined. For further details please refer to *Guidelines – Process for Claiming Mine Subsidence Compensation* at www.subsidenceadvisory.nsw.gov.au.

2.1. NSW Work Health & Safety Legislation

All persons conducting a business or undertaking (PCBUs), including mine operators and contractors, have a primary duty of care to ensure the health and safety of workers they engage, or whose work activities they influence or direct. The responsibilities are legislated in *Work Health and Safety Act 2011* and the *Work Health and Safety (Mines and Petroleum Sites) Act 2013* and associated Regulations (collectively referred to as the 'WHS laws').

The *Work Health and Safety (Mines and Petroleum Sites) Regulation 2014* commenced on 1 February 2015 and contains specific regulations in relation to mine subsidence.

As outlined in the Guide by the NSW Department of Trade & Investment Mine Safety:

"a PCBU must manage risks to health and safety associated with mining operations at the mine by:

- *complying with any specific requirements under the WHS laws*
- *identifying reasonably foreseeable hazards that could give rise to health and safety risks*
- *ensuring that a competent person assesses the risk*
- *eliminating risks to health and safety so far as is reasonably practicable*
- *minimising risks so far as is reasonably practicable by applying the hierarchy of control measures, any risks that it is are not reasonably practical to eliminate*
- *maintaining control measures*
- *reviewing control measures.*

The mine operator's responsibilities include developing and implementing a safety management system that is used as the primary means of ensuring, so far as is reasonably practicable:

- *the health and safety of workers at the mine, and*
- *that the health and safety of other people is not put at risk from the mine or work carried out as part of mining operations."*

Detailed guidelines have also been released by the NSW Department of Planning & Environment, Resources Regulator, Mine Safety Operations (MSO, 2017).

The risk management process has been carried out in accordance with guidelines published by the NSW Department of Planning & Environment, Resources Regulator, Mine Safety Operations (MSO, 2017). The following main steps of subsidence risk management have been and will be undertaken, in accordance with the guidelines.

1. identification and understanding of subsidence hazards
2. assessment of risks of subsidence
3. development and selection of risk control measures
4. implementation and maintenance of risk control measures, and
5. continual improvement and change management.

Each of the above steps have been or will be conducted together with the following processes.

1. consultation, co-operation and co-ordination, and
2. monitoring and review.

This Management Plan documents the risk control measures that are planned to manage risks to health and safety associated with the mining of LW S1A-S7A in accordance with the WHS laws.

2.2. General

The method of assessing potential mine subsidence impacts in the Management Plan is consistent with the Australian/New Zealand Standard for Risk Management (AS/NZS ISO 31000:2009). The Standard defines the terms used in the risk management process, which includes the identification, analysis, assessment, treatment and monitoring of potential mine subsidence impacts. In this context:-

2.2.1. Consequence

'The outcome of an event expressed qualitatively or quantitatively, being a loss, injury, disadvantage or gain. There may be a range of possible outcomes associated with an event.' The consequences of a hazard are rated from negligible to catastrophic.

2.2.2. Likelihood

'Used as a qualitative description of probability or frequency'. The likelihood can range from rare to almost certain.

2.2.3. Hazard

'A source of potential harm or a situation with a potential to cause loss.'

2.2.4. Method of assessment of potential mine subsidence impacts

The method of assessing potential mine subsidence impacts combines the likelihood of an impact occurring with the consequence of the impact occurring. In this Management Plan, the likelihood and consequence are combined via the SIMEC Risk Matrix to determine an estimated level of risk for particular events or situations. A copy of the Risk Matrix is included in the Appendix of this Management Plan.

3.1. Maximum predicted conventional subsidence parameters

Predicted mining-induced conventional subsidence movements were provided in Report No. MSEC1192, which was prepared in support of Tahmoor Coal's Extraction Plan for LW S1A-S6A. Tahmoor Coal has revised its forecast extraction heights since the previous predictions were provided in Report No. MSEC1192. The changes are generally minor, in the range of 50 to 100 mm greater than previously forecast.

Revised predicted mining-induced conventional subsidence movements were provided in Report No. MSEC1348, which was prepared in support of Tahmoor Coal's application to extract LW S7A.The predictions do not materially change the assessment of potential impacts on Jemena infrastructure (MSEC1348). This Management Plan provides subsidence predictions based on the revised predictions that were provided in Report No. MSEC1348.

A summary of the maximum predicted values of incremental conventional subsidence, tilt and curvature, due to the extraction of LW S1A-S7A, is provided in Table 3.1.

The predicted ground strains are discussed in Section 3.3. The predicted tilts provided in this table are the maxima after the completion of each of the proposed longwalls. The predicted curvatures are the maxima at any time during or after the extraction of each of the proposed longwalls.

Table 3.1 Maximum predicted incremental conventional subsidence ,tilt and curvature resulting from the extraction of each of the proposed longwalls

Longwall	Maximum predicted incremental conventional subsidence (mm)	Maximum predicted incremental conventional tilt (mm/m)	Maximum predicted incremental conventional hogging curvature (km^{-1})	Maximum predicted incremental conventional sagging curvature (km^{-1})
LW S1A	825	7.0	0.08	0.23
LW S2A	950	8.0	0.09	0.22
LW S3A	950	8.0	0.09	0.22
LW S4A	975	8.0	0.09	0.22
LW S5A	975	8.0	0.10	0.22
LW S6A	975	8.3	0.09	0.23
LW S7A	1050	8.9	0.10	0.24

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature, after the extraction of LW S1A-S7A, is provided in Table 3.2.

Table 3.2 Maximum predicted total conventional subsidence, tilt and curvature resulting from the extraction of each of the proposed longwalls

Longwalls	Maximum predicted total conventional subsidence (mm)	Maximum predicted total conventional tilt (mm/m)	Maximum predicted total conventional hogging curvature (km^{-1})	Maximum predicted total conventional sagging curvature (km^{-1})
LW S1A	825	7.0	0.08	0.23
LW S2A	1,050	8.1	0.10	0.23
LW S3A	1,250	8.3	0.11	0.23
LW S4A	1,300	8.7	0.13	0.22
LW S5A	1,350	9.2	0.14	0.23
LW S6A	1,400	9.7	0.14	0.23
LW S7A	1,400	10.0	0.14	0.25

The maximum predicted total subsidence, after the completion of LW S1A-S7A, is 1,400 mm. The maximum predicted total conventional tilt is 10 mm/m (i.e. 1.0 %), which represents a change in grade of 1 in 100. The maximum predicted total conventional curvatures are 0.14 km^{-1} hogging and 0.25 km^{-1} sagging, which represent minimum radii of curvature of 7 kilometres and 4 kilometres, respectively.

The values provided in the above table are the maximum predicted conventional subsidence parameters which occur above LWs S1A to S7A. The locations of the maximum predicted conventional subsidence parameters do not necessarily coincide with Jemena infrastructure. Specific predictions along Jemena infrastructure is provided later in this Management Plan.

3.2. Comparison between Observed and Predicted Subsidence during the mining of Longwalls LW S1A and S2A

Extensive monitoring has been undertaken by Tahmoor Coal during the mining of LW S1A and the current mining of LW S2A. Observed incremental subsidence due to the extraction of LW S1A has correlated reasonably well with predictions, as shown in Fig. 3.1, Fig. 3.3, Fig. 3.4 and Fig. 3.5.

Subsidence was observed to vary in magnitude along the centreline of LW S1A. Maximum subsidence was measured at Peg V51 on the V-Line, which is located between Teatree Hollow and the Tributary to Teatree Hollow. Observed subsidence was reduced in magnitude over the northern half of the longwall panel at the Main Southern Railway and Tahmoor Mine Site (Pier 2).

As shown in Fig. 3.1, observed subsidence at Peg V51 was slightly greater than predicted but within the accuracy of the prediction model of ± 15% (Reports Nos. MSEC1123 and MSEC1192). Observed subsidence values at other locations above LW S1A were less than predicted.

As at March 2024, monitoring during the mining of LW S2A has measured subsidence movements developing within predictions, as shown in Fig. 3.2. Whilst observed subsidence along Jemena infrastructure on Remembrance Drive has been less than predicted, increased compressive strains have been observed at two locations, as shown in Fig. 3.5. Jemena and Tahmoor Coal are currently managing potential impacts at these two locations in accordance with this Management Plan, and the previously agreed Revision A of this Management Plan.

As recommended in Report No. MSEC1192, Tahmoor Coal is monitoring during mining to compare observations with predictions. Tahmoor Coal has extensive experience in successfully managing potential subsidence impacts on surface features, even when actual subsidence is substantially greater than the magnitudes that have been predicted above LW S3A. Subsidence management plans have been developed to manage potential impacts that could occur if greater than predicted subsidence occurs.

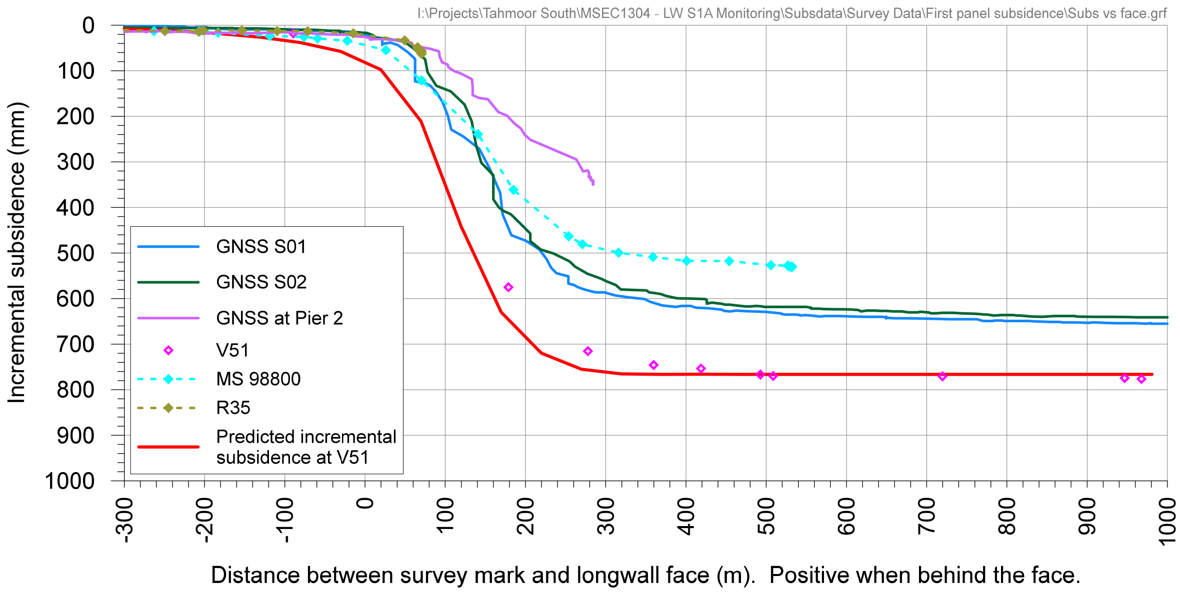


Fig. 3.1 Comparison between predicted and observed subsidence above centreline of LW S1A

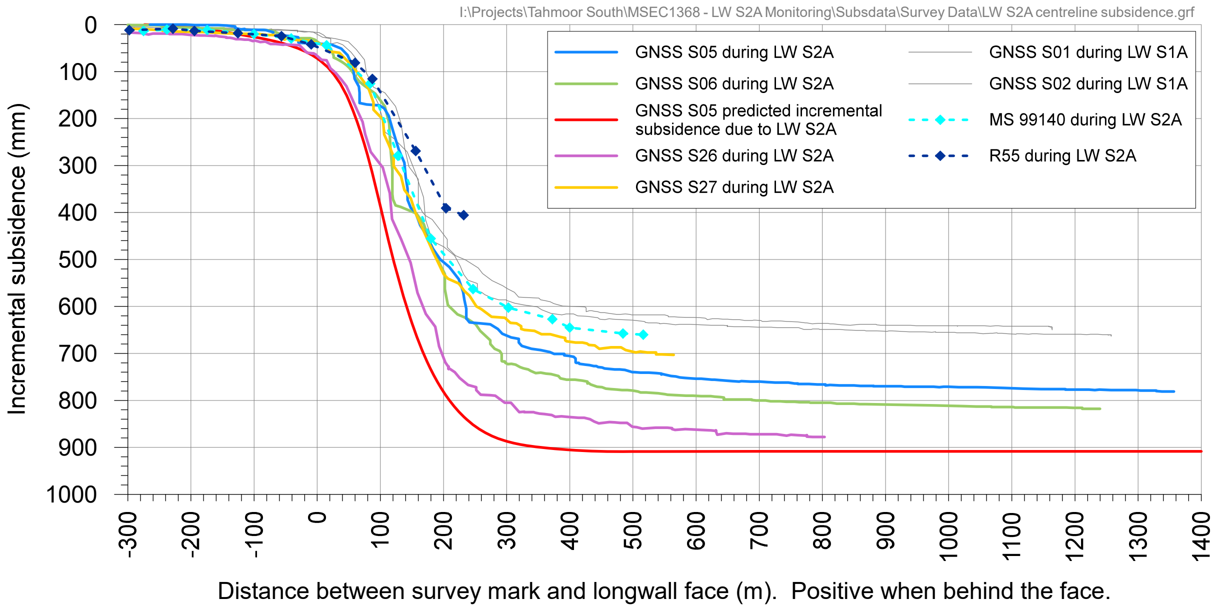


Fig. 3.2 Comparison between predicted and observed subsidence above centreline of LW S2A

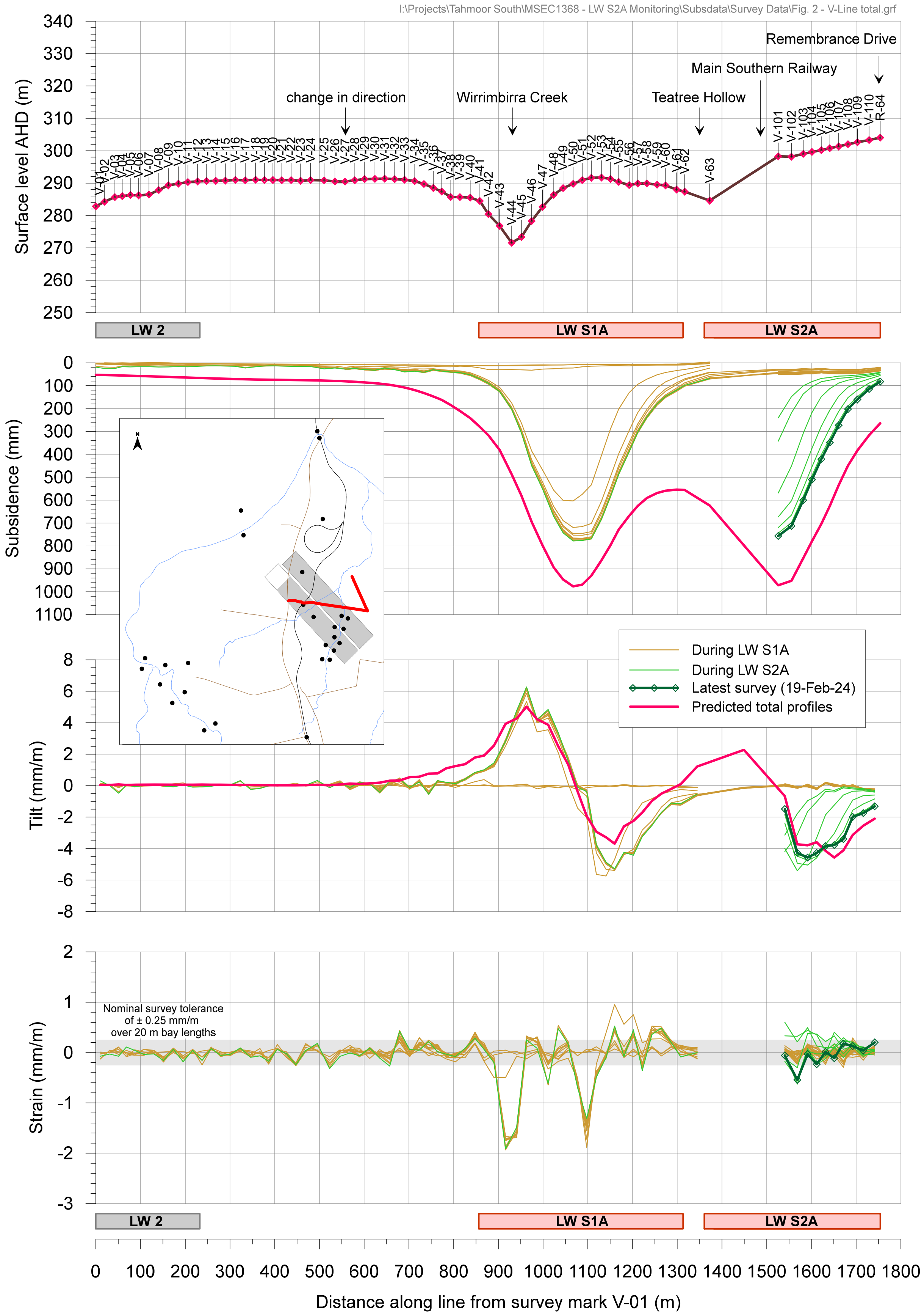


Fig. 3.3 Observed subsidence along V Line during the mining of LW S1A and S2A

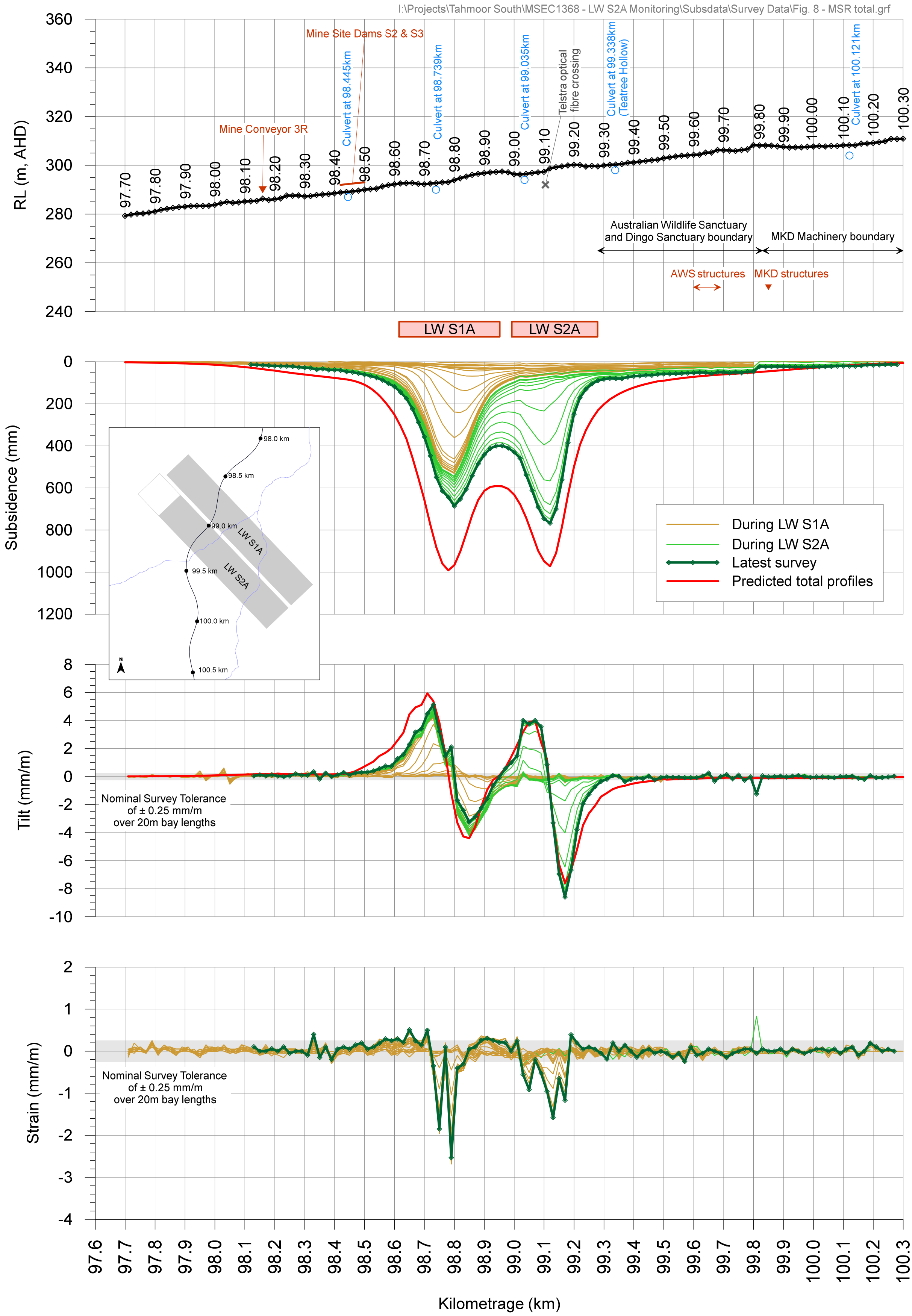


Fig. 3.4 **Observed subsidence along Main Southern Railway during the mining of LW S1A and S2A**

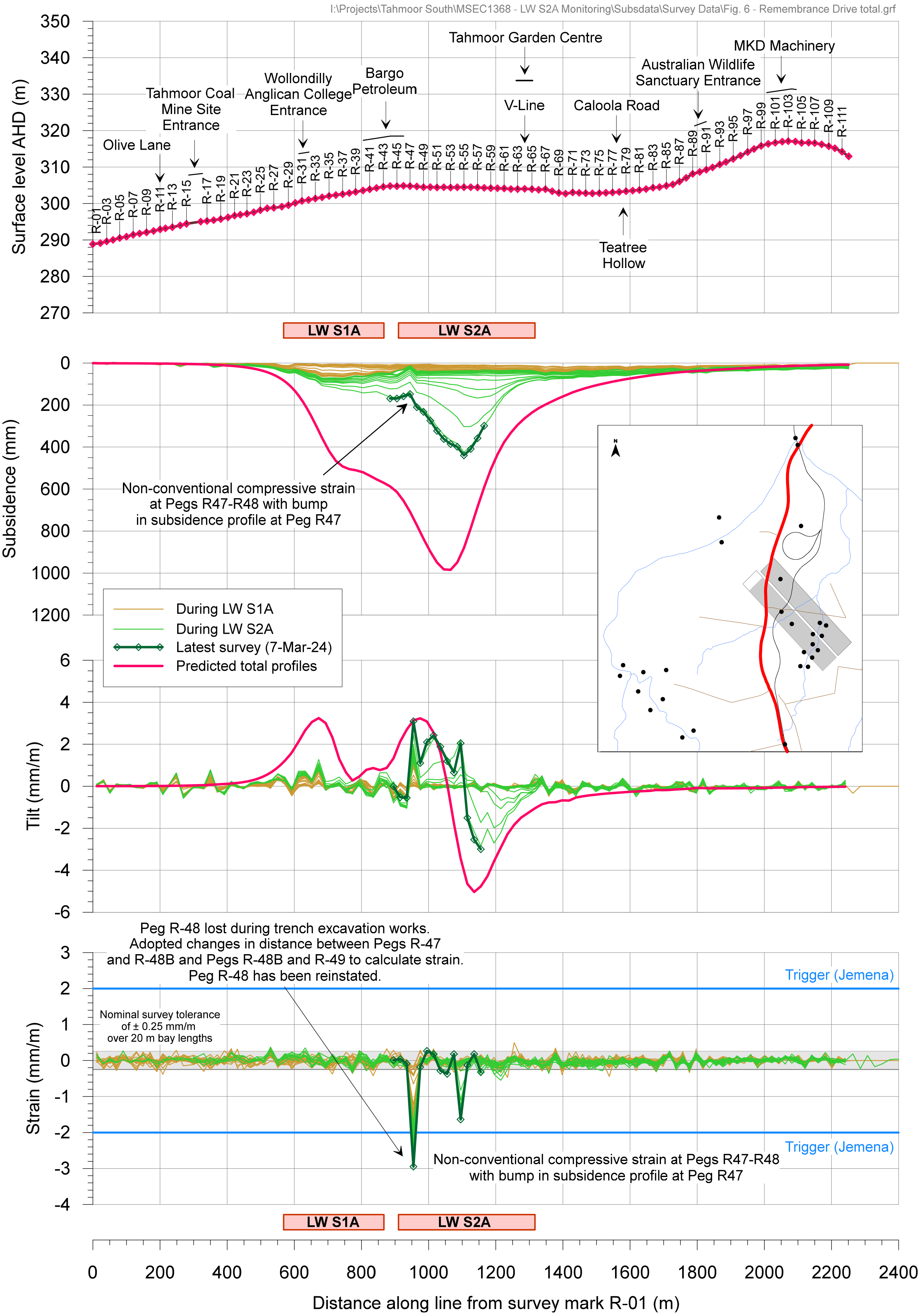


Fig. 3.5 Observed subsidence along Remembrance Drive during the mining of LW S1A and S2A

3.3. Predicted strain

The prediction of strain is more difficult than the predictions of subsidence, tilt and curvature. The reason for this is that strain is affected by many factors, including ground curvature and horizontal movement, as well as local variations in the near surface geology, the locations of pre-existing natural joints at bedrock, and the depth of bedrock. Survey tolerance can also represent a substantial portion of the measured strain, in cases where the strains are of a low order of magnitude. The profiles of observed strain, therefore, can be irregular even when the profiles of observed subsidence, tilt and curvature are relatively smooth.

In previous MSEC subsidence reports, predictions of conventional strain were provided based on the best estimate of the average relationship between curvature and strain. Similar relationships have been proposed by other authors. The reliability of the strain predictions was highlighted in these reports, where it was stated that measured strains can vary considerably from the predicted conventional values.

Adopting a linear relationship between curvature and strain provides a reasonable prediction for the conventional tensile and compressive strains. The locations that are predicted to experience hogging or convex curvature are expected to be net tensile strain zones and locations that are predicted to experience sagging or concave curvature are expected to be net compressive strain zones. In the Southern Coalfield, it has been found that a factor of 15 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains.

At a point, however, there can be considerable variation from the linear relationship, resulting from non-conventional movements or from the normal scatters which are observed in strain profiles. When expressed as a percentage, observed strains can be many times greater than the predicted conventional strain for low magnitudes of curvature. In this report, therefore, we have provided a statistical approach to account for the variability, rather than providing a single predicted conventional strain.

The data used in the analysis of observed strains included those resulting from both conventional and non-conventional anomalous movements, but did not include those resulting from valley-related effects. The strains resulting from damaged or disturbed survey marks have also been excluded.

3.3.1. Analysis of strains measured in survey bays

For features that are in discrete locations, such as building structures, farm dams and archaeological sites, it is appropriate to assess the frequency of the observed maximum strains for individual survey bays.

Predictions of strain above goaf

A database of survey data has been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of the previous longwalls at Tahmoor, Appin and West Cliff Collieries, for survey bays that were located directly above goaf or the chain pillars that are located between the extracted longwalls, which has been referred to as "*above goaf*".

A histogram of the maximum observed total tensile and compressive strains measured in survey bays above goaf, for monitoring lines at Tahmoor, Appin and West Cliff Collieries is provided in Fig. 3.6. Probability distribution functions, based on fitted *Generalised Pareto Distributions (*GPDs), have also been shown in this figure.

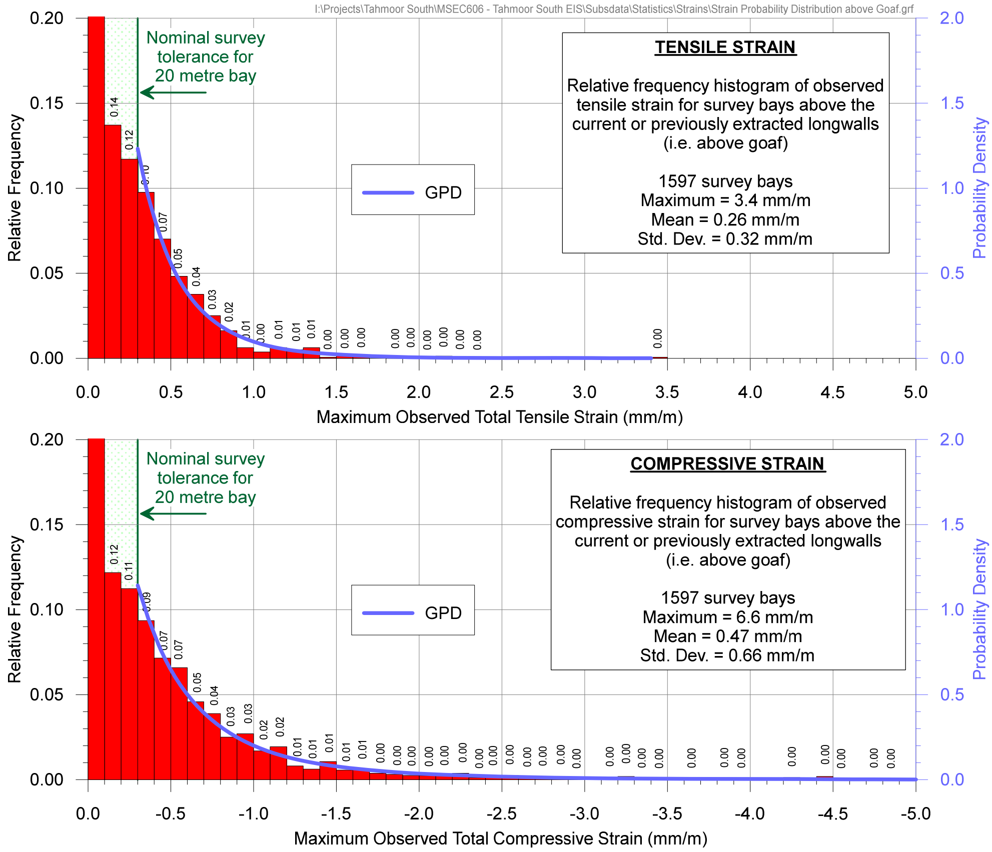


Fig. 3.6 Distributions of the maximum measured tensile and compressive strains for survey bays located above goaf at Tahmoor, Appin and West Cliff Collieries

The 95 % confidence levels for the maximum total strains that the individual survey bays *above goaf* experienced at any time during mining at Tahmoor, Appin and West Cliff Collieries were 0.9 mm/m tensile and 1.6 mm/m compressive. The strains for the proposed longwalls are predicted to be 20 % to 40 % greater than those previously observed at these collieries and, therefore, it is expected that 95 % of the strains measured *above goaf* would be less than 1.3 mm/m tensile and 2.2 mm/m compressive.

The 99 % confidence levels for the maximum total strains that the individual survey bays *above goaf* experienced at any time during mining at Tahmoor, Appin and West Cliff Collieries were 1.4 mm/m tensile and 3.1 mm/m compressive. Similarly, it is expected that 99 % of the strains measured *above goaf* for the proposed longwalls would be less than 2.0 mm/m tensile and 4.3 mm/m compressive.

Predictions of strain above solid coal

The survey database has also been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of the previous longwalls at Tahmoor, Appin and West Cliff Collieries, for survey bays that were located beyond the goaf edges of the mined panels and positioned on unmined areas of coal, i.e. outside panels but within 200 metres of the nearest longwall goaf edge, which has been referred to as "*above solid coal*".

A histogram of the maximum observed tensile and compressive strains measured in survey bays above solid coal, for monitoring lines at Tahmoor, Appin and West Cliff Collieries is provided in Fig. 3.7. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

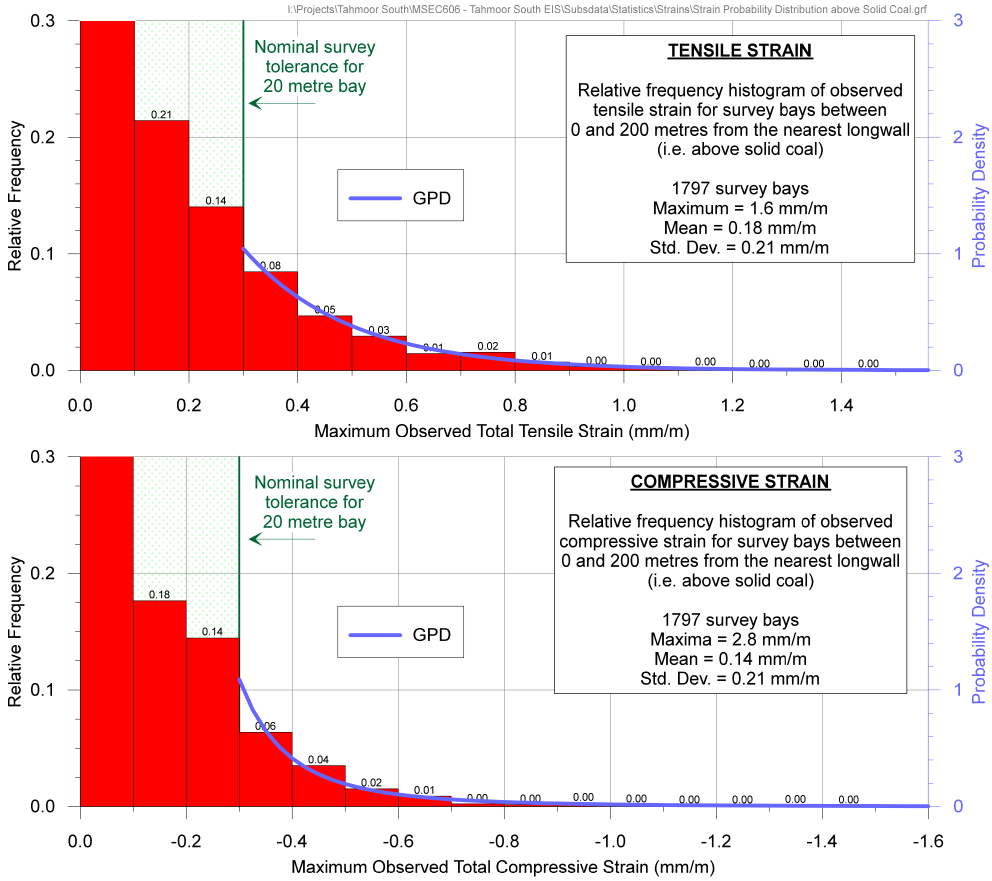


Fig. 3.7 Distributions of the maximum measured tensile and compressive strains for survey bays located above solid coal at Tahmoor, Appin and West Cliff Collieries

The 95 % confidence levels for the maximum total strains that the individual survey bays *above solid coal* experienced at any time during mining at Tahmoor, Appin and West Cliff Collieries were 0.6 mm/m tensile and 0.5 mm/m compressive. The strains for the proposed longwalls are predicted to be 20 % to 40 % greater than those previously observed at these collieries and, therefore, it is expected that 95 % of the strains measured *above solid coal* would be less than 1.0 mm/m tensile and compressive.

The 99 % confidence levels for the maximum total strains that the individual survey bays *above solid coal* experienced at any time during mining at Tahmoor, Appin and West Cliff Collieries were 0.9 mm/m tensile and compressive. Similarly, it is expected that 99 % of the strains measured *above solid coal* adjacent to the proposed longwalls would be less than 1.5 mm/m tensile and compressive.

3.3.2. Analysis of strains measured along whole monitoring lines

For linear features such as roads, cables and pipelines, it is more appropriate to assess the frequency of the maximum strains measured along whole monitoring lines, rather than for individual survey bays. That is, an analysis of the maximum strains measured anywhere along the monitoring lines, regardless of where the strain occurs.

A histogram of maximum observed total tensile and compressive strains measured anywhere along the monitoring lines, at any time during or after the extraction of the previous longwalls Tahmoor, Appin and West Cliff Collieries, is provided in Fig. 3.8.

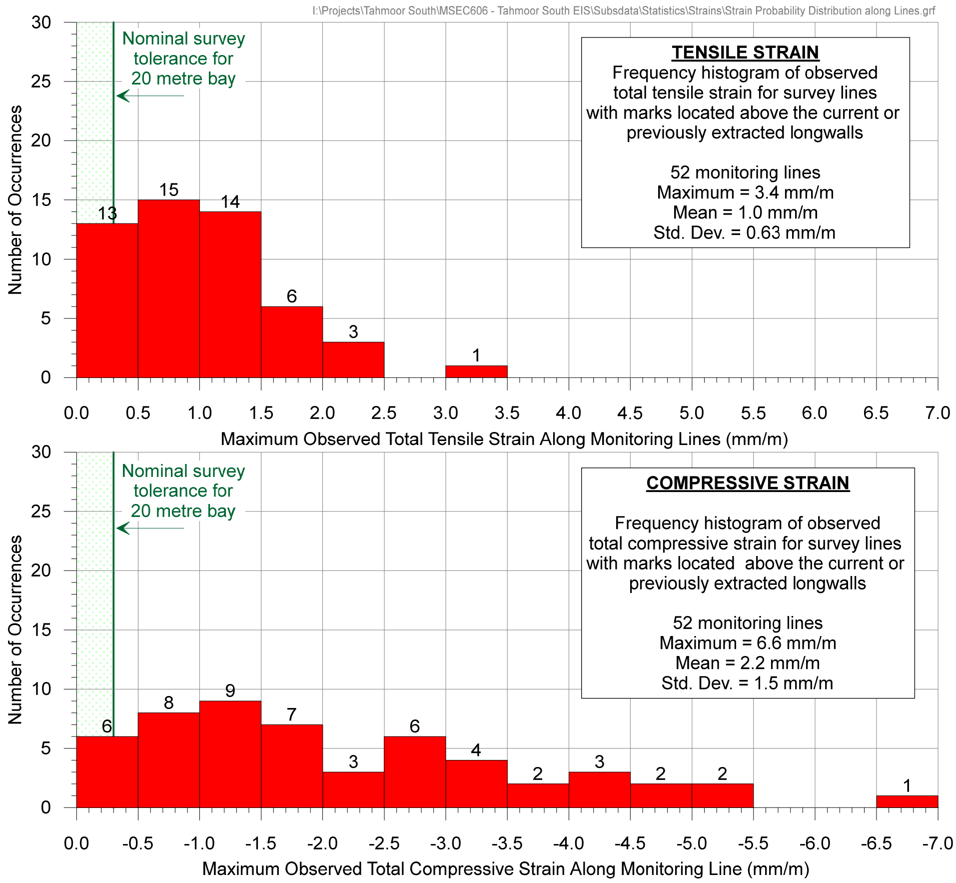


Fig. 3.8 Distributions of maximum measured tensile and compressive strains anywhere along monitoring lines at Tahmoor, Appin and West Cliff Collieries

It can be seen from the above figure, that 42 of the 52 monitoring lines (i.e. 92 % of the total) at Tahmoor, Appin and West Cliff Collieries had recorded maximum total tensile strains of 2.0 mm/m, or less. The strains for the proposed longwalls are predicted to be 20 % to 40 % greater than those previously observed at these collieries and, therefore, it is expected that 92 % of the monitoring lines above the proposed longwalls would experience maximum tensile strains of 3.0 mm/m, or less.

It can also be seen, that 45 of the 52 monitoring lines (i.e. 87 % of the total) at Tahmoor, Appin and West Cliff Collieries had recorded maximum total compressive strains of 4.0 mm/m, or less. The strains for the proposed longwalls are predicted to be 20 % to 40 % greater than those previously observed at these collieries and, therefore, it is expected that 87 % of the monitoring lines above the proposed longwalls would experience maximum compressive strains of 5.5 mm/m, or less.

3.4. Managing public safety

The primary risk associated with mining beneath potable water infrastructure is public safety. Tahmoor Coal has previously directly mined beneath or adjacent to more than 2000 houses and civil structures, commercial and retail properties, the Main Southern Railway and local roads and bridges. It has implemented extensive measures prior to, during and after mining to ensure that the health and safety of people have not been put at risk due to mine subsidence. People have not been exposed to immediate and sudden safety hazards as a result of impacts that have occurred due to mine subsidence movements.

Emphasis is placed on the words "immediate and sudden" as in rare cases, some structures have experienced severe impacts, but the impacts did not present an immediate risk to public safety as they developed gradually with ample time to repair the structure.

In the case of this Subsidence Management Plan, the potential for impacts on public safety has been assessed on a case by case basis.

3.4.1. Subsidence Impact Management Process for Infrastructure

Tahmoor Coal has developed and acted in accordance with agreed subsidence management plans to manage potential impacts during the mining of Longwalls 22 to 32 and LW W1-W4 at Tahmoor North. The management strategy has been reviewed and updated based on experiences gained during the mining of these longwalls and the strategy for LW S1A-S7A at Tahmoor South includes the following process:

1. Regular consultation with Jemena before, during and after mining;
2. Site-specific investigations;
3. Implementation of mitigation measures following inspections by Jemena; and
4. Surveys and inspections during mining within the active subsidence area:
   - Detailed visual inspections and vehicle-based inspections along the streets;
   - Ground surveys along streets; and
   - Specific ground surveys and visual inspections, where recommended by an engineer based on the inspections and assessments.

A flowchart illustrating the subsidence impact management process prior to, during and after Jemena infrastructure experiences mine subsidence movements is shown in Fig. 3.9.

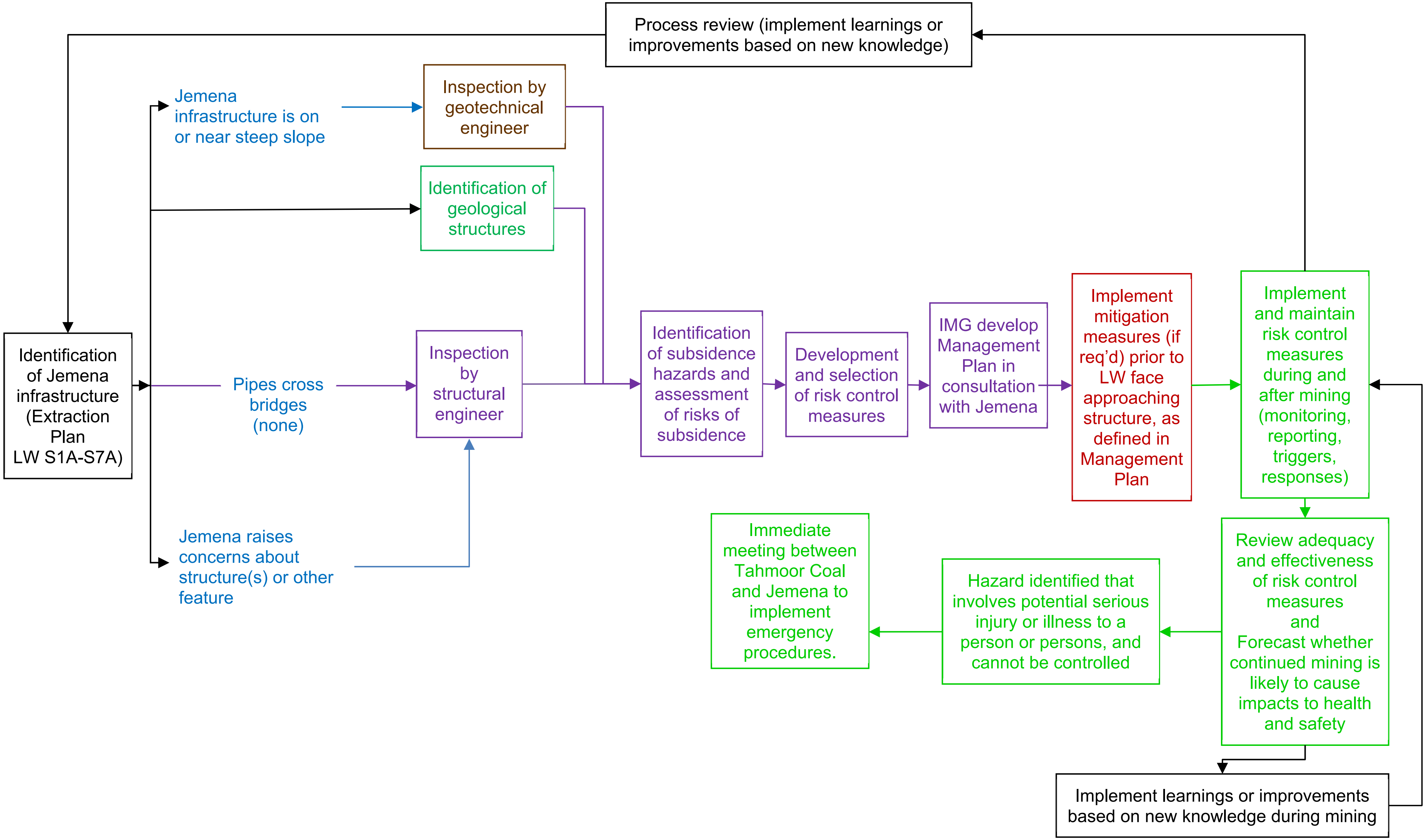


Fig. 3.9 Flowchart for Subsidence Impact Management Process

3.5. Summary of potential impacts

A summary of potential impacts on Jemena infrastructure for LWs S1A and S2A is provided in Table 3.3. A risk assessment for LWs S1A and S2A was conducted by Tahmoor Coal, Jemena and engineering specialists Worley (pipeline engineer) and MSEC (subsidence engineer) in April 2022. The risk assessment was facilitated by HMS Consultants (2022).

The results of the risk assessments are included in the Appendix.

Table 3.3 Summary of potential mine subsidence impacts for LWs S1A and S2A

Risk	Likelihood	Consequence	Level of Potential Impact
Ground strains and curvatures exceed pipeline allowable or actual yield strength resulting in a gas leak due to conventional subsidence movements	UNLIKELY	MINOR	LOW
Ground strains and curvatures exceed pipeline allowable or actual yield strength resulting in a gas leak due to conventional subsidence movements, which grows to full bore rupture due to less than adequate detection of leaks	RARE	MODERATE	LOW
Ground strains and curvatures exceed pipeline allowable or actual yield strength resulting in a gas leak due to conventional subsidence movements, which grows to full bore rupture due to less than adequate access to carry out timely maintenance or repair of pipeline	UNLIKELY	MODERATE	MEDIUM
Ground strains and curvatures exceed pipeline allowable or actual yield strength resulting in a gas leak due to non-conventional subsidence movements in plateau area over a fault or dyke	UNLIKELY	MINOR	LOW
Ground strains and curvatures exceed pipeline allowable or actual yield strength resulting in a gas leak due to non-conventional subsidence movements at a creek crossing (exposed or hidden creek)	RARE	MINOR	LOW
Gas leak results in disruption of gas supply to community resulting in unacceptable public impacts	RARE	MODERATE	LOW
Gas leak results in reputation impacts due to road closure until repairs can be made	RARE	MODERATE	LOW
Gas leak results in evacuation of Wollondilly Anglican College	RARE	MODERATE	LOW
Gas leak results in evacuation of petrol station	RARE	MINOR	LOW
Gas leak results in evacuation of residences and businesses	RARE	MINOR	LOW
Gas leak results in disruption of other services (power line, water main, sewer, optic fibre)	RARE	MINOR	LOW
Monitoring controls are not adequate to trigger timely action	RARE	MODERATE	LOW
Pipeline damages after it is exposed to relieve effect of mining-induced ground strains and curvatures	UNLIKELY	MODERATE	MEDIUM

A risk assessment for LWs S3A to S7A was conducted by Tahmoor Coal, Jemena, Wollondilly Shire Council and engineering specialists Worley (pipeline engineer) and MSEC (subsidence engineer) on 18 October 2023. The risk assessment was facilitated by Axys Consulting (2023).

A summary of potential impacts on Jemena infrastructure for LWs S3A to S7A is provided in Table 3.4.

Table 3.4 Summary of potential mine subsidence impacts for LWs S3A to S7A

Risk	Likelihood	Consequence	Level of Potential Impact
Ground strains and curvatures in plateau areas exceed pipeline allowable or actual yield strength resulting in a gas leak due to conventional subsidence movements	UNLIKELY	MINOR	LOW
Ground strains and curvatures at creek crossing at Caloola Road exceed pipeline allowable or actual yield strength resulting in a gas leak due to conventional subsidence movements	LIKELY	MINOR	MEDIUM
Ground strains and curvatures at Remembrance Drive Cutting exceed pipeline allowable or actual yield strength resulting in a gas leak due to conventional subsidence movements	UNLIKELY	MINOR	LOW
Ground strains and curvatures at unnamed creek crossing above LW S5A exceed pipeline allowable or actual yield strength resulting in a gas leak due to conventional subsidence movements	UNLIKELY	MINOR	LOW
Ground strains and curvatures at creek crossing at Yarran Road exceed pipeline allowable or actual yield strength resulting in a gas leak due to conventional subsidence movements	UNLIKELY	MINOR	LOW
Ground strains and curvatures at creek crossing at Wellers Road exceed pipeline allowable or actual yield strength resulting in a gas leak due to conventional subsidence movements	RARE	MINOR	LOW

Additional information on each potential impact is provided below.

3.6. Identification of subsidence hazards that could give rise to risks to health and safety

Clause 34 of the Work Health and Safety Regulation (2017) requires that the duty holder (in this case Tahmoor Coal), in managing risks to health and safety, must identify reasonably foreseeable hazards that could give rise to risks to health and safety.

This section of the Management Plan summarises hazards that have been identified in Chapter 3, which could rise to risks to health and safety of people in the vicinity of Jemena infrastructure.

Using the processes described in Section 3.4 of this Management Plan, mine subsidence hazards have been identified, investigated and analysed in a systematic manner by examining each aspect of infrastructure, as described in Section 3.7 of this Management Plan. Each of the aspects below could potentially experience mine subsidence movements that give rise to risks to the health and safety of people:

- 150 mm diameter steel main;
- Local nylon gas mains; and
- Gas pipelines at minor creek crossings.

The following mine subsidence hazards were identified that could give rise to risks to health and safety on Jemena infrastructure due to the extraction of LW S1A-S2A.

- Potential damage to pipes resulting in a gas leak (refer Section 3.7).

The identification and risk assessment process took into account the location of infrastructure relative to LW S1A-S7A and the associated timing and duration of the subsidence event, as described in Section 1.8 of this Management Plan.

Whilst mine subsidence predictions and extensive past experiences from previous mining at Tahmoor Coal were taken into account, the identification and risk assessment process recognised that there are uncertainties in relation to predicting subsidence movements, and uncertainties in how mine subsidence movements may adversely impact Jemena infrastructure, as discussed in Section 1.4 and Chapter 3 of this Management Plan. In this case, creeks have been mapped that intersect gas pipelines.

Tahmoor Coal has considered the outcomes of the hazard identification and risk assessment process when developing measures to manage potential impacts on the health and safety of people, and potential impacts on Jemena infrastructure in general. These are described in Chapter 4 of this Management Plan.

3.7. Gas pipelines

There are three gas pipelines located within the Study Area for LWs S1A-S7A, as shown in Drawing No. MSEC1193-06-01:

- 150 mm diameter steel main
  A 150 mm diameter steel main generally follows the alignment of Remembrance Drive. The pipeline is directly above LWs S1A to S5A.
- 50 mm diameter nylon main
  A short length of 50 mm nylon pipe connects to the 150 mm diameter steel main approximately 175 m north of LW S1A.
- 32 mm diameter nylon main
  A very short section of nylon gas main along Wellers Road is located approximately 200 m southwest of LW S7A.

The steel gas main was constructed in 1994 and was designed and constructed in accordance with the requirements of SA NSW. The pipe has a minimum design life of 50 years. The take-off point for the 150 mm steel main from the Moomba-Sydney Gas Pipeline is located on Hawthorne Road outside the Study Area. The section of gas main above LW S1A-7A supplies gas to approximately 1,000 customers in the townships of Tahmoor, Thirlmere and Picton. The local Jemena gas infrastructure servicing the Bargo township and includes the nylon gas main along Wellers Road has a separate take-off point at the same location. The take-off point consists of a number of buried pits, a pillar box and guard rail.

The steel pipe has cathodic protection, which is monitored approximately every 6 months. Routine pipeline patrols are conducted once to twice a month and gas detection is conducted approximately once every 5 years. Jemena advises that based on a Leakage Survey in 2019 covering Bargo, Tahmoor and Picton, there were no leaks detected in the gas main Remembrance Drive between Wellers Road and Bargo Rover Bridge.

On 17 June 2022, Macarthur Gas completed a pre-mining gas detection survey of the 150 mm gas pipeline located along Remembrance Drive. The survey was conducted for the section of pipeline between Olive Lane and Wellers Road. No leaks were recorded.

The gas main has been designed to accommodate a maximum operating pressure of 1,050 kPa. The current maximum operating design pressure is 300 kPa.

Tahmoor Coal commissioned an as-built survey of the pipeline to confirm its depth and location. The survey was completed in July 2022. The pipeline was exposed by potholing at 7 locations. It was found that the mains were located between 1000 mm and 1200 mm beneath the surface. No traces of sand were found covering the pipes.

The gas main does not cross over any major creeks above LW S1A-S2A. The gas main crosses Teatree Hollow above LW S3A on the southbound side of the Remembrance Drive embankment at the intersection with Caloola Road (refer Fig. 3.14). The gas pipeline generally runs along the crest of the embankment, stepping up near the northern end of the embankment, as shown in Drawing No. MSEC1193-03-07.

The gas main crosses the headwaters of some creeks, which have been “hidden” by Tahmoor Mine’s surface facilities. One of the creek crossings is shown in Fig. 3.13.

The gas main then runs along the toe of a road cutting on Remembrance Drive above LW S4A (refer Fig. 3.15 and Fig. 3.16), before crossing two unnamed tributaries to Teatree Hollow above LW S5A, one of which is located just south of No.3166 Remembrance Drive (refer Fig. 3.17 and Fig. 3.18) and another just south of the intersection near Yarran Road (Fig. 3.19 and Fig. 3.20). Another unnamed tributary to Teatree Hollow crosses the gas main to the south of LW S6A, just north of Wellers Road and a photograph is shown in Fig. 3.21.

The gas main generally runs along the southbound (eastern) side of Remembrance Drive. The section of pipeline directly above LW S1A-S2A runs alongside the Tahmoor Mine site, where there is clear access to the pipeline, as shown in Fig. 3.10. Further south, the pipeline runs one residential property north of Caloola Road intersection. It then passes the Australian Wildlife Sanctuary and a concrete mixing plant at MKD Machinery above LW S4A. The pipeline then runs between Remembrance Drive and the railway corridor above LW S5A and south of LW S6A.

A number of features are located near the gas main above LW S1A-S7A.

- Tahmoor Mine (same side of road)
- Wollondilly Anglican College (opposite side of road)
- Bargo Petroleum petrol station (opposite side of road (Fig. 3.11)
- Tahmoor Garden Centre (opposite side of road)
- Houses (both sides of road)
- Australian Wildlife Sanctuary (same side of road)
- Concrete batching plant at MKD Machinery (same side of road)
- Endeavour Energy 11kV overhead power line (same side of road)
- Telstra / NBN optical fibre cables (same side of road)
- Telstra copper cables (both sides of road)
- Sydney Water potable water main (opposite side of road)
- Sydney Water sewer main (opposite side of road)
- Main Southern Railway (same side of road).

Fig. 3.10 View along gas main looking south alongside Remembrance Drive above LW S1A

Fig. 3.11 View of gas main alongside petrol station across Remembrance Drive

Fig. 3.12 View along gas main looking south alongside Remembrance Drive above LW S2A

Fig. 3.13 View of creek crossing alongside Remembrance Drive above LW S2A

Fig. 3.14 View along gas main looking south alongside Remembrance Drive at Teatree Hollow above LW S3A

Photograph courtesy Douglas Partners

Fig. 3.15 Remembrance Drive cutting above LW S4A looking east

Source: Google Streetview

Fig. 3.16 Remembrance Drive cutting showing cross-section

Photograph courtesy Douglas Partners

Fig. 3.17 Remembrance Drive embankment north of Yarran Road on northbound side (near No. 3166 Remembrance Drive)

Photograph courtesy Douglas Partners

Fig. 3.18 Remembrance Drive embankment north of Yarran Road on southbound side (near No. 3166 Remembrance Drive)

Fig. 3.19 Remembrance Drive embankment south of Yarran Road on southbound side

Fig. 3.20 Remembrance Drive embankment south of Yarran Road on southbound side

Source: Google Streetview

Fig. 3.21 Remembrance Drive embankment north of Wellers Road on downstream side

3.7.1. Predicted subsidence movements

The predicted profiles of conventional subsidence, tilt and curvature for the 150 mm steel main along the gas main adjacent to Remembrance Drive due to the extraction of LW S1A-S7A are shown in Fig. 3.22.

A summary of the maximum predicted total conventional subsidence parameters for gas main along Remembrance Drive, after the extraction of each of the proposed longwalls, is provided in Table 3.5.

The predicted tilts are the maxima along the alignment of the pipeline after the completion of each of the proposed longwalls. The predicted curvatures are the maxima in any direction at any time during or after the extraction of each of the proposed longwalls.

Table 3.5 Maximum predicted total conventional subsidence parameters for gas main along Remembrance Drive due to the extraction of LWs S1A to S7A

Longwall	Maximum predicted subsidence (mm)	Maximum predicted tilt along alignment (mm/m)	Maximum predicted hogging curvature in any direction (km^{-1})	Maximum predicted sagging curvature in any direction (km^{-1})
LW S1A	325	2.5	0.06	0.06
LW S2A	1000	5.0	0.08	0.20
LW S3A	1200	6.5	0.10	0.21
LW S4A	1300	6.0	0.12	0.21
LW S5A	1350	6.5	0.12	0.21
LW S6A	1375	7.5	0.12	0.21
LW S7A	1400	7.5	0.12	0.21

The maximum predicted conventional strains for the pipeline after the extraction of LW S7A, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1.9 mm/m tensile and 3.2 mm/m compressive. Non-conventional movements can also occur as a result of, among other things, anomalous movements.

The analysis of strains provided in Section 3.3 includes those resulting from both conventional and non-conventional anomalous movements. In summary, it is expected that 95 % of the strains measured *above goaf* would be less than 1.3 mm/m tensile and 2.2 mm/m compressive and 99 % of the strains measured *above goaf* for the proposed longwalls would be less than 2.0 mm/m tensile and 4.3 mm/m compressive.

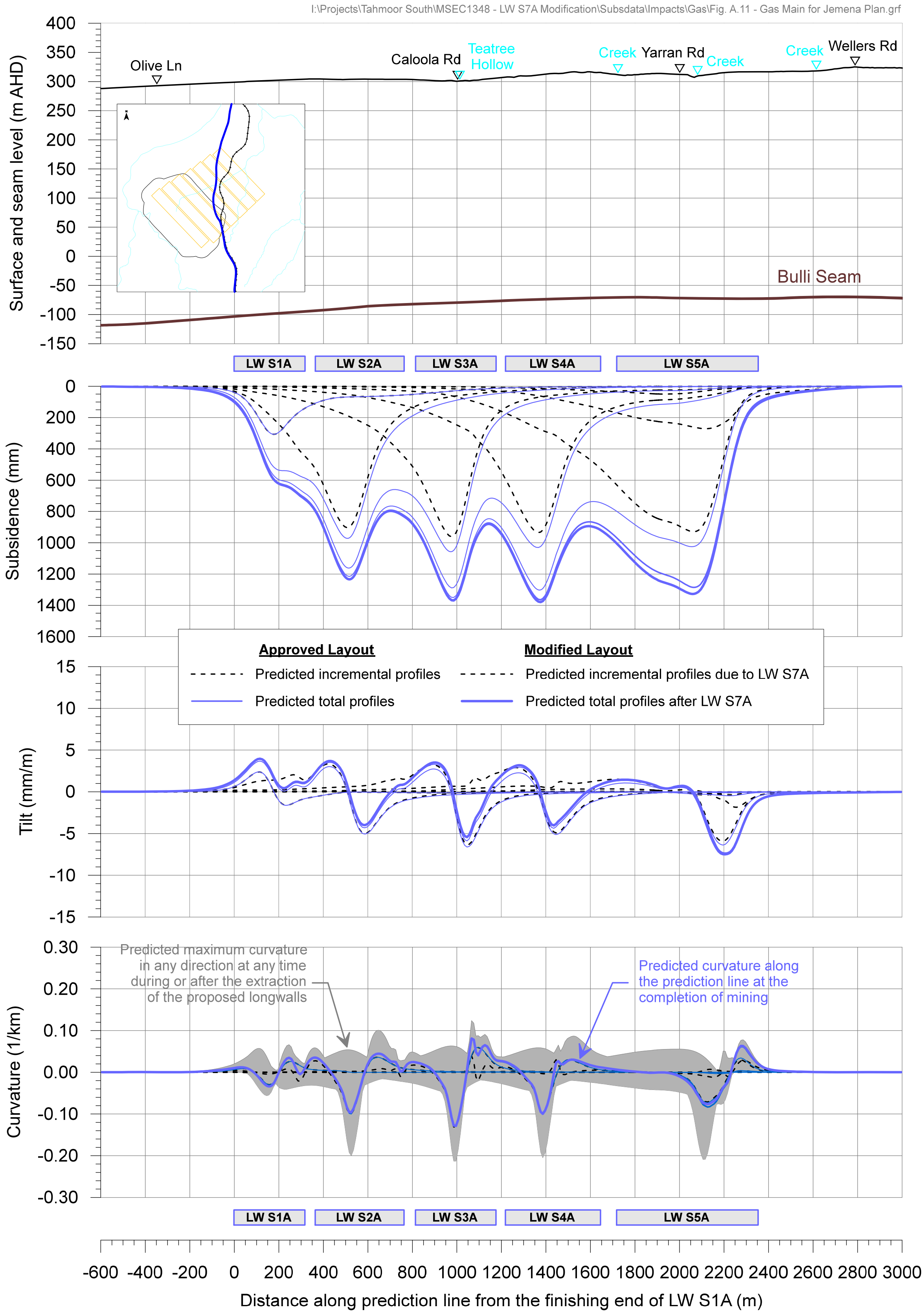


Fig. 3.22 Predicted profiles of total subsidence, tilt and curvature for the gas pipeline along Remembrance Driveway after the mining of LW S1A-S7A

Predictions were also provided for every 10 metres of extraction along the pipeline during the extraction of LW S1A-S6A, as shown in Fig. 3.23 toFig. 3.28. The predictions were included in modelling conducted by Advisian, now Worley. Detail predictions were not provided for LW S7A as the extraction of LW S7A is predicted to result in a maximum increase of 60 mm of additional subsidence, with negligible changes in tilt, curvature and strain.

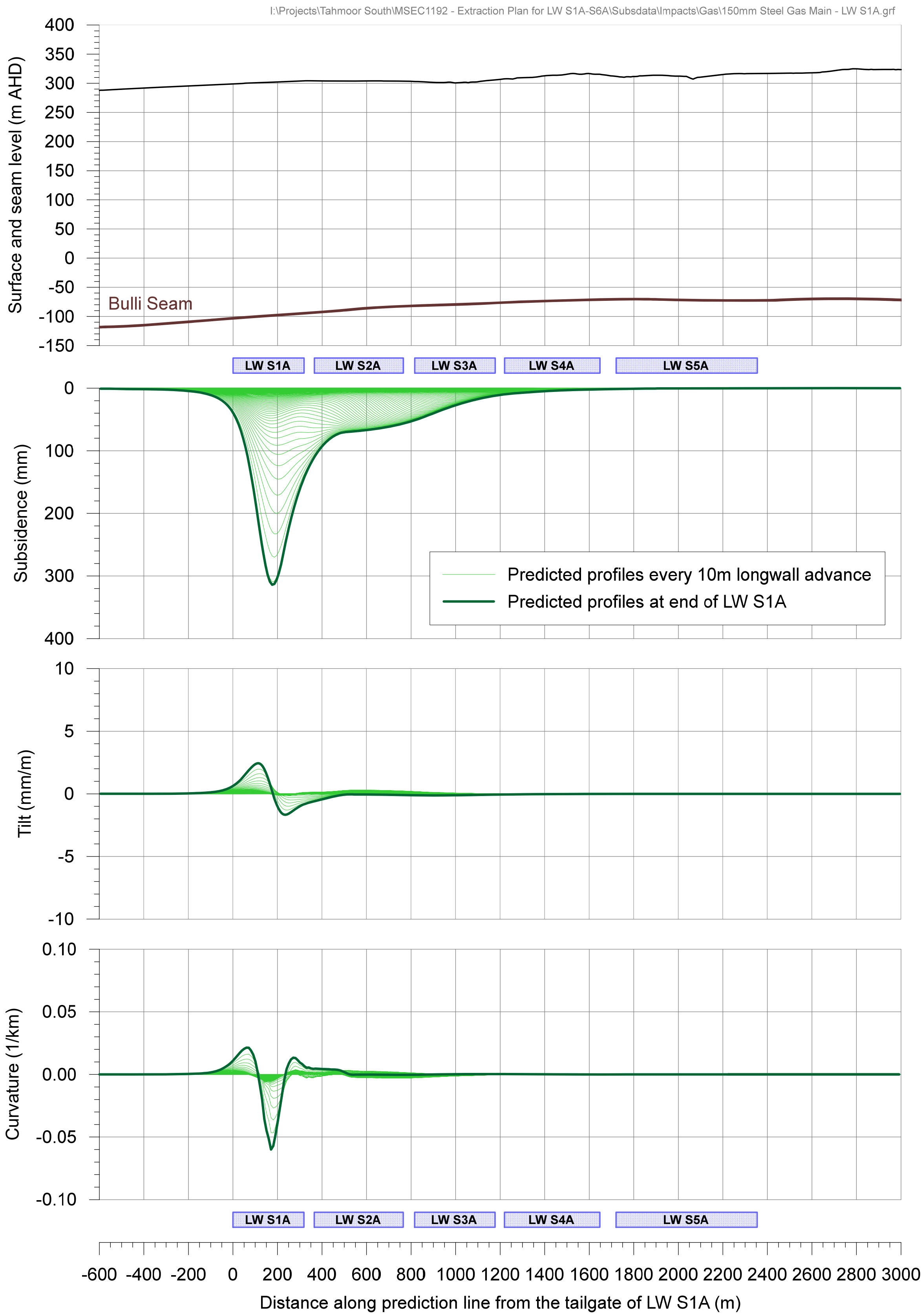


Fig. 3.23 Predicted profiles of incremental subsidence, tilt and curvature for the gas pipeline along Remembrance Driveway during the mining of LW S1A

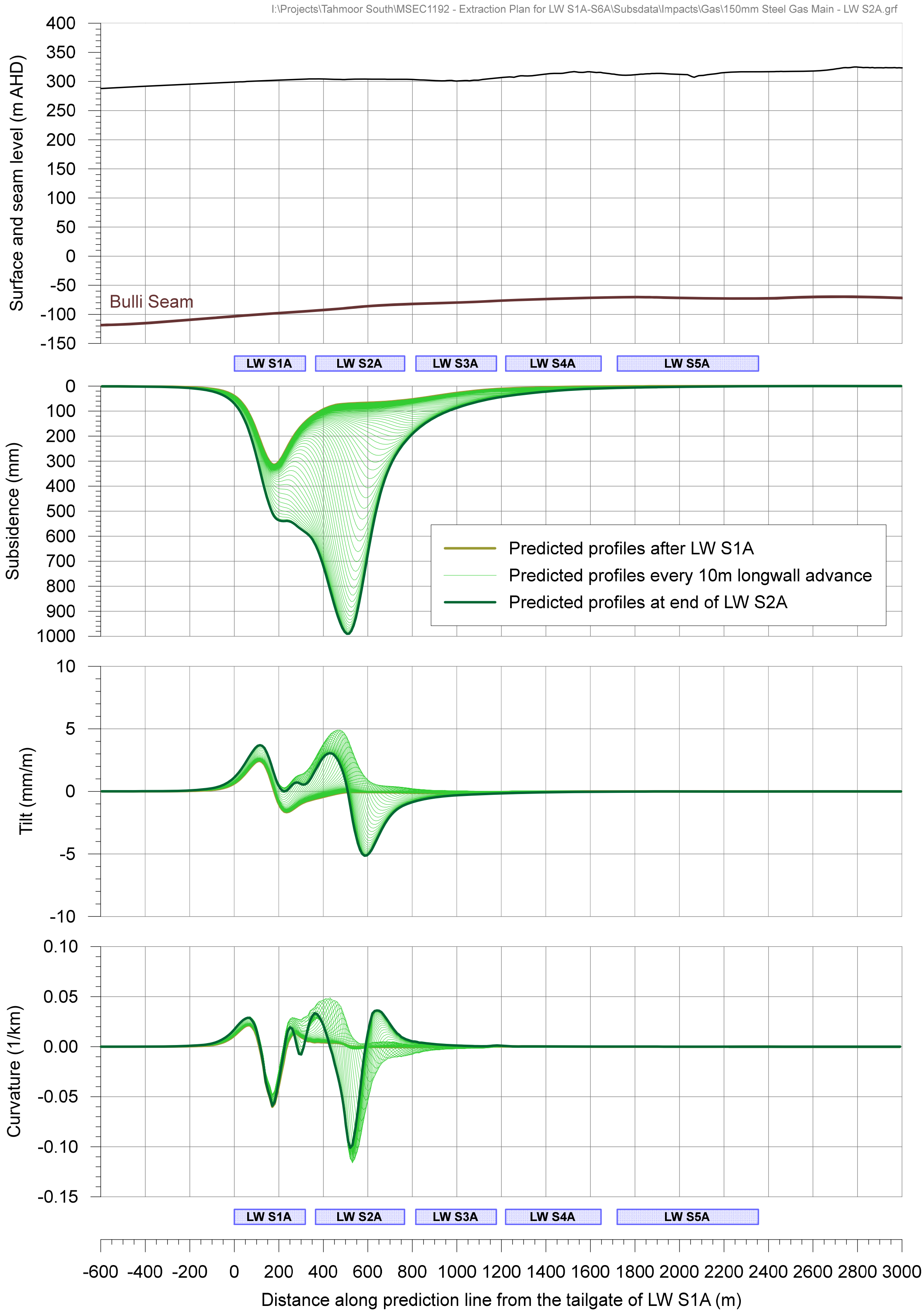


Fig. 3.24 Predicted profiles of total subsidence, tilt and curvature for the gas pipeline along Remembrance Driveway during the mining of LW S2A

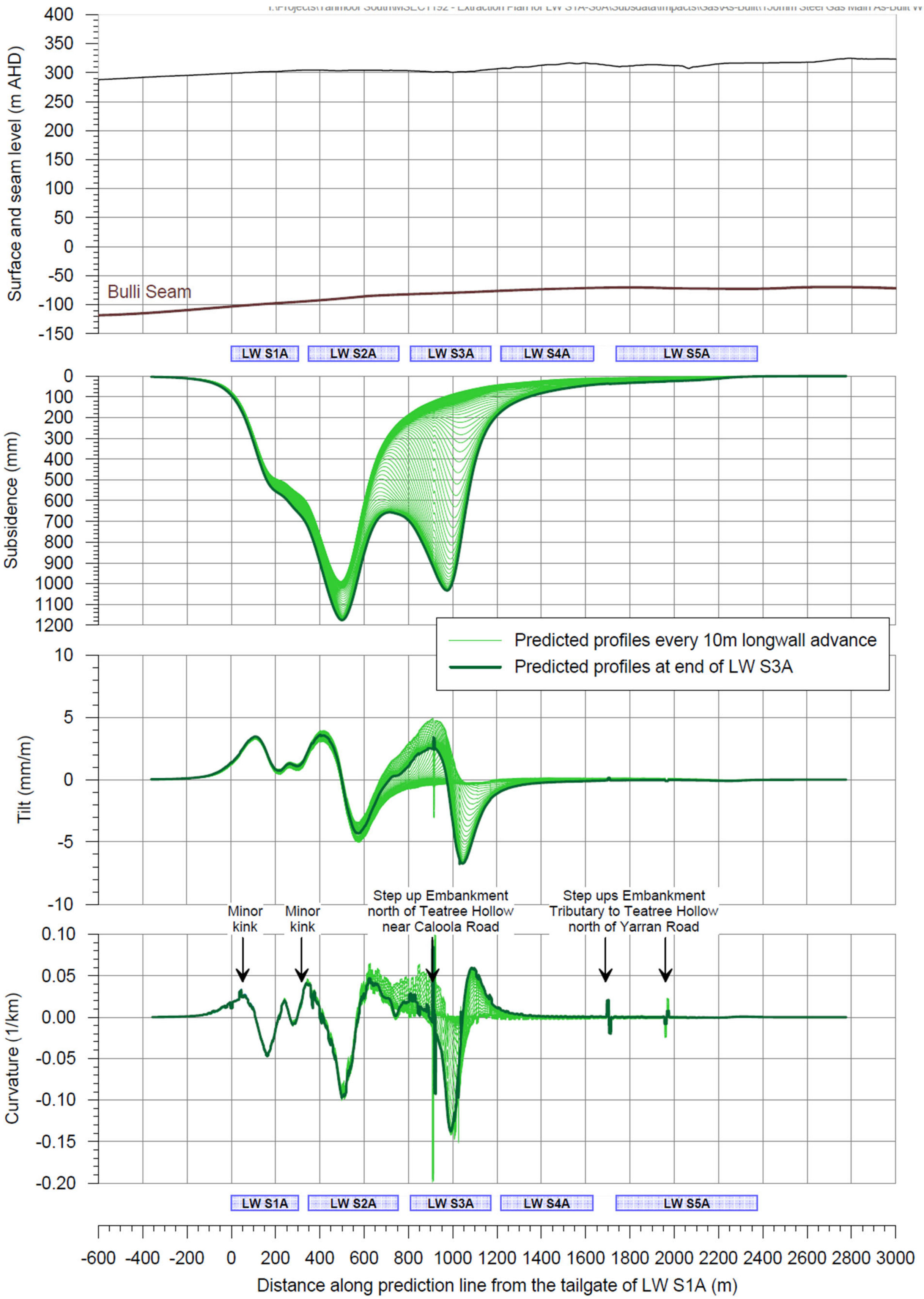


Fig. 3.25 Predicted profiles of total subsidence, tilt and curvature for the gas pipeline along Remembrance Driveway during the mining of LW S3A

The short spikes in the results for LW S3A are due to short, sharp changes in direction of the pipeline and not reflective of predicted ground strains at these locations.

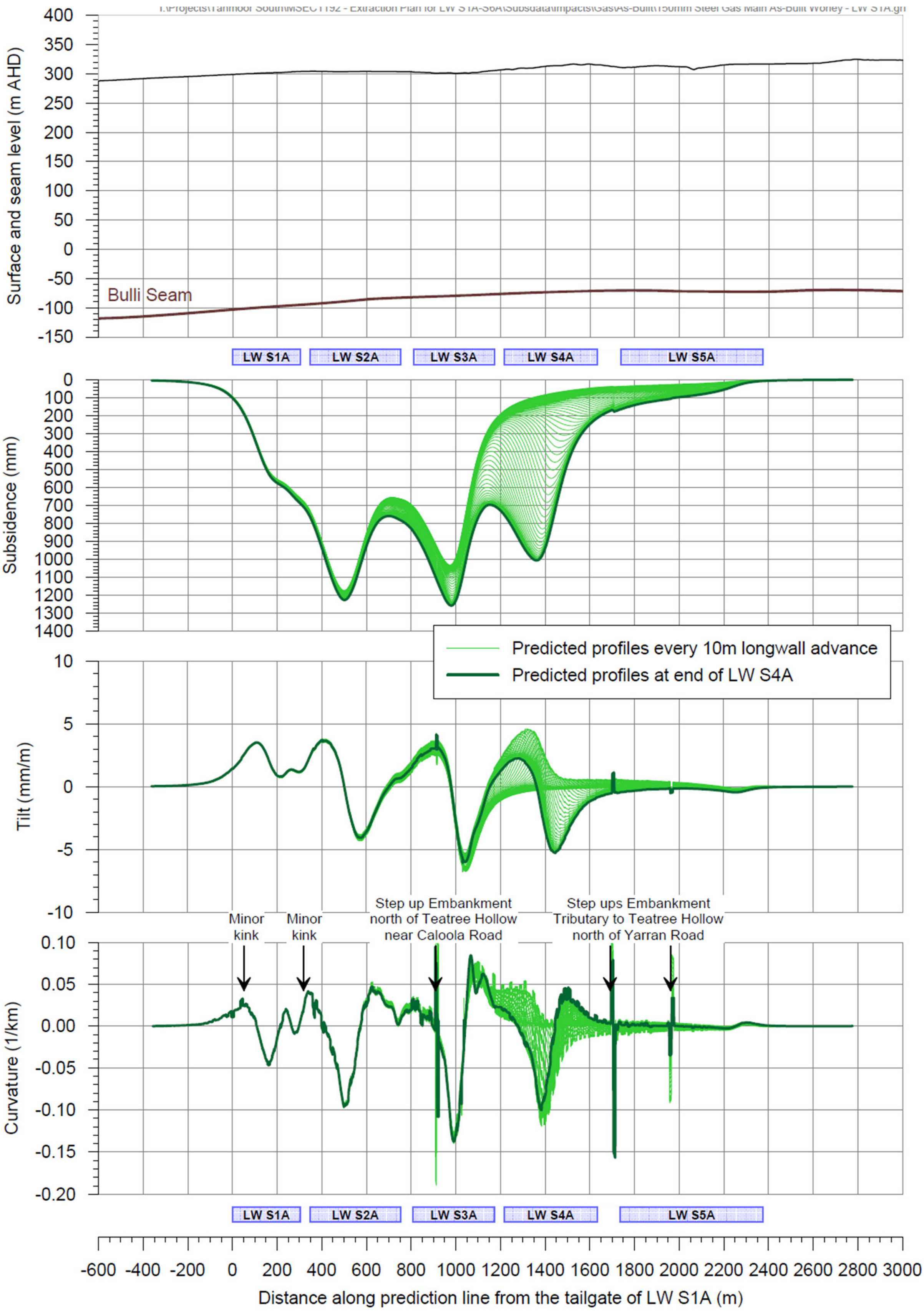


Fig. 3.26 Predicted profiles of total subsidence, tilt and curvature for the gas pipeline along Remembrance Driveway during the mining of LW S4A

The short spikes in the results for LW S4A are due to short, sharp changes in direction of the pipeline and not reflective of predicted ground strains at these locations.

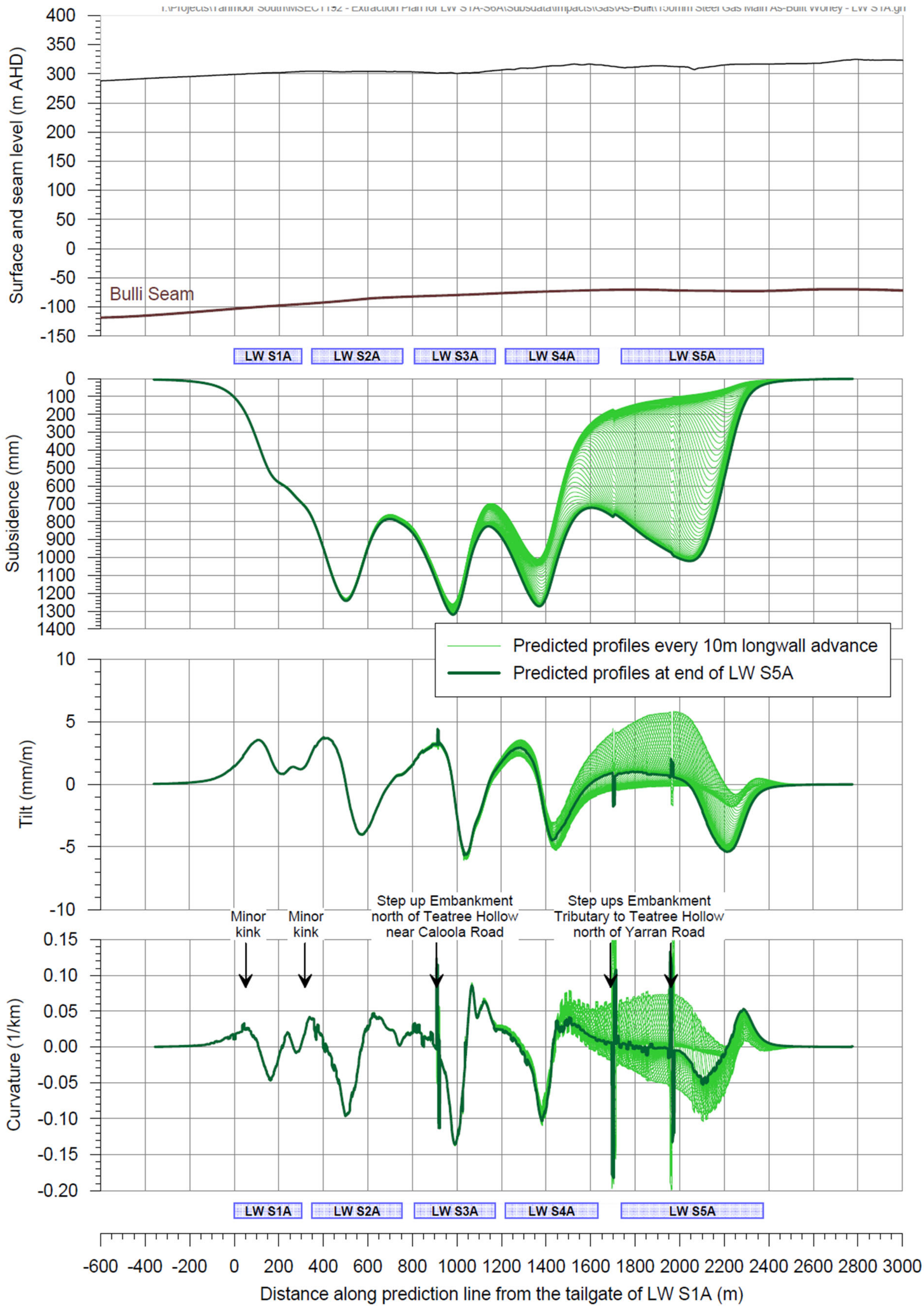


Fig. 3.27 Predicted profiles of total subsidence, tilt and curvature for the gas pipeline along Remembrance Driveway during the mining of LW S5A

The short spikes in the results for LW S5A are due to short, sharp changes in direction of the pipeline and not reflective of predicted ground strains at these locations.

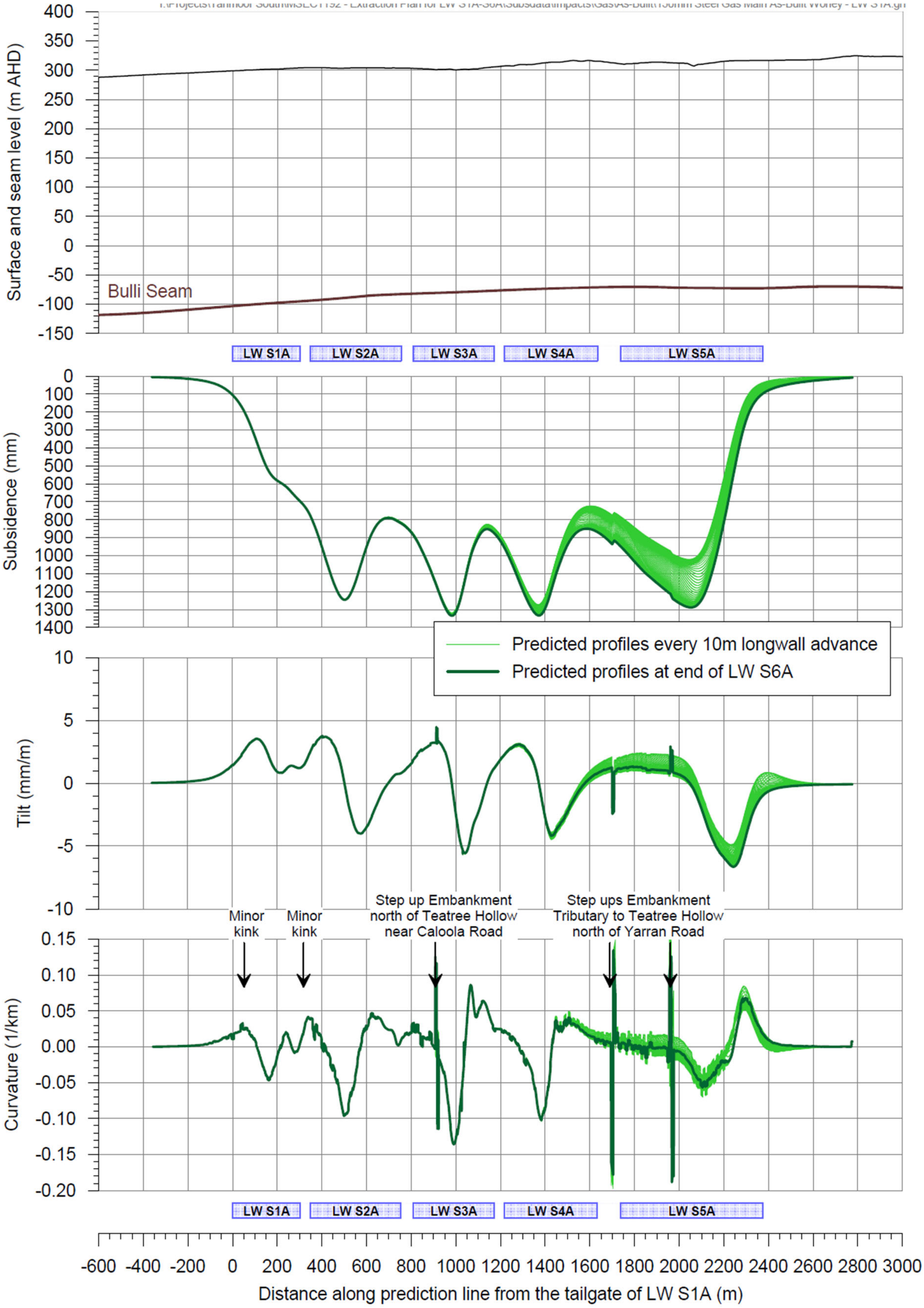


Fig. 3.28 Predicted profiles of total subsidence, tilt and curvature for the gas pipeline along Remembrance Driveway during the mining of LW S6A

The short spikes in the results for LW S6A are due to short, sharp changes in direction of the pipeline and not reflective of predicted ground strains at these locations.

3.7.2. Predicted valley closure and upsidence at creek crossings

The gas main along Remembrance Drive crosses Teatree Hollow and a number of its tributaries within the Study Area and valley-related movements could be experienced in these locations. A summary of the maximum predicted conventional subsidence and valley related movements for the crossing at Teatree Hollow is provided in Table 3.6.

Table 3.6 Predicted Conventional Subsidence and Valley Related Movements for the gas pipeline creek crossings along Remembrance Drive within the Study Area

Location	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt along Culvert (mm/m)	Maximum Predicted Total Hogging Curvature (1/km)	Maximum Predicted Total Sagging Curvature (1/km)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
Opposite Tahmoor Mine	1250	4.3 (decrease in grade)	0.05	-0.18	100	50
Teatree Hollow (Caloola Road)	1300	6.9 (increase in grade)	0.06	-0.18	250	150
Tributary to Teatree Hollow above LW S5A	1100	3.6 (decrease in grade)	0.05	-0.04	125	100
Tributary to Teatree Hollow (Yarran Road)	1300	6.7 (increase in grade)	0.05	-0.22	150	75
Tributary to Teatree Hollow (Wellers Road)	25	< 0.5	< 0.01	< 0.01	40	25

More detailed predictions for each creek crossing are provided below.

Table 3.7 Predicted Conventional Subsidence and Valley Related Movements for the creek crossing at Teatree Hollow (Caloola Road)

Longwall	Maximum predicted subsidence (mm)	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
LW S1A	30	< 20	< 20
LW S2A	100	30	40
LW S3A	1000	125	100
LW S4A	1250	200	125
LW S5A	1300	225	140
LW S6A	1300	250	150
LW S7A	1300	250	150

Table 3.8 Predicted Conventional Subsidence and Valley Related Movements for the creek crossing at Tributary to Teatree Hollow above LW S5A (near No. 3166 Remembrance Drive)

Longwall	Maximum predicted subsidence (mm)	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
LW S1A	< 20	< 20	< 20
LW S2A	< 20	< 20	< 20
LW S3A	40	< 20	< 20
LW S4A	175	40	50
LW S5A	900	100	80
LW S6A	1100	125	100
LW S7A	1150	135	110

Table 3.9 Predicted Conventional Subsidence and Valley Related Movements for the creek crossing at Tributary to Teatree Hollow (Yarran Road)

Longwall	Maximum predicted subsidence (mm)	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
LW S1A	< 20	< 20	< 20
LW S2A	< 20	< 20	< 20
LW S3A	20	< 20	< 20
LW S4A	100	25	25
LW S5A	1000	100	50
LW S6A	1300	150	75
LW S7A	1350	175	85

Table 3.10 Predicted Conventional Subsidence and Valley Related Movements for the creek crossing at Tributary to Teatree Hollow (Wellers Road)

Longwall	Maximum predicted subsidence (mm)	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
LW S1A	< 20	< 20	< 20
LW S2A	< 20	< 20	< 20
LW S3A	< 20	< 20	< 20
LW S4A	< 20	< 20	< 20
LW S5A	< 20	< 20	< 20
LW S6A	25	40	25
LW S7A	35	50	30

3.7.3. Experiences observed during the mining of LWs S1A and S2A

Tahmoor Mine has extracted LW S1A and is currently extracting LW S2A. Observed total subsidence, tilt and strain is shown in Fig. 3.29.

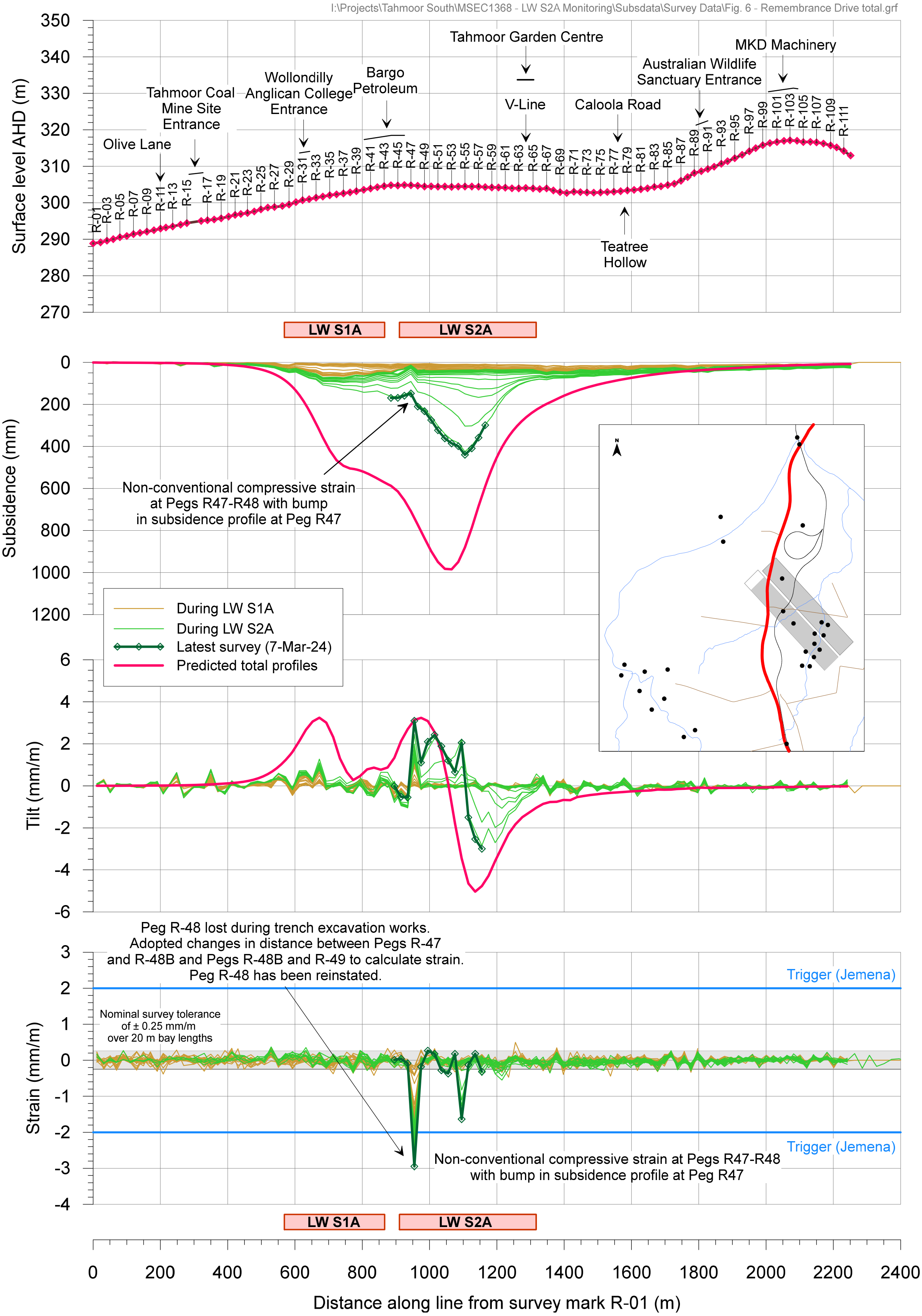


Fig. 3.29 Observed total subsidence, tilt and strain along Remembrance Driveway during the mining of LWs S1A and S2A as at March 2024

While observed subsidence has been less than predicted, non-conventional subsidence movements have been observed at two locations between Pegs R47 and R48 and between Pegs R53 and R55. The non-conventional movements are characterised by increased compressive strain at isolated locations and a bump in the observed subsidence profiles.

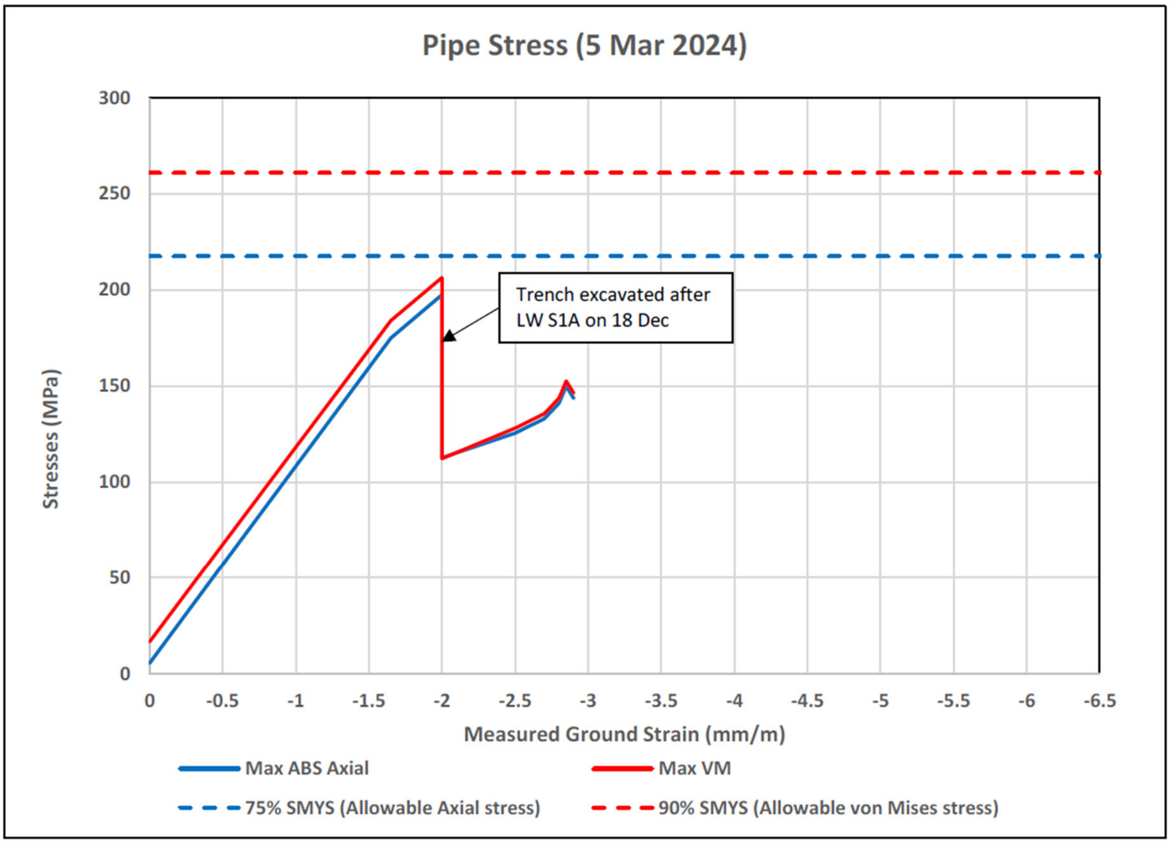
Tahmoor Coal excavated to expose and decouple the pipe from the ground at the site of increased compressive strain between Pegs R47 and R48 in December 2023, prior to the influence of LW S2A. The excavated pipeline is generally covered by steel road plates and protected by concrete vehicle barriers.

The pipe was observed to bend laterally once it was exposed, as shown in Fig. 3.30. The decoupling of the pipe from the ground, which has allowed the pipe to bend laterally, has reduced the mining-induced build-up of stresses in the pipe, as expected.

Fig. 3.30 Photograph of exposed gas main near Pegs R47 and R48 in December 2023

Fig. 3.31 Photograph of exposed gas main site near Pegs R47 and R48 in January 2024

Worley have assessed the deformation and compression of the exposed pipe, which has been surveyed weekly during the period of active subsidence of LW S2A. An example is provided in Fig. 3.32. If the calculated pipe stresses are forecast to exceed the maximum allowable stress (90% Specified Minimum Yield Strength, SMYS), Tahmoor Coal will further expose the pipeline and dissipate the pipe stresses.



Graph courtesy Worley

Fig. 3.32 Calculated pipe stresses near Pegs R47 and R48 in March 2024 based on surveyed deformation of pipe

A similar approach has been implemented for the section of pipeline between Pegs R53 and R55. In both cases, the trenches will be backfilled when rates of change in subsidence reduce to low levels.

3.7.4. Potential subsidence impacts on gas pipelines

Pre-mining impact assessments prior to LW S1A

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 during longwall extraction at Tahmoor Mine to date. While no impacts have been experienced to date, it is acknowledged that the most vulnerable element of the system is the rigid copper pipe connections between the gas mains and houses, which can be readily repaired.

A difference between the gas infrastructure at Bargo compared to the gas infrastructure at Tahmoor is the existence of the 150 mm steel gas main at Bargo. Steel gas pipelines of similar and larger diameter have been successfully mined directly beneath in the past in the Southern Coalfield (McGill, 2007) and Newcastle Coalfield (Robinson, 2007). Being of relatively small diameter, the pipe is expected to withstand considerable ground deformation before it becomes unserviceable.

Prior to the extraction of LW S1A, Tahmoor Coal has consulted with Jemena and engaged specialist pipeline engineers Advisian (2022) who are experienced in mine subsidence to conduct analyses to assess the potential for impacts on the pipeline. The analyses included an assessment of changes in pipe stresses due to the predicted subsidence, tilt, curvature and strain movements and a sensitivity analysis to assess the magnitudes at which differential movements may exceed acceptable limits. A 3D finite element model was used to compute the pipe response.

The results indicated that the pipeline could tolerate the predicted conventional subsidence movements due to the extraction of LW S1A-S2A. Modelling found that if the ground subsides in a conventional manner as predicted, the pipeline can tolerate substantial additional compressive ground strains, up to 30 mm/m for LW S1A and 23 mm/m for LW S2A.

In reality, ground strains at the magnitudes quoted above do not occur in the Southern Coalfield unless they are non-conventional in nature, where substantial changes in vertical and/or lateral misalignment occur concurrently with increased compressive ground strains. An early warning ground strain trigger of 2 mm/m ground strain has been adopted in this Management Plan to initiate planned response measures.

Advisian investigated potential impacts due to non-conventional subsidence movements in the form vertical steps and lateral shear displacements. The pipeline was found to reach the allowable code limits in response to a vertical step of 85 mm and a lateral shear of 90 mm.

If observed ground strains or severe ground deformations are observed to develop during mining, the pipe can be exposed and adjusted to decouple the pipe from the differential ground movements. Pre-planned traffic control and security measures are required to be implemented if these works are required. Tahmoor Coal (2024) has developed a contingency plan in consultation with Jemena, which is appended to the plan.

Observed experiences during the mining of LWs S1A and S2A

Non-conventional movements have been observed at two locations along Remembrance Drive, as described in Section 3.7.3. The experiences have found that measured non-conventional compressive ground strains, in combination with measured vertical and lateral misalignment of the pipe can result in pipe stresses approaching acceptable limits for the pipeline (90% Specified Minimum Yield Strength, SMYS).

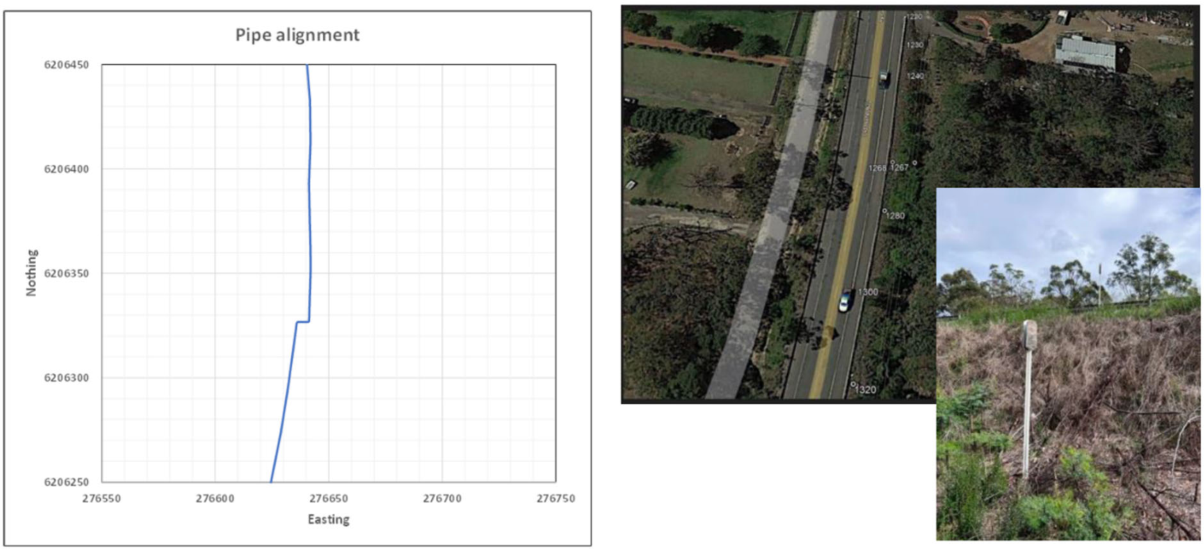
In the case of the first impact site between Pegs R47 and R48, compressive strain has been calculated by Worley to approach 90% SMYS at approximately 2.5 mm/m, in combination with the measured vertical and lateral misalignment of the pipe. It is also noted that this particular section of the pipeline was laid with a designed lateral bend.

Pre-mining impact assessments prior to LW S3A

Worley (2023) have assessed potential impacts on the gas pipeline due to the predicted movements of LWs S1A to S6A. The predictions took into account predictions of valley closure and vertical or lateral misalignment due to upsidence, using idealised deformations in consultation with MSEC.

The results indicated that the pipeline can likely accommodate mining-induced stresses due to the predicted conventional and non-conventional subsidence movements due to the extraction of LW S1A, S2A, S4A, S5A and S6A. Worley (2023), however, recommended mitigation works to reduce the potential impacts due to the extraction of LW S3A where the pipeline crosses Teatree Hollow with two sharp bends north of Teatree Hollow directly above the longwall.

Maps and photographs of the bends provided by Worley (2023) are reproduced in Fig. 3.33. The section of pipeline containing the bends and the creek crossing are located within the crest of the southbound batter of the Remembrance Drive embankment over Teatree Hollow, opposite the intersection with Caloola Road.



Images courtesy Figure 3-2 of Worley (2023)

Fig. 3.33 Plan view, aerial image and photograph showing sharp bends north of Teatree Hollow

Tahmoor Coal, Jemena, Zinfra, Worley and MSEC identified and assessed risk control options for managing potential impacts at the sharp bends and Teatree Hollow creek crossing at the risk assessment on 18 October 2023. Options included installing a flexible pipeline that bypasses the bends, or excavating a 50 metre long trench, exposing the pipeline along the crest of the embankment for the purposes of decoupling the pipeline from the embankment fill.

After considering options, Tahmoor Coal and Jemena agreed to select the decoupling option, which will be implemented prior to the influence of LW S3A on this section of the pipeline. A cross-section showing the planned mitigation works is shown in Fig. 3.34. The section has been drawn based on site surveys of the embankment profile, pavement, guard rail, fog line and pipeline. The excavation will be 50 metres long, as marked up on a photograph in Fig. 3.35.

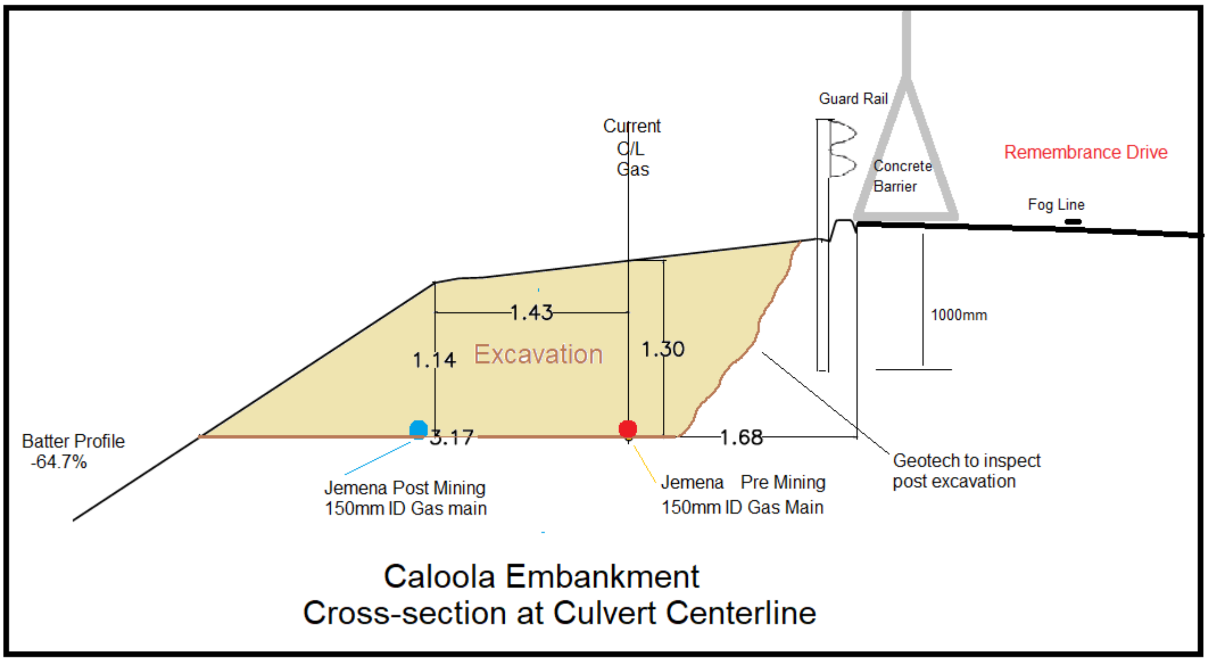


Fig. 3.34 Cross-section showing planned mitigation works for the sharp bends and Teatree Hollow crossing in the Remembrance Drive embankment at Caloola Road intersection

Fig. 3.35 Location of planned mitigation works for the sharp bends and Teatree Hollow crossing in the Remembrance Drive embankment at Caloola Road intersection

Worley (2023) recommended that the pipeline be able to bend laterally by up to 1.5 metres to accommodate the predicted conventional and valley closure movements. The bends in the pipeline will remain buried, adjacent to the exposed pipeline, such that mining-induced pipe stresses can be dissipated along the decoupled pipe rather than build-up at the bends. In the event that greater than expected closure develops, the excavation can be extended in length and/or deepened to allow the pipeline to bend further.

Subject to actual observations, it is planned to backfill the pipeline after the influence of LW S3A. If greater than predicted closure develops during LW S4A to LW S7A, the pipeline can be exposed again to allow it to bend further and dissipate mining-induced stresses. Whilst past performance is not an indicator of future performance, it is noted that valley closure was not observed at the Teatree Hollow crossing during the mining of LW S2A, while predicted closure after the mining of LW S2A was 40 mm.

Tahmoor Coal consulted with Wollondilly Shire Council regarding the excavation of the road embankment. A representative from Council was also present at the risk assessment. The excavation of the embankment has been assessed by a geotechnical engineer. A geotechnical inspection during and after excavation will ensure that the pavement remains supported by the remaining embankment fill.

Potential mitigation risk controls were considered at other bends and creek crossing locations within the Study Area. Worley (2023) advise that the pipeline is expected to accommodate the predicted conventional and valley closure movements. Mitigation controls, therefore, have not been selected at these locations. In the event that greater than predicted non-conventional movements are experienced, the pipeline can be temporarily exposed by trench excavation, as conducted above LW S2A. The decoupling methodology will maintain the creek bed, to reduce the potential for impacts on the pipeline to water flow.

Non-conventional movements can potentially occur within the road cutting above LW S4A. The pipeline runs along the toe of the cutting batter slope on the southbound side of Remembrance Drive. Tahmoor Coal has developed a contingency plan to manage potential impacts on the pipeline within the cutting. The contingency plan includes the implementation of a traffic management plan, with designs developed to reduce the period of temporary speed restrictions on the pavement.

Given that the maximum operating pressure of 300 kPa is relatively low compared to other high pressure gas mains, Jemena does not expect a gas leak or rupture will require a road closure or evacuation of adjacent premises, including the Wollondilly Anglican College, the petrol station or other properties.

Nylon gas mains

The 50 mm diameter nylon main has experienced approximately 20 mm of subsidence with negligible strains and curvatures during the mining of LWs S1A and S2A. No impacts have been detected and negligible additional subsidence movements are predicted to occur at this location during the extraction of LWs S3A-S7A.

The 32 mm diameter nylon main runs along the edge of the Study Area. The pipeline is predicted to experience approximately 20 mm of subsidence with negligible strains and curvatures due to the extraction of LW S7A.

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 during longwall extraction at Tahmoor Mine to date. While no impacts have been experienced to date, it is acknowledged that the most vulnerable element of the system is the rigid copper pipe connections between the gas mains and houses, which can be readily repaired.

Contingency plan

In the event of a minor gas leak, Jemena advises that the pipeline can be repaired without interruption to services rather than shutting down the pipeline. The following repair methods are available to Jemena.

- Temporary patch over leak.
- Hot tapping diversion of gas and replace damaged section of pipeline. It takes approximately 4 hours to replace the pipe section.
- In the worst case of a full bore rupture, the pipeline will be shut off at the isolation valve on Hawthorne Road at Bargo and squeezed off within the polyethylene main north of the Bargo River to isolate the pipeline and repair it. A re-lighting process is then followed to return services to customers, which takes approximately 48 hours.

Selected risk control measures

Tahmoor Coal has developed and selected risk control measures in consultation, co-ordination and co-operation with Jemena in accordance with WHS legislation. The controls have been implemented during the mining of Longwalls 22 to 32, LW W1-W4 and LWs S1A and S2A.

In this instance, there are no reasonably practicable controls which could eliminate, substitute or isolate the identified risks, nor engineering controls that could put in place a structure or item that prevents or minimises risks.

Tahmoor Coal has identified controls that will manage potential issues associated with damage to pipelines resulting in gas leaks during the extraction of LW S1A-S7A by implementing the following measures:

- Excavate and expose 50 metres of gas pipeline along the southbound crest of the Teatree Hollow embankment along Remembrance Drive near the Caloola Road intersection, prior to the influence of LW S3A;
- Pre-mining gas detection survey of gas pipelines potentially affected by the extraction of LW S1A-S7A (completed);
- Pre-mining as built survey, including potholing of gas pipelines potentially affected by the extraction of LW S1A-S7A (completed);
- Excavation along southbound crest of Remembrance Drive embankment over Teatree Hollow prior to the influence of LW S3A;
- Regular ground surveys along streets located within the active subsidence zone;
- Regular visual inspections along streets located within the active subsidence zone;
- Regular consultation with the community to report potential impacts. As the gas has been odourised, the community are more likely to report gas leaks if they occur;
- Additional inspections and gas patrols if triggered by observations of increased ground strains, ground curvature or localised surface deformations;
- Exposing pipeline to relieve it of stress if triggered by monitoring results;
- Repair pipeline leak by temporary clamp and/or repair leak by hot tapping gas main and replacing damaged section; and
- In the worst case, repair of damaged pipeline by temporarily isolating the pipeline and replacing the damaged section.

In considering monitoring options, it was agreed that real-time gas detection at fixed points would not be feasible as the sensors would need to be effectively directly above the leak to sense it. Additional gas patrols will be conducted if triggered by ground surveys or visual inspections.

3.8. Jemena gas mains on Remembrance Drive Bridge over the Bargo River

There are no bridges along local roads within the vicinity of LW S1A-S7A, though some bridges may experience far field movements during the mining of LW S1A-S7A. Jemena's 150 mm steel gas main is located on the Remembrance Drive Bridge over the Bargo River with vertical pipe bends at each end to manage thermal changes in length of the Bridge (refer Fig. 3.37 to Fig. 3.39). Substantial clearances are visible where the pipes penetrate through the concrete bridge elements.

A summary of the closest distance of LW S1A-S7A to the bridge is provided in Table 3.11.

Table 3.11 Bridges with Jemena gas mains that may be potentially affected by far field movements

Bridge	Closest distance (m)	Closest LW	Closest LW end
Remembrance Drive Bridge over the Bargo River and Main Southern Railway	1,690 m	LW S1A	Finishing end (North-western end)

The potential for impacts on the pipeline crossings do not result from absolute far-field horizontal movements, but rather from differential horizontal movements. It can be seen from Fig. 3.36 that infrastructure located well away from active longwalls are likely to experience relatively small differential horizontal movements, particularly given that a large proportion of the measured variations are within survey tolerance. Statistical analyses were not conducted for offset distances greater than 1800 metres as there are insufficient measurements beyond the nominal survey tolerance of 3 mm.

The gas main on the Bridge is located approximately 1,700 metres from LWs S1A to S7A. It can be seen from Fig. 3.36 that only 1% of previously observed differential horizontal movements have exceeded 5 mm over a bay length of 20 metres. Differential movements of this magnitude are likely to be accommodated at the pipe bends, even if they concentrate at one location.

Whilst past performance is not an indicator of future performance, it is noted that no measurable differential movements have been observed at the Remembrance Drive Bridge during the mining of LWs S1A and S2A.

Tahmoor Coal is managing potential impacts on the bridges in consultation with Wollondilly Shire Council and the Australian Rail Track Corporation. The management plans include monitoring of absolute and differential movements at the bridges and visual inspections. The likelihood of differential far field movements at the bridges are very low due to the remoteness of the longwalls to them.

In the unlikely event that adverse movements develop at a bridge, Tahmoor Coal will modify the bridge to ensure that the bridge remains safe and serviceable during and after the extraction of LW S1A-S7A.

While potential far field differential movements would not adversely impact the gas main if they were buried in the ground, it is possible that the gas main could experience impacts if the differential movements were concentrated at a bridge joint. The potential for impacts are, however, managed by the existing vertical bends in the pipelines at each end of the bridge.

Impacts could also occur as a result of modifications to a bridge. The potential impacts will be managed by consultation with Jemena prior to conducting works and implementing measures to control the risks due to construction works.

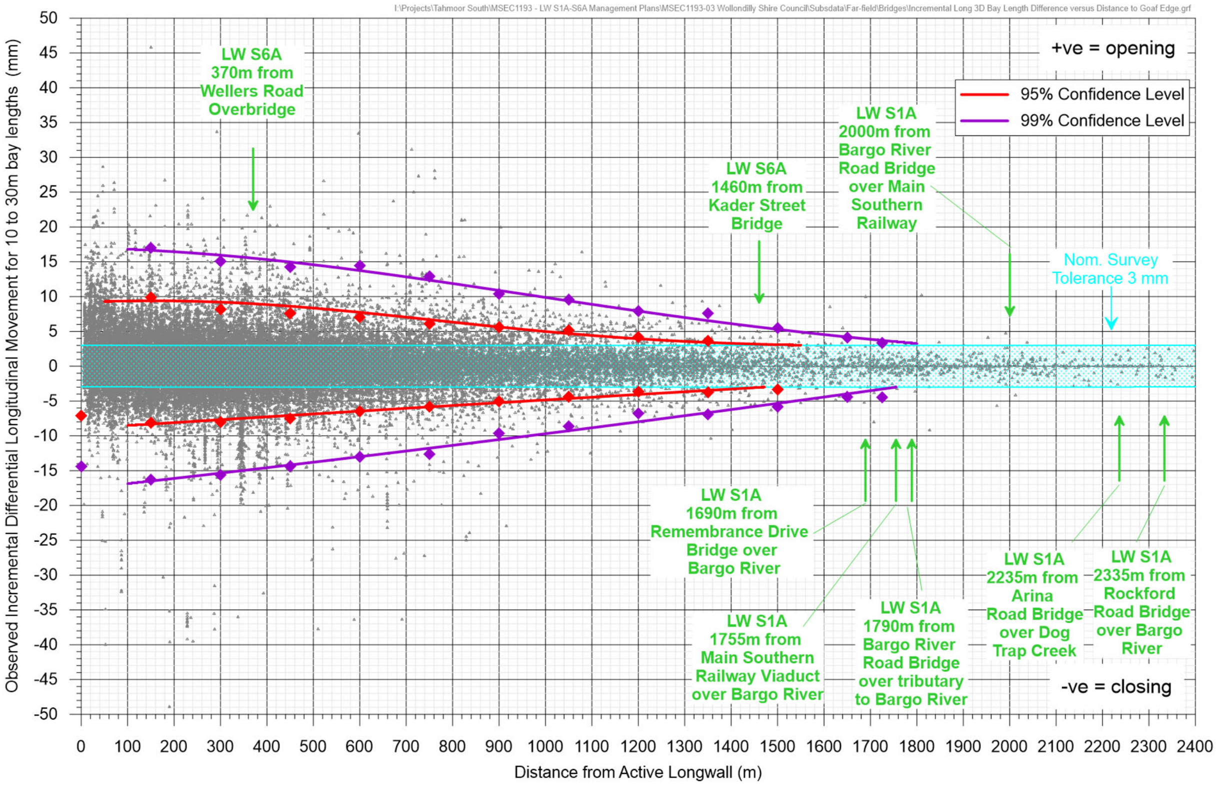


Fig. 3.36 Observed incremental differential longitudinal horizontal movements versus distance from active longwall for marks spaced between 10 and 30 metres

Tahmoor Coal has identified controls that will ensure that Jemena's sewer mains on the bridges will remain safe and serviceable during and after the extraction of LW S1A-S7A by implementing the following measures:

- Regular absolute and local 3D surveys of the bridge during mining;
- Regular visual inspections of the bridges during mining;
- Baseline survey of expansion joints on the pipework at the bridge joints;
- Regular consultation with the community to report potential impacts;
- Additional surveys and/or inspections, if triggered by monitoring results;
- If triggered by monitoring results, expose the pipeline to relieve it from ground deformations; and
- In the worst case, repair of damaged pipeline.

Fig. 3.37 Photograph of Jemena gas main on Remembrance Drive Bridge over the Bargo River

Fig. 3.38 Photograph of Jemena gas main vertical pipe bend on Remembrance Drive Bridge over the Bargo River

Fig. 3.39 Photograph of Jemena gas main pipe penetration for pipe bend on Remembrance Drive Bridge over the Bargo River

4.1. Infrastructure Management Group (IMG)

The Infrastructure Management Group (IMG) is responsible for taking the necessary actions required to manage the risks that are identified from monitoring the infrastructure and to ensure that the health and safety of people who may be present on public property or Jemena property are not put at risk due to mine subsidence. The IMG develops and reviews this management plan, collects and analyses monitoring results, determines potential impacts and provides advice regarding appropriate actions. The members of the IMG are highlighted in Chapter 8.

4.2. Development and selection of risk control measures

Tahmoor Coal has developed and selected risk control measures in consultation, co-ordination and co-operation with the landowner in accordance with WHS legislation. In accordance with Clauses 35 and 36 in Part 3.1 of the *Work Health and Safety Regulation (2017)* and the guidelines (MSO, 2017), a hierarchy of control measures has been considered and selected where reasonably practicable, using the following process:

1. Eliminate risks to health and safety so far as is reasonably practicable, and
2. If it is not reasonably practicable to eliminate risks to health and safety – minimise those risks so far as is reasonably practicable, by doing one or more of the following:
   (a) substituting (wholly or partly) the hazard giving rise to the risk with something that gives rise to a lesser risk;
   (b) isolating the hazard from any person exposed to it;
   (c) implementing engineering controls;
3. If a risk then remains, minimise the remaining risk, so far as is reasonably practicable, by implementing administrative controls;
4. If a risk then remains, the duty holder must minimise the remaining risk, so far as is reasonably practicable, by ensuring the provision and use of suitable personal protective equipment.

A combination of the controls set out in this clause may be used to minimise risks, so far as is reasonably practicable, if a single control is not sufficient for the purpose.

There are primarily two different methods to control the risks of subsidence, namely:

- Method A – Selection of risk control measures to be implemented prior to the development of subsidence, (Items 1 and 2 above), and
- Method B – Selection of risk control measures to be implemented during the development of subsidence (Items 3 and 4 above).

Method A and B risk control measures are described in Section 4.3 to Section 4.6. Prior to selecting Method B risk control measures, Tahmoor Coal has investigated and confirmed that the measures are feasible and effective for the site-specific conditions during the extraction of LW S1A-S7A.

4.3. Selection of risk control measures for gas infrastructure

Based on its own assessments, Tahmoor Coal considered Method A and Method B risk control measures, in accordance with the process described in Section 4.2.

Elimination

In this instance, no reasonably practicable controls could be identified that would eliminate the identified risks.

Substitution

In this instance, no reasonably practicable controls could be identified that will change the environment so the hazards could be substituted for hazards with a lesser risk.

Isolation

In this instance, no reasonably practicable controls could be identified to isolate a hazard from any person exposed to it.

Engineering Controls

The following engineering control has been identified to put in place a structure or item that prevents or minimises risks:

- Excavate and expose 50 metres of gas pipeline along the southbound crest of the Teatree Hollow embankment along Remembrance Drive near the Caloola Road intersection, prior to the influence of LW S3A.

Administrative Controls

The following Administrative Controls were identified and selected that will put in place procedures on site to minimise the potential of impacts on the health and safety of people in relation to mining-induced damage to gas infrastructure:

- Implementation of a Monitoring Plan and Trigger Action Response Plan (TARP)
  As described in the Management Plan, Tahmoor Coal and Jemena has developed and implemented a management strategy of detecting early the development of potential adverse subsidence movements in the ground, so that contingency response measures can be implemented before impacts on the safety and serviceability develop. The TARP includes the following:
  - Pre-mining gas detection survey within the area potentially affected by the extraction of LW S1A-S7A (completed);
  - Pre-mining as built survey, including potholing of gas pipelines potentially affected by the extraction of LW S1A-S7A (completed)
  - Continuous GNSS monitoring along the centrelines of LWs S1A to S3A, and at each end of the Main Southern Railway Viaduct over the Bargo River (installed and operating). A GNSS unit will also be installed where the rail corridor is located directly above the centreline of LW S5A at approximate rail kilometrage of 100.55 km. ;
  - Local 2D surveys along local roads and Main Southern Railway as shown in Drawing No. MSEC1193-01-01. These include Remembrance Driveway (installed and surveyed for LWs S1A and S2A and will be extended prior to influence of each subsequent LW);
  - Absolute 3D survey of subsidence along Remembrance Drive (installed and surveyed for LWs S1A and S2A and will be extended prior to influence of each subsequent LW);
  - Local 3D / Absolute 3D survey of the Teatree Hollow embankment and other road embankments along Remembrance Drive with pegs spaced along the crest and toe on both sides of each embankment. Pegs spacings are generally every 20 metres. The layout of survey marks is shown in Drawing No. MSEC1193-03-07 to MSEC1193-03-10 (pegs installed and surveyed for Teatree Hollow);
  - Local 3D / Absolute 3D survey of the cutting on Remembrance Drive with pegs spaced along the crest and toe on both sides of the cutting. Pegs spacings are generally every 20 metres. The layout of survey marks is shown in Drawing No. MSEC1193-03-11 (pegs installed);
  - Local 3D / Absolute 3D of structure and ground marks on the Remembrance Drive Bridge over the Bargo River, as shown in Drawing No. MSEC1193-03-02 (installed and surveyed);
  - Local 3D surveys of exposed gas pipeline along the southbound crest of the Teatree Hollow embankment along Remembrance Drive;
  - Visual inspections along Remembrance Drive within the active subsidence zone;
  - Additional surveys and/or inspections, if triggered by monitoring results;
  - Regular consultation with the community to report potential impacts. As the gas has been odourised, the community are more likely to report gas leaks if they occur;
  - Gas detection patrols, if triggered by monitoring results;
  - Additional inspections and gas patrols by Jemena if triggered by observations of increased ground strains, ground curvature or localised surface deformations;
  - Exposing pipeline to relieve it of stress if triggered by monitoring results (refer contingency plan by Tahmoor Coal (2024));
  - Repair pipeline leak by temporary clamp and/or repair leak by hot tapping gas main and replacing damaged section;
  - In the worst case, implement Jemena's emergency procedures and repair of damaged pipeline by temporarily isolating squeezing off the pipeline, and replacing the damaged section; and
  - Follow Jemena procedures to monitor and respond to impacts.

4.4. Monitoring measures

A number of monitoring measures will be undertaken during mining.

4.4.1. Continuous GNSS monitoring

Global Navigation Satellite System (GNSS) units are fixed survey stations that continuously measure their absolute horizontal and vertical positions in real time.

The locations of GNSS units are shown in Drawings No. MSEC1193-01-01 and the GNSS units that are relevant to managing Jemena infrastructure are summarised below:

- Centrelines of LWs S1A to S3A – The GNSS units are located in bushland within the Australian Wildlife Sanctuary. The units are proposed to track the development of subsidence and horizontal movements above the commencing ends of the longwalls. The monitoring data will provide the first subsidence results for each panel to compare against subsidence predictions. Conventional survey lines are not possible in this area due to thick vegetation, preventing lines of sight;
- Main Southern Railway above centreline of LW S5A – A GNSS unit will be installed where the rail corridor is located directly above the centreline of LW S4A at approximate rail kilometrage of 100.55 km. The purpose of the GNSS unit is to detect the initial development of subsidence and trigger the commencement of regular ground surveys; and
- Railway Viaduct across Bargo River – Two GNSS units have been installed within the Main Southern Railway corridor to measure far field movements, if any, between the abutments of the Viaduct. The two GNSS units will also allow valley closure, if any, to be detected. The units are located near the Remembrance Drive Bridge over the Bargo River. The results will be cross-checked by manual surveys across the Remembrance Drive Bridge over the Bargo River.

4.4.2. Early warning survey lines

LW S1A Tahmoor Mine Boundary

A survey line has been installed along the southern boundary of Tahmoor Mine's property, as shown in Drawing No. MSEC1192-01-01. The survey line has been installed with pegs spaced nominally 20 metres apart. The survey line commences at the south-eastern end at the end of an unsealed road that is accessed from Charlies Point Road. The line terminates at the top of Teatree Hollow due to thick vegetation.

The purpose of the survey line is to measure the subsidence profile across the width of LW S1A prior to experiencing significant subsidence along the Main Southern Railway and Remembrance Drive. It is planned to survey the line once a month during the period of active subsidence of LW S1A. Additional surveys can be conducted, if required.

Main Southern Railway

LWs S1A to S4A will extract directly beneath the Main Southern Railway prior to mining directly beneath Remembrance Drive.

A survey has been installed along the Main Southern Railway, as shown in Drawing No. MSEC1192-01-01. The survey line has been installed with pegs spaced nominally 20 metres apart.

Surveys along the Railway will provide an early warning of the magnitude of subsidence that is likely to develop. The surveys will also detect the development of non-conventional subsidence movements along the Railway and provide an opportunity to project locations where potential non-conventional subsidence movements may occur along Remembrance Drive. The IMG can assess the monitoring results and assess whether any additional monitoring and management measures may be required to manage potential impacts along Remembrance Drive.

It is planned to survey the line weekly during periods of active subsidence. Additional surveys can be conducted, if required.

4.4.3. Ground Surveys along Remembrance Drive road embankments and culverts

Tahmoor Mine will conduct the following surveys and inspections of culverts and embankments along Remembrance Drive:

- Absolute 3D and 2D surveys along a monitoring line along Remembrance Drive.
- Local 3D / Absolute 3D survey of embankment across Teatree Hollow along Remembrance Drive with pegs spaced along the crest and toe on both sides of each embankment. Pegs spacings are generally every 20 metres. The layout of survey marks is shown in Drawing No. MSEC1193-03-07.

- Visual inspections of the pavement, culvert and embankment during mining by a building inspector and geotechnical engineer.

4.4.4. Ground and Structure Surveys at the Remembrance Drive Bridge over the Bargo River

Tahmoor Mine will conduct the following surveys and inspections at the Remembrance Drive Bridge over the Bargo River:

- Continuous GNSS monitoring at two locations across the bend in the Bargo River. The two units S11 and S12 have been installed within the railway corridor near the Railway Viaduct, where access is available.
- Local 3D surveys of structure and ground marks on the Remembrance Drive Bridge over the Bargo River, as shown in Drawing No. MSEC1193-03-02, including a measurement of gaps between the bridge deck and the northern abutment; and
- Visual inspections of the Bridge.

4.4.5. Local 3D pipeline surveys

Local 3D surveys will be conducted along the section of gas pipeline along the southbound crest of the Teatree Hollow embankment along Remembrance Drive. The purpose of the surveys is to measure the deflected shape of the pipeline in response to mine subsidence movements and allow pipeline engineers to estimate pipeline stresses.

4.4.6. Visual inspections

Visual inspections will be undertaken during the period of active subsidence by an experienced inspector appointed by Tahmoor Coal who is familiar with mine subsidence impacts. The inspector will undertake the following:

- Visual inspections along the pipeline along Remembrance Drive within the active subsidence zone; and
- Visual inspections of culverts, embankments, cuttings and bridges.

4.4.7. Gas patrols

On 17 June 2022, Macarthur Gas completed a pre-mining gas detection survey of the 150 mm gas pipeline located along Remembrance Drive. The survey was conducted for the section of pipeline between Olive Lane and Wellers Road, as shown in Drawing No. MSEC1193-06-01.

Additional gas detection surveys can be undertaken if triggered by monitoring results.

4.4.8. Changes to monitoring frequencies

Monitoring frequencies will continue while Jemena infrastructure is experiencing active subsidence due to the extraction of LW S1A-S7A. As the gas pipeline is located near the finishing ends of LW S1A-S2A, monitoring will continue until one month has passed since the longwall extraction is completed. Monitoring, however, may continue if ongoing adverse impacts are observed.

4.5. Triggers and responses

Trigger levels have been developed by Tahmoor Coal based on engineering assessments and consultation with Jemena and engineering specialists Advisian and MSEC.

Trigger levels for each monitoring parameter are described in the risk control procedures in Table 4.1.

Immediate responses, if triggered by monitoring results, may include:

- Increase in survey and inspection frequencies if required by the IMG;
- Additional gas detection surveys;
- Additional surveys and inspections;
- Exposing pipeline to relieve it of stress;
- Repair of impacts that create a serious public safety hazard; and
- In the worst case, restriction on entry, or access to, Jemena infrastructure.

The risk control measures described in this Management Plan have been developed to ensure that the health and safety of people in the vicinity of Jemena infrastructure are not put at risk due to mine subsidence. It is also an objective to avoid disruption to services, or if unavoidable, keep disruption and inconvenience to minimal levels.

A gas leak could possibly result in severe impacts that could give rise to the need for an emergency response. The likelihood is considered extremely remote and would require substantial differential subsidence movements to develop before such an event occurs.

As discussed in Section 3.1, mine subsidence movements will develop gradually and there will be ample time to identify the development of potentially adverse differential subsidence movements early, consider whether any additional management measures are required, and repair or adjust affected surface features, in close consultation with Jemena. Regular consultation with the community is important. As the gas has been odourised, the community are more likely to report gas leaks if they occur.

As documented in Section 4.6, Tahmoor Coal and the IMG will review and assess monitoring reports and consider whether any additional management measures are required on a weekly basis. If potentially adverse differential subsidence movements are detected, it is anticipated that a focussed inspection will be undertaken in the affected area, and a decision will likely be made to increase the frequency of surveys and/or inspections. Additional management measures may also be implemented. It is therefore expected that, as a potential adverse situation escalates, Tahmoor Coal will be present on site on a more frequent basis to survey or inspect the affected site, and that Jemena will be consulted on a more frequent basis.

A contingency plan has been developed by Tahmoor Coal (2024) in consultation with Jemena in the event that the gas pipeline needs to be exposed so that it is decoupled from mining-induced ground strains. The contingency plan has been implemented twice during the mining of LWs S1A and S2A and describes the following aspects:

- Site survey (completed)

  Comprehensive location and survey of the gas pipeline, including potholing to confirm the depth of the pipeline. It was found that the location of the pipe was not accurately mapped by the Dial-Before-You-Dig database. The location of the pipeline was marked on site, with offsets measured from fence lines and the fog line along Remembrance Drive. Mapping was also conducted of other public utilities that are within 3 metres of the gas pipeline;

- Set-up of worksite area, including concrete jersey kerbs and ATF fencing;
- Traffic management plan, including coordinating with Wollondilly Shire Council regarding s138 permits (complete);
- Gas main excavation / uncoupling

  Excavation and exposure of the gas main will be undertaken under the supervision of specialist Jemena Permit issuing officers and standby officer in accordance with Jemena safety procedures. Excavation will be up to 100 mm below the level of the existing pipe and will, therefore, be less than 1500 mm in depth. A geotechnical engineering will supervise the excavation. Shoring boxes will be installed, if required.

  Road plates or ground matting will be installed along the top of the trench and the pipe will be covered by hessian covers and plywood.

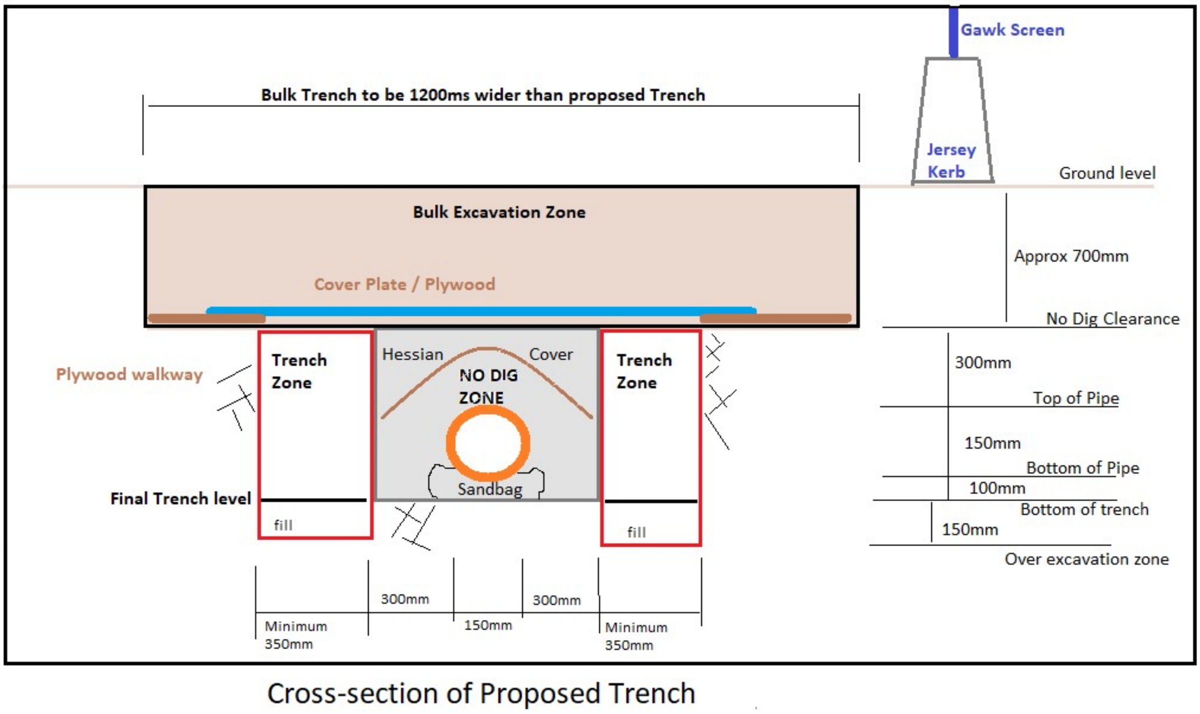


Fig. 4.1 Cross-section showing planned excavation of gas pipeline

Notwithstanding the above, if a hazard has been identified that involves potential serious injury or illness to a person or persons on public property or in the vicinity of Jemena infrastructure, and cannot be controlled, the immediate response is to remove people from the hazard. If such a situation is observed or is forecast to occur by either Tahmoor Coal or by people on public property, Tahmoor Coal and Jemena will immediately meet and implement emergency procedures.

4.6. Subsidence Impact Management Procedures

The procedures for the management of potential impacts are provided in Table 4.1.

Table 4.1 Risk Control Procedures during the extraction of Tahmoor South LW S1A-S7A

INFRASTRUCTURE	HAZARD / IMPACT	RISK	TRIGGER	CONTROL PROCEDURE/S	FREQUENCY	BY WHOM?
Gas infrastructure	Impacts to Jemena gas infrastructure	Low	None	Excavate and expose 50 metres of gas pipeline along the southbound crest of the Teatree Hollow embankment along Remembrance Drive near the Caloola Road intersection, under supervision from Jemena	Prior to 800m of extraction of LW S3A	Tahmoor Coal
				Continuous GNSS monitoring as shown in Drawing No. MSEC1193-01-01	GNSS units installed with exception of GNSS on Railway above centreline of LW S5A, which will be installed prior to start of LW S4A Continuous readings, with data averaged over 24 hours and recorded once per day until end of LW S7A.	Tahmoor Coal (Unit Zero)
				2D survey line along Tahmoor Mine property boundary	Pegs installed. Baseline survey complete Monthly survey during LW S1A between 200m and 1300m extraction, and continue if ongoing adverse movements are observed. (complete) End of LW S1A (complete).	Tahmoor Coal (SMEC)
				Conduct 2D / Absolute 3D surveys along Main Southern Railway in accordance with Railway Management Plan	Monthly 3D / Weekly 2D surveys for pegs within active subsidence zone during LWs S1A to S7A	Tahmoor Coal (SRS)
				Conduct 2D / Absolute 3D surveys along Remembrance Drive	Pegs installed from northern boundary of Tahmoor Mine site to No. 3166 Remembrance Drive. Baseline survey complete up to LW S3A. Extend line and baseline survey pegs within predicted limit of incremental subsidence of LWs S4A to LW S7A, prior to start of each LW Monthly 3D / Weekly 2D surveys for pegs within active subsidence zone commencing as per below: LW S1A: start after 1300m extraction (complete) LW S2A: start after 900m extraction (complete) LW S3A: start after 500 m extraction LW S4A: start after GNSS at 100.55km subsides more than 20 mm due to LW S4A or 300 m extraction, whichever occurs first LW S5A: start after GNSS at 100.55km subsides more than 20 mm due to LW S5A or 200 m extraction, whichever occurs first LW S6A: start after GNSS at 100.55km subsides more than 20 mm due to LW S6A or 200 m extraction, whichever occurs first LW S7A start after 200 m extraction Continue surveys until outside active subsidence zone or one month after end of LW and continue further if ongoing adverse movements are observed. End of each LW	Tahmoor Coal (SMEC)
				Conduct Local 3D / Absolute 3D survey of Remembrance Drive Embankment over Teatree Hollow at Caloola Drive (RE4) as per Drawing No. MSEC1193-03-07, Remembrance Drive Embankment North of Yarran Road (RE3) as per Drawing No. 1193-03-08, Remembrance Drive Embankment South of Yarran Road (RE2) as per Drawing No. 1193-03-09, and Remembrance Drive Embankment at Wellers Road (RE1) as per Drawing No. MSEC1193-03-10.	Install and baseline survey prior to influence of LWs. Monthly 3D / Weekly 2D surveys within active subsidence zone of each LW Continue if ongoing adverse movements are observed. End of each LW.	Tahmoor Coal (SMEC)
				Conduct Local 3D / Absolute 3D survey of Remembrance Drive Cutting (RC1) as per Drawing No. MSEC1193-03-11.	Install and baseline survey prior to LW S2A. 3D Survey at end of LW S2A. Monthly 3D / Weekly 2D surveys within active subsidence zone commencing as per below: LW S3A: start after 500m extraction LW S4A: start after 500m extraction LW S5A: start after 500m extraction LW S6A: start after 500m extraction Continue if ongoing adverse movements are observed. End of LWs S3A to S7A.	Tahmoor Coal (SMEC)
				Conduct Local 3D survey of structure and ground marks on the Remembrance Drive Bridge over the Bargo River as per Drawing No. MSEC1193-03-02, with one mark on the Bridge to be surveyed in Absolute 3D. The survey includes a measurement of the gap between the deck and the northern abutment.	Baseline survey prior to LW S1A. (complete) Monthly surveys between 1000m and one month after end of extraction of LWs S1A to S3A and continue if ongoing adverse movements are observed. End of LWs S1A to S3A.	Tahmoor Coal (SRS)
				Baseline survey of gaps at expansion joints on sewer main on the Remembrance Drive Bridge over the Bargo River	Baseline survey complete	Tahmoor Coal (SRS)

INFRASTRUCTURE	HAZARD / IMPACT	RISK	TRIGGER	CONTROL PROCEDURE/S	FREQUENCY	BY WHOM?
				Visual inspection of Remembrance Drive Bridge over the Bargo River	Baseline inspection prior to LW S1A (complete) Monthly inspections between 1000m and one month after end of extraction of LWs S1A to S3A and continue if ongoing adverse movements are observed. End of LWs S1A to S3A	Tahmoor Coal (BIS)
				Detailed visual inspections of pavement, culverts, embankments and cuttings along the route of the gas main along Remembrance Drive	Weekly for areas within the active subsidence zone or one month after end of LW and continue if ongoing adverse movements or impacts are observed.	Tahmoor Coal (BIS)
				Detailed visual inspections by geotechnical engineer for Remembrance Drive embankments and cutting	Monthly for areas within the active subsidence zone during periods of active subsidence of each LW, and continue if ongoing adverse movements are observed.	Douglas Partners
				Inform Sydney Water Call Centre of mining in area and possible issues.	Completed	Sydney Water
				Notify residents of potential mine subsidence impacts and contact numbers.	Completed	Tahmoor Coal
				Analyse and report results to IMG, including information on the position of the longwall face.	Weekly during LW S1A-S7A after the length of the extraction exceeds 200 metres.	Tahmoor Coal
			Ground strain along Remembrance Drive exceeds 2 mm/m or Non-conventional ground movement detected along Remembrance Drive	Notify Jemena	Within 24 hours	Tahmoor Coal
				Notify Jemena and convene an IMG meeting. Consider additional monitoring and mitigation measures based on observed monitoring results, which may include: - increase frequency of ground surveys at affected site - increase frequency of visual inspections - conduct additional gas detection surveys - excavate to expose pipe and reduce distortion or strain on pipe (as per contingency plan) - increase frequency of IMG meetings - any other additional management actions	As required by IMG	Tahmoor Coal
			Leakage of gas observed	Contact Jemena as per contact protocol.	As required by Jemena	Jemena
				Investigate cause of gas leak to ascertain whether leak might be due to subsidence	Within 24 hours	Jemena
				If gas leak is subsidence related, notify all stakeholders, including Jemena, Tahmoor Coal, Wollondilly Shire Council, Sydney Water, Telstra, NBN, Endeavour Energy, neighbouring residents and businesses, Subsidence Advisory NSW and Resources Regulator	Within 24 hours	Tahmoor Coal
				Convene IMG meeting to consider additional monitoring and mitigation measures based on observed monitoring results, which may include: - increase frequency of surveys - increase frequency of visual inspections - conduct additional gas detection surveys - excavate to expose pipe and repair with either temporary clamp or full repair - decide whether to backfill pipe or leave exposed during remaining period of active subsidence - increase frequency of IMG meetings - any other additional management actions	As required by IMG	Tahmoor Coal and Jemena
			A hazard has been identified that involves potential serious injury or illness to a person or persons on public property or, or in vicinity of gas infrastructure and cannot be controlled	IMG, Tahmoor Coal and Jemena meet to decide whether any additional management measures are required, including: - shut off gas main and repair damaged pipe, - emergency evacuation of hazardous area - demarcation to prevent people entering hazardous area	Immediately	Tahmoor Coal and Jemena
				Notify stakeholders, including Jemena, Tahmoor Coal, Wollondilly Shire Council, Sydney Water, Telstra, NBN, Endeavour Energy, neighbouring residents and businesses, Subsidence Advisory NSW and Resources Regulator of trigger exceedance and any management decisions undertaken	Within 24 hours of decision	Tahmoor Coal

INFRASTRUCTURE	HAZARD / IMPACT	RISK	TRIGGER	CONTROL PROCEDURE/S	FREQUENCY	BY WHOM?
			Closure between abutments on Remembrance Drive Bridge over Bargo River exceeds 7 mm or Impacts observed to bridge	Notify Jemena	Within one week	MSEC
				Jemena and IMG meet and consider whether any additional management measures are required, which may include: - conduct additional inspection of gas main on Remembrance Drive Bridge over the Bargo River - conduct additional gas detection surveys - undertake structural engineering inspection - increase monitoring frequency and reporting procedures - excavate to expose pipe and reduce distortion or strain on pipe at pipe bend - consider potential risks and implement control measures to protect the gas main if it is decided to conduct modification works on the bridge	Within one week	IMG
				Report trigger exceedance and actions taken to IMG, Jemena, SA NSW & MSO in Status Report	Within one week	Tahmoor Coal

5.1. Consultation, co-operation and co-ordination

Substantial consultation, co-operation and co-ordination has taken place between Tahmoor Coal and Jemena prior to the development of this Management Plan, as detailed in Section 1.3.1.

The following procedures will be implemented during and after active subsidence to ensure the continued effective consultation, co-operation and co-ordination of action with respect to subsidence between Tahmoor Coal and Jemena:

- Reporting of observed impacts to Tahmoor Coal either during the weekly visual inspection or at any time directly to Tahmoor Coal.
- Distribution of monitoring reports, which will provide the following information on a weekly basis during active subsidence:
    - Position of longwall;
    - Summary of management actions since last report;
    - Summary of consultation with Jemena since last report;
    - Summary of observed or reported impacts, incidents, service difficulties, complaints;
    - Summary of subsidence development;
    - Summary of adequacy, quality and effectiveness of management process;
    - Any additional and/or outstanding management actions; and
    - Forecast whether there will be any subsidence impacts to the health and safety of people due to the continued extraction of LW S1A-S7A.
- Convening of meetings between Tahmoor Coal and Jemena at any time as required, as discussed in Section 5.2;
- Arrangements to facilitate timely repairs, if required; and
- Immediate contact between Tahmoor Coal and Jemena if a mine subsidence induced hazard has been identified that involves potential serious injury or illness to a person or persons on public property or private property and may require emergency evacuation, entry restriction or suspension of work activities.

5.2. IMG meetings

The IMG undertakes reviews and, as necessary, revises and improves the risk control measures to manage risks to health and safety, and potential impacts to infrastructure.

The reviews are undertaken weekly during the period of active subsidence based on the results of the weekly surveys and visual inspections and summarised in the monitoring reports, as described in Section 5.1.

The purpose of the reviews is to:

- Detect changes, including the early detection of potential impacts on health and safety and impacts to Jemena infrastructure;
- Verify the risk assessments previously conducted;
- Ensure the effectiveness and reliability of risk control measures; and
- Support continual improvement and change management.

IMG meetings may be held between Tahmoor Coal and Jemena for discussion and resolution of issues raised in the operation of the Management Plan. The frequency of IMG Meetings will be as agreed between Tahmoor Coal and Jemena.

IMG Meetings will discuss any incidents reported in relation to the relevant infrastructure, the progress of mining, the degree of mine subsidence that has occurred, and comparisons between observed and predicted ground movements.

It will be the responsibility of the meeting representatives to determine whether the incidents reported are due to the impacts of mine subsidence, and what action will be taken in response.

In the event that a significant mine subsidence impact is observed, any party may call an emergency IMG Meeting, with one day's notice, to discuss proposed actions and to keep other parties informed of developments in the monitoring of the infrastructure.

6.0 AUDIT AND REVIEW

This Management Plan has been agreed between parties and can be reviewed and updated to continually improve the risk management systems based on audit, review and learnings from the development of subsidence during mining and manage changes in the nature, likelihood and consequence of subsidence hazards.

The review process will be conducted to achieve the following outcomes:

- Gain an improved understanding of subsidence hazards based on ongoing subsidence monitoring and reviews, additional investigations and assessments as necessary, ongoing verification of risk assessments previously conducted, ongoing verification of assumptions used during the subsidence hazard identification and risk assessment process, ongoing understanding of subsidence movements and identified geological structures at the mine;
- Revise risk control measures in response to an improved understanding of subsidence hazards;
- Gain feedback from stakeholders in relation to managing risks, including regular input from business or property owners;
- Ensure on-going detection of early warnings of changes from the results of risk assessments to facilitate corrective or proactive management actions or the commencement of emergency procedures in a timely manner; and
- Ensure timely implementation of a contingency plan in the event that the implemented risk control measures are not effective.

Some examples where review may be applied include:

- Observation of greater impacts on surface features due to mine subsidence than was previously expected;
- Observation of fewer impacts or no impacts on surface features due to mine subsidence than was previously expected; and
- Observation of significant variation between observed and predicted subsidence.

Should an audit of the Management Plan be required during that period, an auditor shall be appointed by Tahmoor Coal to review the operation of the Management Plan and report at the next scheduled Plan Review Meeting. The Management Plan shall be audited for compliance with ISO 31000, or alternative standard agreed with Jemena.

7.0 RECORD KEEPING

Tahmoor Coal will keep and distribute minutes of any IMG Meeting.

8.0 CONTACT LIST

Organisation	Contact	Phone	Email
Jemena Control Centre	Emergency Contact	131909	
Jemena Engineering Support Manager	John Martin	(02) 9867 7219 0407 105 128	John.Martin@jemena.com.au
Jemena Engineer – Distribution, Engineering Support Asset Management	Andrew Walker*	(02) 9867 8346	andrew.walker@jemena.com.au
Jemena Engineer	Darryl Tolentino	(02) 9867 7237	darryl.tolentino@jemena.com.au
Jemena Engineer	Muhammad Umer Siddiqui*	(02) 9867 7237	muhammad.siddiqui@jemena.com.au
Jemena Engineering Services Specialist	Layton Manuel	(02) 9867 7335	layton.manuel@jemena.com.au
NSW Department of Planning and Environment – Resources Regulator	Ray Ramage	(02) 4063 6485 0442 551 293	ray.ramage@planning.nsw.gov.au
	Phil Steuart	(02) 4063 6484	phil.steuart@planning.nsw.gov.au
Subsidence Advisory NSW	Matthew Montgomery	(02) 4677 1967 0425 275 564	Matthew.Montgomery@customerservice.nsw.gov.au
Mine Subsidence Engineering Consultants (MSEC)	Daryl Kay*	(02) 9413 3777 0416 191 304	daryl@minesubsidence.com
SIMEC Mining Tahmoor Coal Project Manager	Ross Barber*	(02) 4640 0028 Mob: 0419 466 143	ross.barber@simecgfg.com
SIMEC Mining Tahmoor Coal Approvals Specialist	April Hudson	(02) 4640 0022 0466 380 992	April.Hudson@simecgfg.com
SIMEC Mining Tahmoor Coal Environment and Community	Amanda Fitzgerald*	(02) 4640 0057 0414 848 213	Amanda.Fitzgerald@simecgfg.com

* denotes member of Infrastructure Management Group

APPENDIX A. Drawings and Supporting Documentation

The following supporting documentation is provided in Appendix A.

Drawings

Drawing No.	***Description***	***Revision***
MSEC1193-01-01	Monitoring plan	B
MSEC1193-06-01	Jemena Gas Pipelines	B
MSEC1193-03-02	MSR Rail Viaduct & Remembrance Drive Bridge over Bargo River	B
MSEC1193-03-07	Remembrance Drive Embankment over Teatree Hollow over LW S3A (RE4)	B
MSEC1193-03-08	Remembrance Drive Cutting and Embankment north of Yarran Road over LWs S4A and S5A (RE3)	B
MSEC1193-03-09	Remembrance Drive Embankment south of Yarran Road over LW S5A (RE2)	B
MSEC1193-03-10	Remembrance Drive Embankment at Wellers Road intersection beyond LW S6A (RE1)	B
MSEC1193-03-11	Remembrance Drive Cutting north of Yarran Road over LW S4A and S5A (RC1)	B

Supporting Documentation

Advisian (2022)	Mine Subsidence Impact – Jemena DN150 Steel Gas Pipe, Advisian, Project No. 311023-40903, Rev. 3, March 2022.
Advisian (2023)	Mine Subsidence Impact – Jemena DN150 Steel Gas Pipe, Advisian, Project No. 311023-40903, Rev. 0, August 2023.
Axys (2023)	Longwall LWS3A to LWS7A Subsidence Impacts to Jemena 150mm MP Gas Main – Risk Assessment Report No. AR3793, Revision 2, 27 October 2023.
HMS (2022)	*Risk Assessment on the Tahmoor South Longwall LW1A & LW2A Subsidence Impacts on the Jemena 150mm High Pressure Steel Gas Pipeline*. Report No. HMS1482, HMS Consultants, April 2022.
Tahmoor Coal (2024)	*Contingency Plan to uncouple the 150 mm Jemena Gas pipeline along Remembrance Drive, Bargo, from the ground in the event of a triggered response from longwall mining*, Tahmoor Coal, Rev. 8, March 2024.

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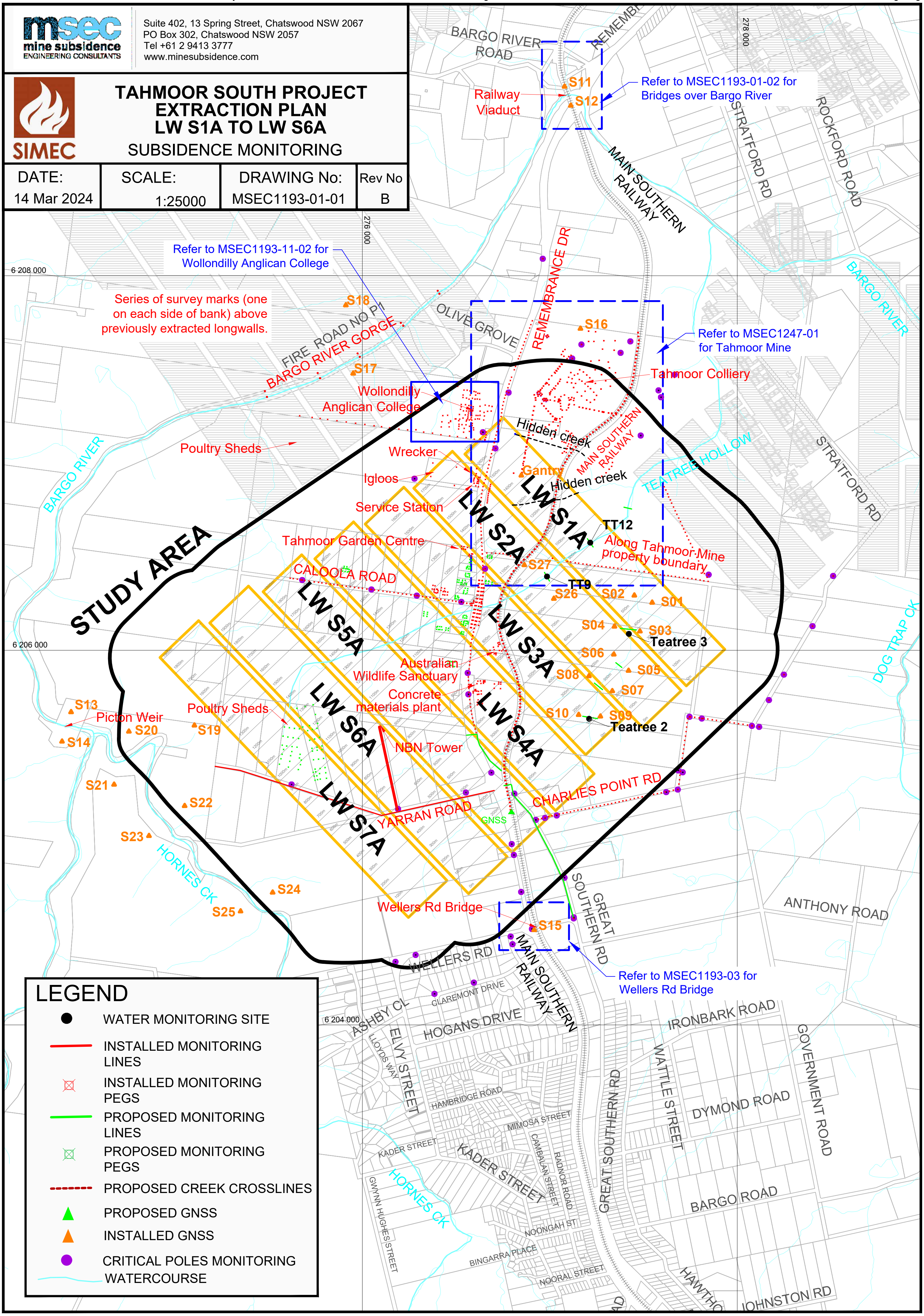
TAHMOOR SOUTH PROJECT EXTRACTION PLAN LW S1A TO LW S6A

SUBSIDENCE MONITORING

DATE:	SCALE:	DRAWING No:	Rev No
14 Mar 2024	1:25000	MSEC1193-01-01	B



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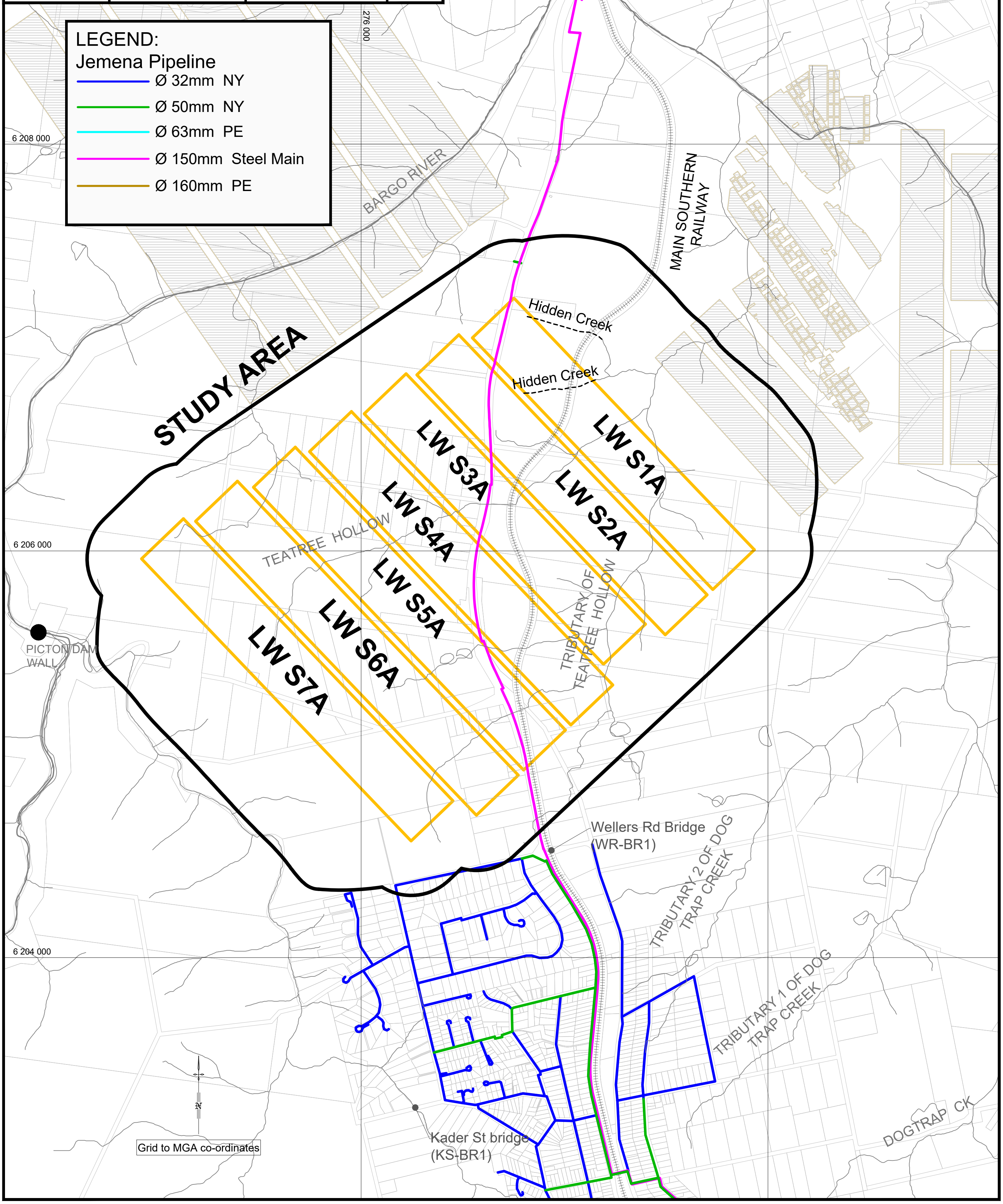
TAHMOOR SOUTH PROJECT
MANAGEMENT PLAN
LW S1A TO LW S6A
JEMENA INFRASTRUCTURE

DATE:	SCALE:	DRAWING No:	Rev No
14 Mar 2024	1:25000	MSEC1193-06-01	B



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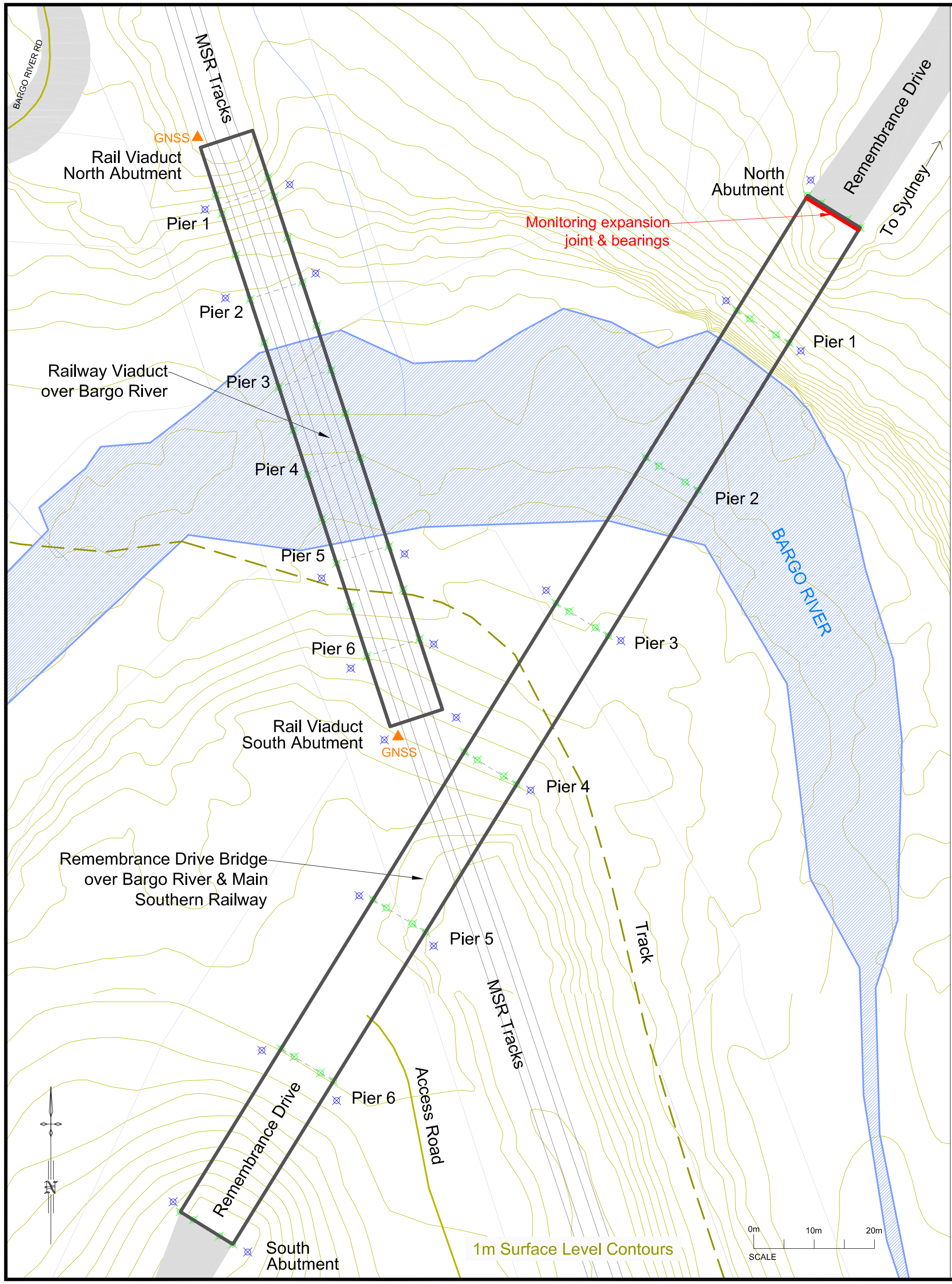
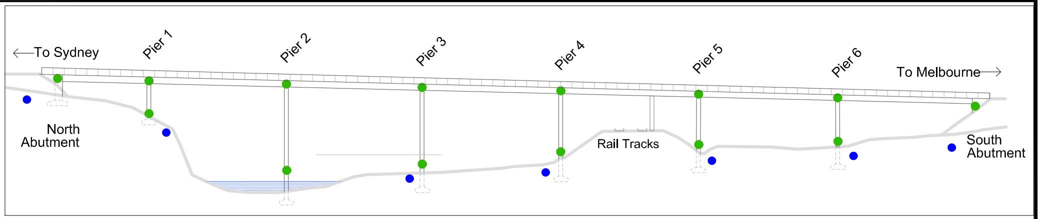
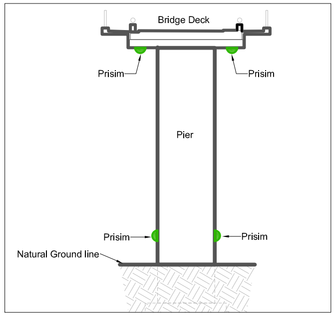
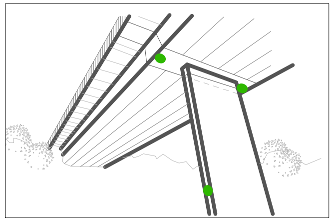




ELEVATION - REMEMBRANCE DRIVE BRIDGE OVER BARGO RIVER

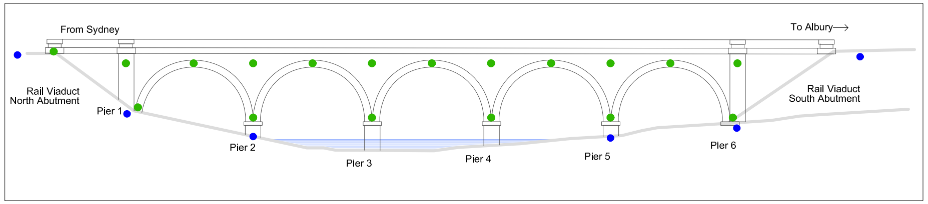


TYPICAL PIER (nts)



DIAGRAM

- PROPOSED STRUCTURE PRISMS
- PROPOSED GROUND PEGS



ELEVATION - RAIL VIADUCT OVER BARGO RIVER

LEGEND

- PROPOSED STRUCTURE PRISMS
- PROPOSED GROUND PEGS
- PROPOSED GNSS

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TAHMOOR SOUTH PROJECT LWS1A TO LWS6A

MSR RAIL VIADUCT & REMEMBRANCE DRIVE BRIDGE OVER BARGO RIVER

DATE:	SCALE:	DRAWING No:	Rev No
19 Oct 2022	as shown	MSEC1193-03-02	B

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REMEMBRANCE DRIVE EMBANKMENT OVER TEATREE HOLLOW OVER LW S3A (RE4)

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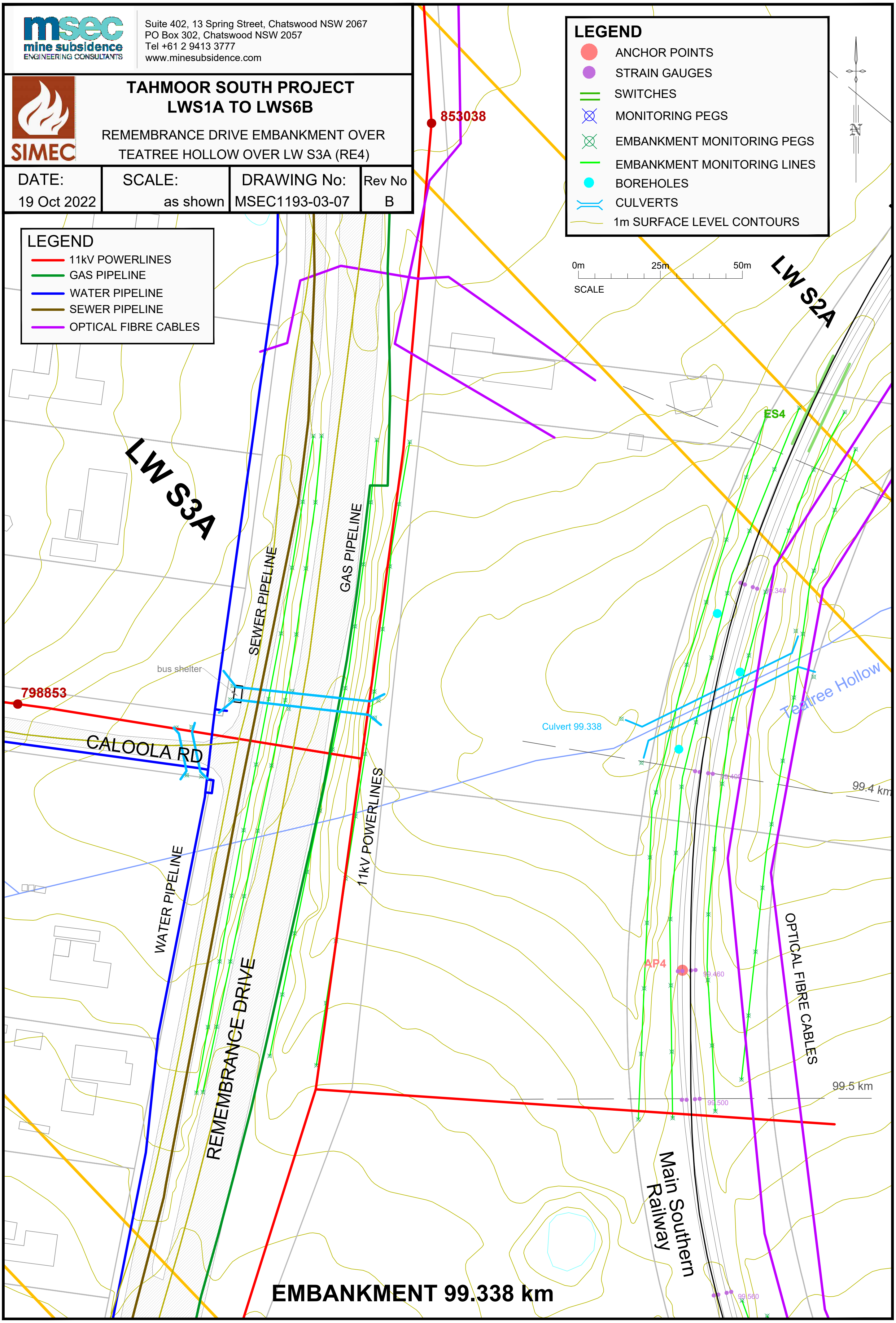

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TAHMOOR SOUTH PROJECT
LWS1A TO LWS6B

REMEMBRANCE DRIVE EMBANKMENT NORTH OF YARRAN RD OVER LW S4A & LW S5A (RE3)

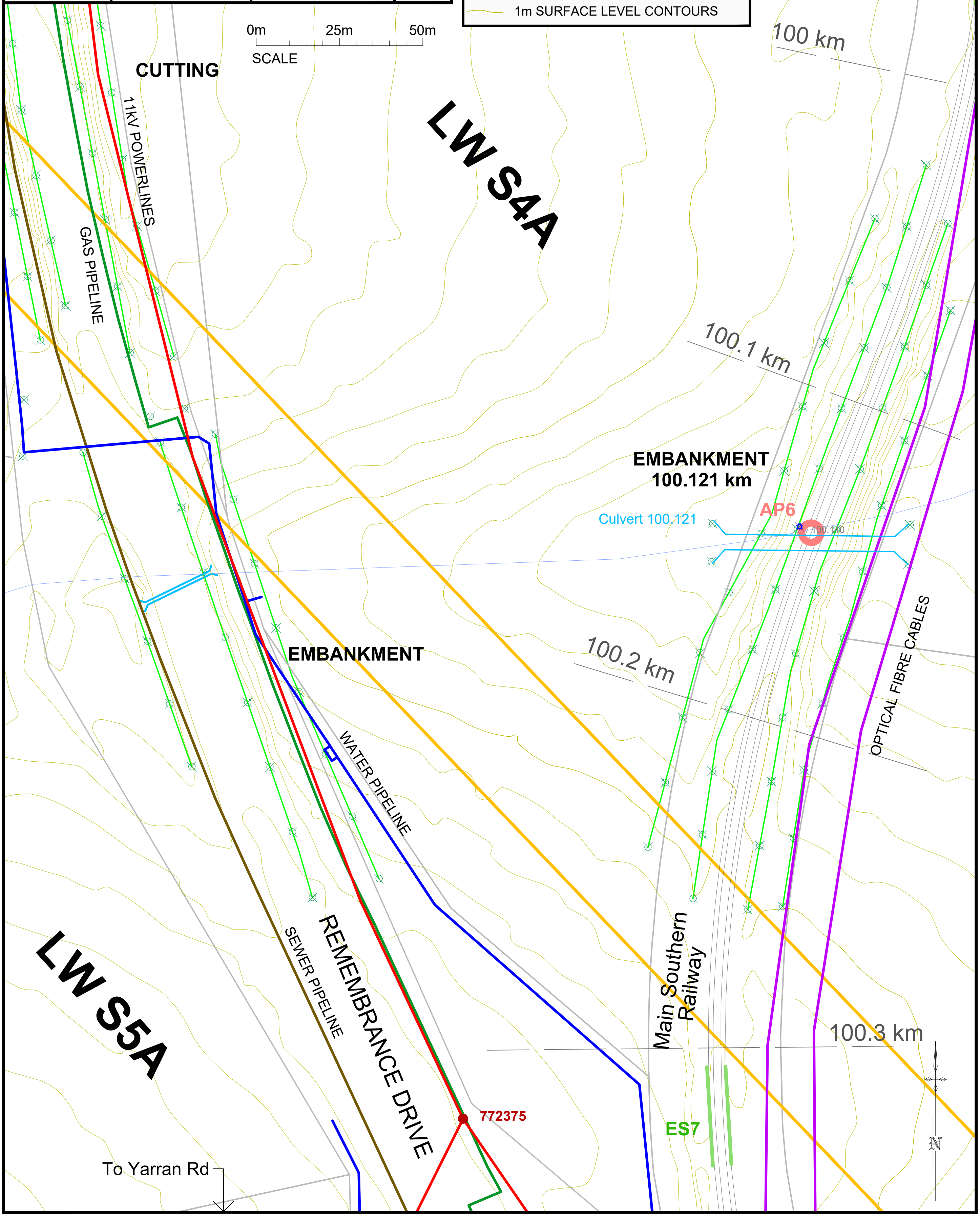
DATE:	SCALE:	DRAWING No:	Rev No
19 Oct 2022	as shown	MSEC1193-03-08	B

LEGEND

- ANCHOR POINTS
- STRAIN GAUGES
- SWITCHES
- MONITORING PEGS
- EMBANKMENT MONITORING PEGS
- EMBANKMENT MONITORING LINES
- BOREHOLES
- CULVERTS
- 1m SURFACE LEVEL CONTOURS

LEGEND

- 11kV POWERLINES
- GAS PIPELINE
- WATER PIPELINE
- SEWER PIPELINE
- OPTICAL FIBRE CABLES



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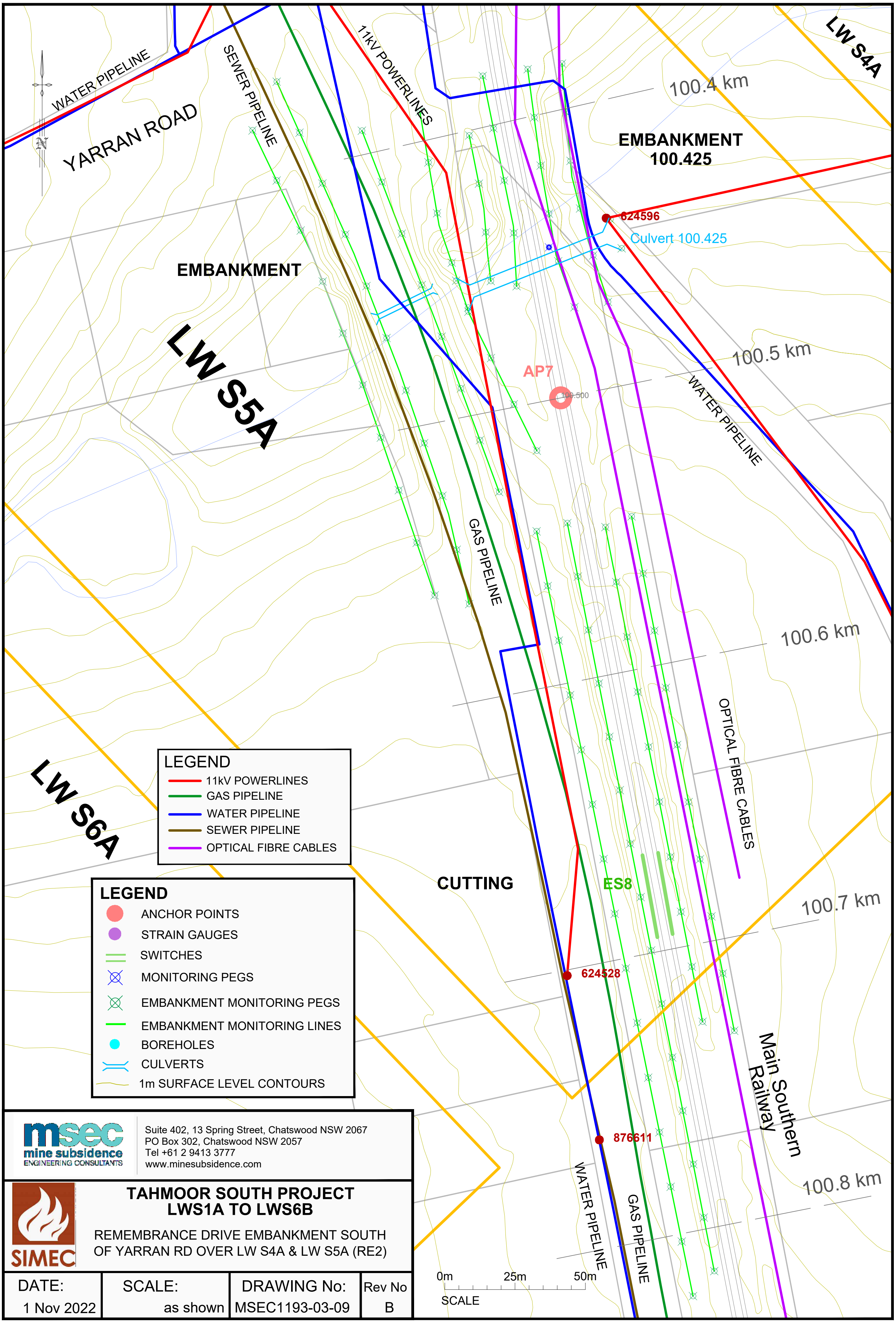

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TAHMOOR SOUTH PROJECT
LWS1A TO LWS6B

REMEMBRANCE DRIVE EMBANKMENT SOUTH OF YARRAN RD OVER LW S4A & LW S5A (RE2)

DATE:	SCALE:	DRAWING No:	Rev No
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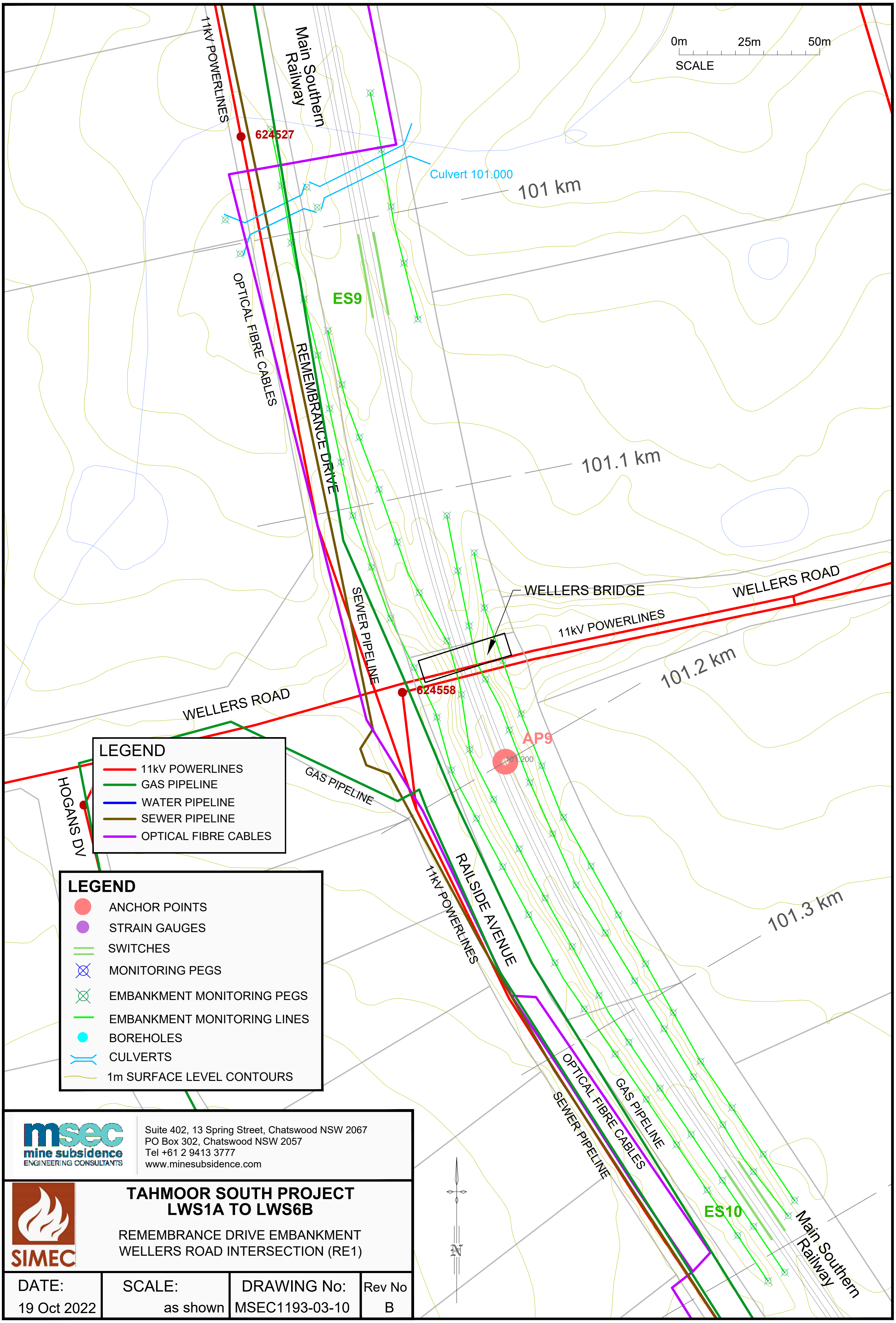

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TAHMOOR SOUTH PROJECT
LWS1A TO LWS6B

REMEMBRANCE DRIVE EMBANKMENT
WELLERS ROAD INTERSECTION (RE1)

DATE:	SCALE:	DRAWING No:	Rev No
19 Oct 2022	as shown	MSEC1193-03-10	B

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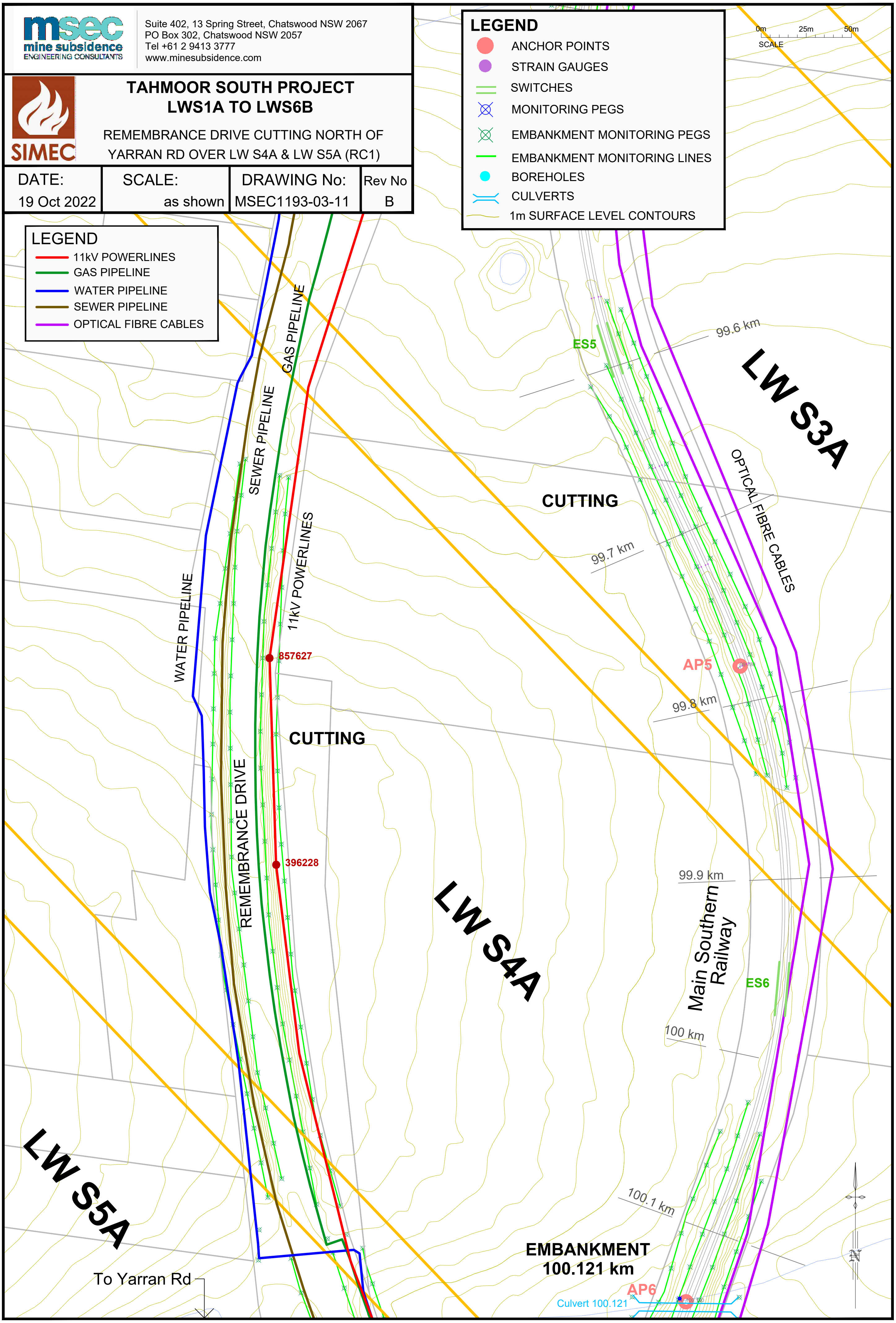
SIMEC

TAHMOOR SOUTH PROJECT LWS1A TO LWS6B

REMEMBRANCE DRIVE CUTTING NORTH OF YARRAN RD OVER LW S4A & LW S5A (RC1)

DATE:	SCALE:	DRAWING No:	Rev No
19 Oct 2022	as shown	MSEC1193-03-11	B



Mine Subsidence Impact

Jemena DN150 Steel Gas Pipe

Tahmoor Coal Pty Ltd - SIMEC

31 March 2022

Project 311023-40903

Advisian
Worley Group

advisian.com

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PROJECT 311023-40903-AAG-REP-001: Mine Subsidence Impact Jemena DN150 Steel Gas Pipe

Rev	Description	Author	Review	Advisian approval	Revision date	Client approval	Approval date
A	Internal review	DKH/ECKL D Ho/E Lo	PGD G Dominish	N/A	14 Mar 22	N/A	N/A
0	Issued for client review	DKH/ECKL D Ho/E Lo	PGD G Dominish	N/A	14 Mar 22	N/A	N/A
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2	Revision	DKH/ECKL D Ho/E Lo	PGD G Dominish	DKH D Ho	31 Mar 22	N/A	N/A

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1 Executive summary

A 3D finite element model of the DN150 steel gas main was used to compute the pipe response caused by the predicted conventional mine subsidence of LW S1A and LW S2A at Tahmoor Mine. The peak pipe stress (von Mises) under the maximum allowable operating pressure of 1.05 MPa with a probable conservative temperature differential of +15ºC, is 39% SMYS and 48% SMYS for LW S1A and LW S2A respectively. They are well below the allowable hoop stress of 20% SMYS (AS 4645.2:2018) and combined stress of 90% SMYS (AS 2885.1:2018). The peak stress is caused by a combination of hoop stress and axial compressive stress in the affected section of the pipe where the maximum settlement occurs. It should be noted that the pipe stress is more sensitive to the axial compressive stress than to the hoop stress. The compressive pipe strains are also within the allowable limit.

Further analysis was performed to investigate the compressive axial ground strain required to cause the pipe stress to reach the allowable limit. The analysis assumed the settlement remained unchanged and the lateral ground displacement increased gradually. It was estimated that the pipe stress will reach the allowable limit when the axial compressive ground strain reached 30 mm/m and 23 mm/m for LW S1A and LW S2A respectively. By tracking the development of pipe stress with compressive ground strain, the trigger limits for 80%, 90% and 100% SMYS were determined as provided in Section 6. They can be used in the Management Plan to mitigate mine subsidence risks to the gas main.

As non-conventional mine subsidence has not been predicted for LWS1A and LWS2A, two separate hypothetical step change cases were considered for a straight and horizontal section of the gas main. One is a vertical "fault" ground movement and the other is a lateral "shear" movement. Under this type of ground deformation, large bending and longitudinal stresses developed in the pipe at the step change. For vertical fault type ground movement, the pipe reaches the allowable stress limit when the differential settlement is approaching 340 mm/m or about 1:2.9 gradient. For the lateral shear type ground movement, the pipe is at the allowable stress limit when the lateral movement is approaching 372 mm/m or about 1:2.7 gradient. It is recommended that a "blue" trigger of 2 mm/m ground strain be used as an early warning that the ground at a particular location may undergo non-conventional ground movement such as a step change or valley closure/upsidence at creek crossings. More frequent and closer peg spacing may be required to confirm if the discontinuity is real and continue to deform. Mitigation measure such as exposing the pipe in a trench may be required.

Although the steel gas main was found to be within the allowable stress limit when subject to the predicted conventional mine subsidence, we recommend that consideration be given to isolate the pipe section in the subsidence zone based on the operational requirements for the pipeline. This would allow isolation in the event that the ground deforms significantly more than predicted or there is an unexpected abrupt ground movement such as a sinkhole or a shear fault deformation. Based on the "Dial Before You Dig" information, currently there is a shutoff valve at Hawthorne Road downstream of the Moomba to Sydney Pipeline off-take location which can be used for emergency shut down purpose. Note that this valve does not affect gas supply to Bargo. North of Bargo River, the DN150 steel gas main transitions to a DN160 PE pipe. This pipe can be squeeze off in an emergency thus isolating the affected gas main over the mining subsidence zone. Note that gas supply to Picton will be affected when the valve is closed and/or the PE pipe is squeezed off. An alternate gas supply will be required to avoid prolonged outage to customers while the affected section of the gas main is repaired.

The present analysis assumed the pipe has a constant depth of cover of 750 mm. It is recommended that the actual depth of cover of the pipe over the mine subsidence zone to be determined. Higher pipe stress will result if the depth of cover is much higher than 750 mm when the pipe is deformed. A low depth of cover means the upheaval buckling may occur especially when the pipe is exposed in a trench with not much depth of cover on either ends of the trench. It will also be useful to check if the pipe is buried in a rock trench or not. It will have implications regarding the pipe responding to abrupt ground movement and trench excavation for mitigation purpose.

If there are faults/dykes that intersect the pipe alignment, relative movement across these discontinuities or weak zones may occur due to stress redistribution in the rock as coal extraction progresses. This would cause an abrupt ground deformation affecting the pipe stress. It is recommended that a geological mapping along the pipe alignment to be carried out to determine if the pipe intersects any of these geological features.

The present analysis assumed the pipe is defect free and no wall thickness loss. It will be prudent to check with Jemena regarding the current condition of the gas main.

It is recommended nearby below ground and above ground services along the pipe alignment be located. Their presence can affect the excavation size and procedure if trenching to expose the pipe is required to mitigate the pipe stress.

2 Introduction

Tahmoor Coal Pty Ltd (SIMEC Group) has requested Advisian (Worley Group) to carry out an investigation of the mine subsidence impact on the Jemena's DN150 steel gas main at Bargo, NSW, which will be undermined by LW S1A to S6A as shown in Figure 2-1. The ground movement associated with the mined longwalls can potentially affect the structural integrity of the pipe.

The main objectives of the investigation are to:

- Perform stress analysis of the buried steel gas main under the design operating condition and subjected to the predicted ground movement
- Assess the pipe stress against the code (AS/NZS 4652.2: 2018) requirements
- Provide potential mitigation solutions if the pipe stress exceeds the code requirement
- Provide input such as trigger levels in the Mine Plan which is being prepared by MSEC
- Provide technical advice to the Gas Team for risk assessment purposes

This report provides results of the gas main due to LW S1A and LW S2A mining. It will be updated when subsidence prediction for the remaining longwalls, LW S3A to LW S6A, is available.

This report presents details of the methodology, inputs, assumptions, results, discussion, conclusions and recommendations.

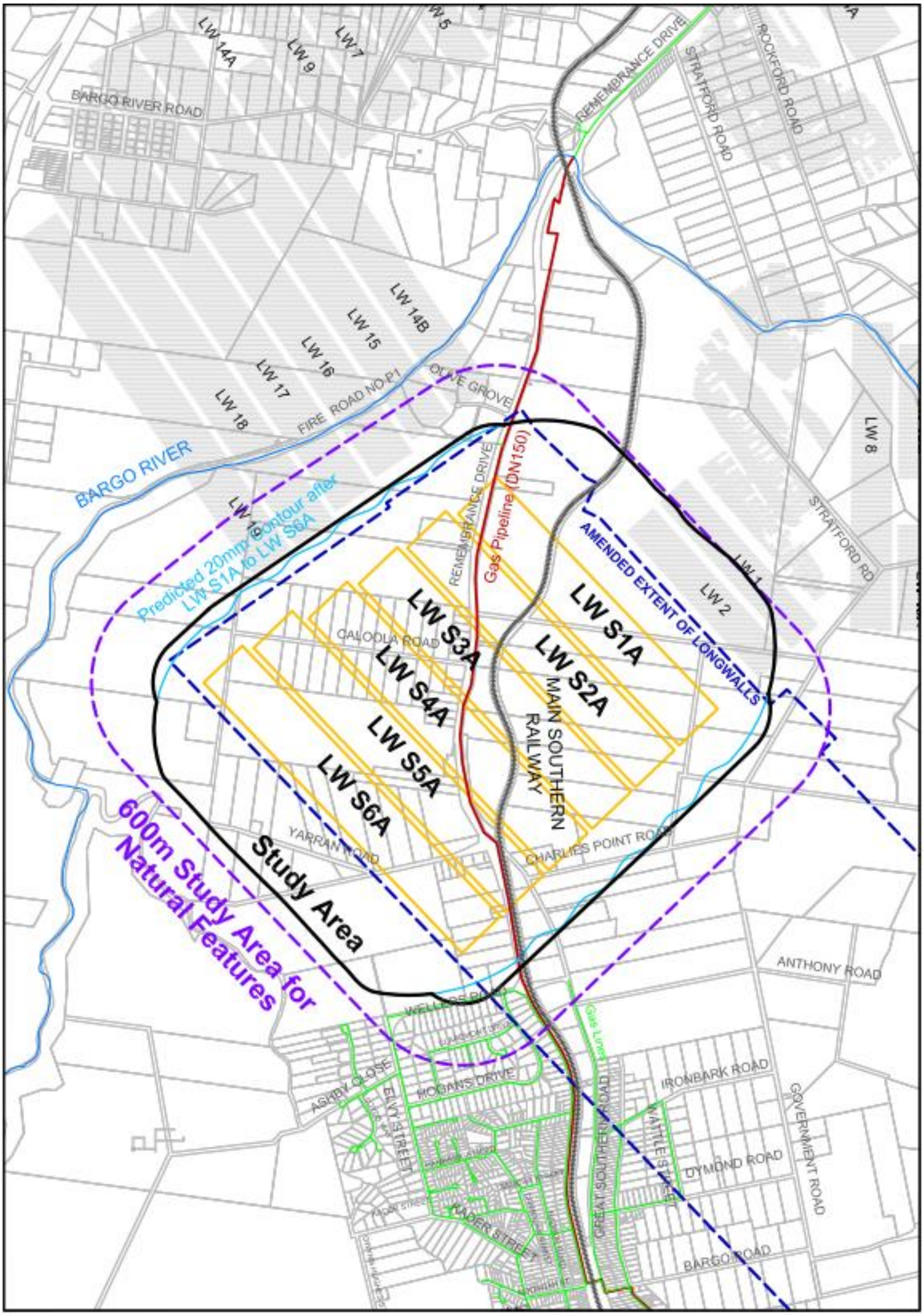

Figure 2-1: Proposed longwall layout. The DN150 gas mine is along Remembrance Drive (Source: MSEC)

3 Scope of Work and Methodology

The following tasks were carried out for the investigation:

1. Gather and review supplied information
2. Set up the DN150 pipe model over the mine subsidence region
3. Perform a series of pipe stress analyses based on the predicted 3D ground movements
4. Assess pipe stress against the relevant requirements in AS/NZS 4652.2: 2018.
5. Recommend mitigation solutions if pipe stress exceeds code allowable limit
6. Implement mitigation solutions in the pipe model for proof of concept
7. Provide technical information to the Mine Plan and the Gas Team to manage the risk

The modelling and pipe stress analysis will be performed using the finite element software, Abaqus, which is licensed to Advisian. Consistent SI units were used in the software: that is, length (m), mass (kg), time (s), force (N), temperature (°C), pressure and stress (Pa).

3.1 Information review

3.1.1 Pipe data

The following information was supplied by Jemena:

- Route layout
- Pipe data (e.g. dimensions, wall thickness and operating pressure)
- Pipe trench
- Pipe bends

The pipe data is summarized in Table 3-1. The provided information was used to create the finite element piping model.

Table 3-1: Pipe Data

Item	Units	Values
Design code	-	AS/NZS 4645.2
Nominal Size	DN	150
Pipe Outer Diameter	mm	168.3
Year Constructed	-	1994
Product Transported	-	Natural Gas
MAOP	kPa.g	1050
Current MOP	kPa.g	300
Pipe Material	-	API 5L X42
SMYS	MPa	290
UTS	MPa	415
Thickness	mm	4.8
Pipe Coating	-	Yellow jacket
Location Class	-	Rural/Residential
Depth of Cover	mm	750
Corrosion Allowance	mm	0
Temperature range covered by AS 4652.2	ºC	-30 to 60

3.1.2 Reference temperature

The reference temperature is used to calculate the longitudinal pipe stress when the buried pipe undergoes thermal expansion or contraction caused by thermal effect due to temperature change. The temperature change is the difference between the content temperature and the temperature of the pipe when it was first installed.

The average monthly air temperature data at the nearest weather station (Picton) was obtained from the Bureau of Meteorology (BOM). This was to estimate the reference temperature of the pipe when it was constructed in 1994. Unfortunately, the BOM data did not have data for that year. Nevertheless, from all the recorded data, the mean annual temperature is 16.2ºC which is calculated from the mean annual maximum temperature of 23.5ºC and the mean annual minimum temperature of 8.8ºC. Considered the relatively shallow depth of cover (750 mm) of the pipe, the reference temperature of the pipe can be similar to the air temperature. Since the duration and season of the pipe installation is not known (except for the year), the mean annual temperature was adopted as the reference temperature.

3.1.3 Operating temperature

The steel gas main is designed to AS 4645.2 which covers operating temperature range of the materials from -30ºC to 60ºC. A positive temperature differential will result in a high pipe stress. It is unlikely the gas temperature will be at 60ºC because the Moomba to Sydney Pipeline has a normal operating pressure of 6.5 MPa and an operating temperature of about 20ºC. Note that the nearest compressor station is at Young more than 200 km west of Bargo. It is reasonable to assume the gas temperature at Bargo will be similar to the soil temperature. Furthermore, the regulator at the off-take reduces the pressure from 6.5 MPa to a maximum pressure of 1.05 MPa (note that the current maximum operating pressure is 300 kPa), this pressure reduction process means the gas temperature in the gas main will be lower than the temperature in the transmission line.

If a reference temperature of 16ºC is assumed, then the positive temperature differential will only be about +5ºC or so. Considering the temperature uncertainties, it is reasonable to assume a +15ºC temperature differential in the study. A hypothetical case of +44ºC (i.e. 60ºC – 16ºC) was also considered in the analysis for sensitivity purpose. Note that a negative temperature differential will cause longitudinal tension in the pipe which is not critical for the combined stress.

3.1.4 Predicted ground subsidence

The following information was supplied by Mine Subsidence Engineering Consultants (MSEC):

- Predicted 3D ground movement along the DN150 pipe alignment for a series of longwall panels including the progression within each longwall. Figure 3-1 and Figure 3-2 show the progressive ground deformation along the gas pipe for LW S1A and LW S2A respectively.

The figures are for conventional subsidence.

At this stage, as the non-conventional subsidence or ground movement is not known, only limited analysis was performed on a straight and horizontal pipeline that was subject to a step ground deformation, that is:

- A vertical drop – a fault type ground deformation
- A lateral shear

The pipe stress was computed as a function of the ground movement. The ground movements corresponding to various pipe stress levels can be used as trigger levels in the Mine Plan.

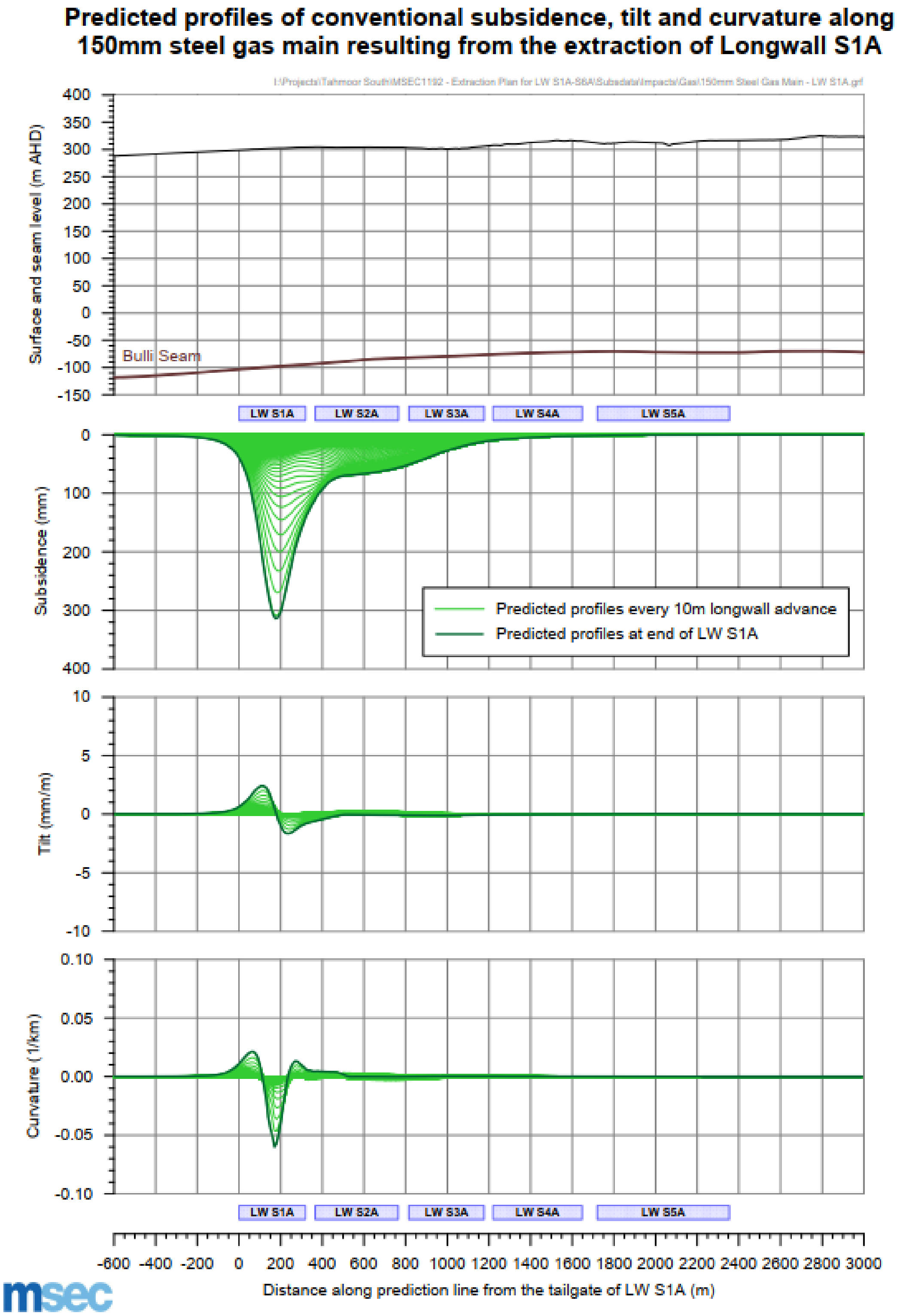

Figure 3-1: Predicted ground deformation along DN150 gas main for LW S1A (Source: MSEC)

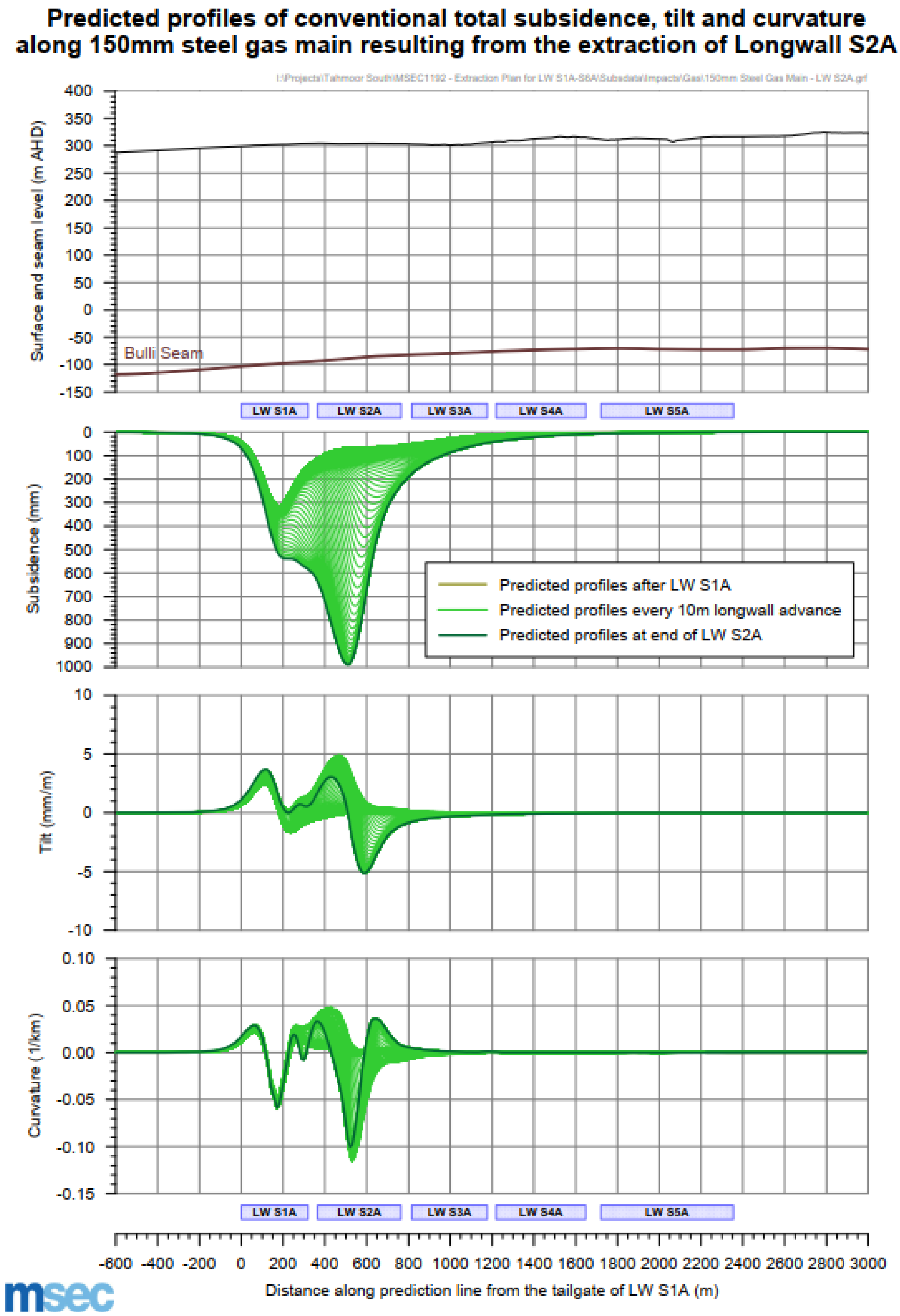

Figure 3-2: Predicted ground deformation along DN150 gas main for LW S2A (Source: MSEC)

3.2 Pipe Stress Analysis

The pipe stress analysis of the DN150 steel gas main was performed in two parts: (1) manual calculations, and (2) finite element analysis.

The manual calculations were to determine the stress state for a long straight pipe operating under internal pressure and a temperature differential. The manual calculation results were also used to validate the finite element analysis results.

The finite element model considered the geometric layout of the pipeline (i.e. pipe bends and direction changes), the nonlinear pipe-soil interaction, 3D ground deformation in addition to the internal pressure and temperature effect. Note that the pipe was assumed to be defect free and no wall thickness loss.

3.2.1 Manual Calculations

A preliminary assessment using manual calculations has been performed for the affected pipeline. The total stress in the pipe is contributed by the following mechanisms that were considered in the calculations:

1. Internal pressure
2. Temperature effects

The manual calculation was performed using the design condition of the pipe. Details are provided in the following sections.

3.2.1.1 Stresses caused by internal pressure

The hoop or circumferential stress, σ_{hoop}, caused by internal pressure is given by:

$$\sigma_{hoop} = P\,(D/2t) \qquad (1)$$

where P = internal pressure = MAOP = 1.05 MPa

D = outer diameter of pipe

and t = wall thickness

For a buried pipe being constrained by soil, the axial or longitudinal stress, σ_L, caused by Poisson's ratio effect is:

$$\sigma_L = \nu\,\sigma_{hoop} \qquad (2)$$

where ν = Poisson's ratio = 0.3.

3.2.1.2 Temperature effects

The longitudinal stress, $\sigma_{L\theta}$, caused by temperature effects on a buried pipe is calculated by:

$$\sigma_{L\theta} = E\,\alpha\,(\theta_1 - \theta_0) \qquad (3)$$

where E = pipe stiffness

α = coefficient = of thermal expansion

θ_1 = operating temperature

and θ_0 = reference temperature

3.2.1.3 Combined stress

The above equations will be combined to give the total longitudinal stress and hoop stress at the location of interest. The von Mises stress, σ_{vm}, which will be used for assessment later, can then be calculated by:

$$\sigma_{vm}=\sqrt{\{½[(\sigma_h-\sigma_L)^2+(\sigma_L-\sigma_r)^2+(\sigma_r-\sigma_h)^2]\}} \quad (4)$$

where σ_h = total hoop stress

σ_L = total longitudinal stress

and σ_r = radial stress.

The radial stress on the inner surface is the internal pressure (compressive). The radial stress on the outer surface of the pipe can assume to be practically zero.

3.2.2 Finite Element Analysis

The 5.8 km of the DN150 pipe over the mine subsidence zone and beyond was modelled. The pipe was represented by a series of 2-node pipe elements of about 0.2 m in length. The depth of cover was modelled using the Pipe-Soil Interface (PSI) elements which represent a series of soil springs along the length of the pipeline. These PSI elements are provided in the Abaqus software for modelling nonlinear pipe-soil interaction in accordance with the methodology provided in the American Lifeline Alliance (2001). The assumed backfill properties for the pipe trench are as follows:

- Unit weight of fill = 20 kN/m^3
- Friction angle = 35^o (assumed a dense sand which is a conservative assumption)
- Cohesion = 0 kPa
- Coating factor = 0.6 (polyethylene)

The pipe stress analysis involved nonlinear geometry effects and nonlinear soil springs. The pipe material was assumed to be linear elastic. This can be modelled with nonlinear stress-strain behaviour to consider yielding and strain-hardening if required after examining the computed pipe stresses.

The pipe material properties adopted in the study are shown in Table 3-2.

The transient ground movements along the pipeline predicted by MSEC were mapped to the corresponding soil nodes in the model.

The following analysis steps were performed:

1. Apply gravity
2. Apply internal pressure

3. Apply temperature effect (max or min effects)
4. Apply the predicated ground movement in a series of ground movement profiles corresponding to the coal extraction of LWS1A to LWS2A.

Where the pipe stress is found to be at its peak but not exceeding the allowable limit, the ground movement for that instance will be increased gradually until the pipe stress reached or exceeded the allowable limit.

If the pipe stress is found to exceed the allowable stress, then the following mitigations can be analysed using the model:

- Reduce the internal pressure
- Reduce the depth of cover along the affected section of the pipe
- Exposed the pipe to decouple the ground strain from the pipe along the affected length

Table 3-2: Pipe material properties

Properties	Units	Values
Young's modulus	MPa	200,000
Poisson's ratio	-	0.3
Density	Kg/m^3	7850
Coefficient of thermal expansion	/C	0.0000117

3.3 Assessment Criteria

3.3.1 Allowable Stress

The pipe was designed to AS 4645.2 which states that the hoop stress shall not be greater than 20% SMYS of the pipe. In this case, SMYS = 290 MPa, and 20% SMYS = 58 MPa. The code does not provide guidance on the longitudinal stress or the combined stress (i.e. von Mises stress).

When the pipe is deformed by the ground, the stress state should consider the change in longitudinal stress in addition to the hoop stress. Although AS 4645.2 only considers the allowable limit for hoop stress, it mentions that "*steel piping systems for gas outside these limits are generally covered by the AS 2885 suite of Standards and for some jurisdictions*". The longitudinal stress in the restrained pipe can be caused by a combination of thermal effect, Poisson's ratio effect, longitudinal bending and strain caused by ground deformation.

In accordance to AS 2885.1 the stress limits for a restrained pipe are:

- Longitudinal stress: 90% SMYS (i.e. 261 MPa)
- Combined stress: 90% SMYS (i.e. 261 MPa)

The allowable stress limits in Table 3-3 are used to assess the pipe stress subject to subsidence.

Table 3-3: Allow stress limits

Stress	Allowable (% SMYS)	Allowable (MPa)	Reference
Hoop	20	58	AS 4645.2
Longitudinal	90	± 261	AS 2885.1
Combined (von Mises)	90	261	AS 2885.1

3.3.2 Allowable Compressive Strains

When the pipe undergoes differential settlement, the pipe will bend and compressive strains will develop at the location. Local buckling (wrinkle) can occur if the compressive strain is large enough. In order to prevent local buckling failure from occurring, the longitudinal compressive strain is limited to the following ALA (2001) critical strain equation:

$$\varepsilon_{cr} = 0.5\frac{t}{D'} - 0.0025 + 3000\left(\frac{pD}{2Et}\right)^2 \qquad (5)$$

where ε_{cr} = critical compressive strain

t = wall thickness = 4.8 mm

p = internal pressure

E = elastic modulus of the steel pipe material = 200,000 MPa

D = outer pipe diameter = 168.3 mm

and D′ = imperfection factor for ovalisation and it is given by:

$$D' = \frac{D}{1 - \frac{3}{D}(D - D_{min})} \quad (6)$$

where D_{min} = minimum outer diameter of an ovalized pipe cross-section.

The above equation was proposed by Gresnigt (1986) that was based on available experimental results, and valid for local buckling failure mode with small or insignificant external pressure. The effect of ovalisation on the equation is relatively minor and D_{min} = D is often assumed.

If D_{min} = D is assumed, the critical compressive strains for the various internal pressures are shown in Table 3-4. It can be seen that the critical compressive strains are not too sensitive to the internal pressure. The values in the table will be used for assessment purposes.

Table 3-4: Critical compressive strains

Internal pressure (MPa g)	Critical compressive strains (%)
0 (empty)	1.1760
0.3	1.1762
1.05	1.1786

4 Manual Calculation Results

The component stresses for the different internal pressures and temperature effects are summarized in Table 4-1. Note that no ground movement has been considered in the calculations and the effects of pipe bends have been ignored. These results are to show the baseline condition for a long straight length of the buried pipe prior to any mine subsidence effect.

It can be seen that when the pipe is operating at MAOP, the hoop stress is well below the allowable limit of 20% SMYS. The longitudinal stress is mainly influenced by the thermal effects. The compressive longitudinal stress gives the highest von Mises stress. However, they are both below 90% SMYS for all the temperature differentials considered.

When the pipe is operating at 0.3 MPa, the hoop stress is much reduced. However, the thermal effect can still cause a high longitudinal stress resulting in a high von Mises stress. Both stresses are below 90% SMYS. Figure 4-1 shows two stress states graphically. Plotted in the figure are the various allowable limits. It can be seen that even with a reduced internal pressure, the von Mises stress as represented by the envelop is of the same size as the one with internal pressure of 1.05 MPa.

The internal pressure needs to increase to 3.308 MPa to cause the hoop stress to reach 20% SMYS. Both the longitudinal stress and von Mises stress are still below 90% SMYS. Note that this is a fictious case because the gas main was designed and operated not to exceed 1.05 MPa internal pressure.

Table 4-1: Pipe stress results - manual calculation

Internal pressure (MPa)	Hoop stress (MPa) [% SMYS]	Longitudinal stress (MPa) [% SMYS]			Radial stress (MPa)	Von Mises stress (MPa) [% SMYS]	Comments
		Poisson's ratio effect	Temperature effect	Total			
1.05	18.41 [6.3%]	5.52 [1.9%]	-102.96 [35.5%]	-97.44 [33.6%]	-1.05	107.45 [37.1%]	MAOP with dT=+44ºC
1.05	18.41 [6.3%]	5.52 [1.9%]	-35.10 [12.1%]	-29.58 [10.2%]	-1.05	41.80 [14.4%]	MAOP with dT=+15ºC
1.05	18.41 [6.3%]	5.52 [1.9%]	32.76 [11.3%]	38.28 [13.2%]	-1.05	34.06 [11.7%]	MAOP with dT=-14ºC
0.3	5.26 [1.8%]	1.58 [0.5%]	-102.96 [35.5%]	-101.38 [35.0%]	-0.3	103.97 [35.9%]	Operating pressure with dT=+44ºC
0.3	5.26 [1.8%]	1.58 [0.5%]	-35.10 [12.1%]	-33.52 [11.6%]	-0.3	36.32 [12.5%]	Operating pressure with dT=+15ºC
0.3	5.26 [1.8%]	1.58 [0.5%]	32.76 [11.3%]	34.34 [11.3%]	-0.3	32.22 [11.1%]	Operating pressure with dT=-14ºC
3.308	58 [20.0%]	17.4 [6.0%]	-102.96 [35.5%]	-85.56 [29.5%]	-3.308	124.76 [43.0%]	Pressure that causes hoop stress to reach 20% SMYS, dT=+44ºC
3.308	58 [20.0%]	17.4 [6.0%]	-35.10 [12.1%]	-17.7 [6.1%]	-3.308	69.62 [24.0%]	Pressure that causes hoop stress to reach 20% SMYS, dT=+15ºC
3.308	58 [20.0%]	17.4 [6.0%]	32.76 [11.3%]	50.16 [17.3%]	-3.308	57.78 [19.9%]	Pressure that causes hoop stress to reach 20% SMYS, dT=-14ºC

Notes:

1. -ve stress is compressive stress.
2. No pipe bends considered.

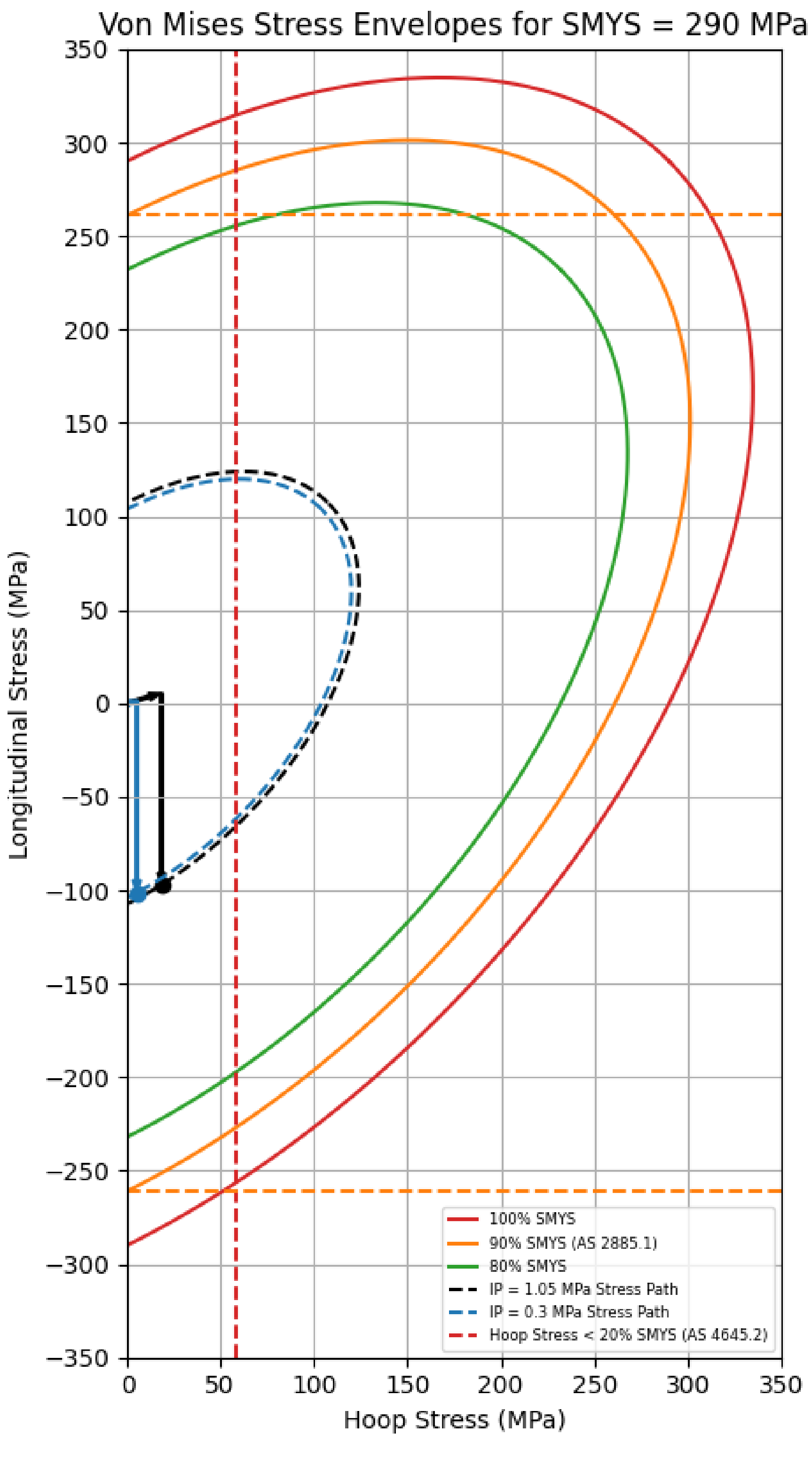

Figure 4-1: Stress plot showing the stress paths the two internal pressure cases with dT=+44°C. The allowable limits are also illustrated

5 FEA Results and Assessment

5.1 Prior to Mine Subsidence

The von Mises stress for internal pressure of 1.05 MPa (MAOP) with the maximum positive temperature differential prior to mine subsidence is shown in Figure 5-1. A closer view of the pipe stress is shown in Figure 5-2. In both figures, there are many stress spikes which are an artifact of the discretization of the geometry model. That is, the geometry was created using coordinates at 10 m intervals. The stress spikes can be reduced by further smoothing of the pipe alignment geometry. In Figure 5-2, the theoretical pipe stress is shown in green and it can be seen the FE model results match this very well when not considering the artificial stress spikes. Therefore, away from significant pipe bends we will interpret the computed results based on the “average” or “trend” rather than stress spikes.

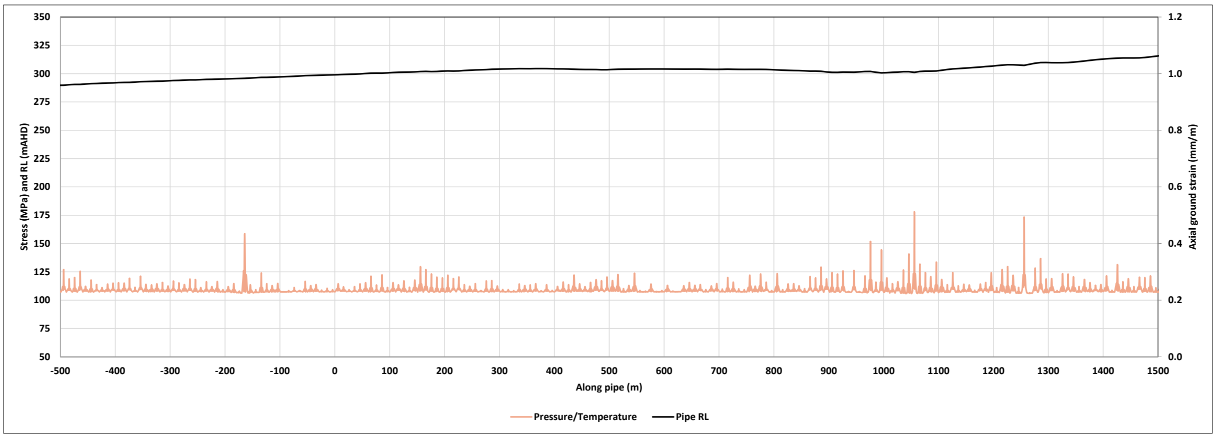

Figure 5-1: von Mises stress (IP = 1.05 MPa, dT = +44 deg C)

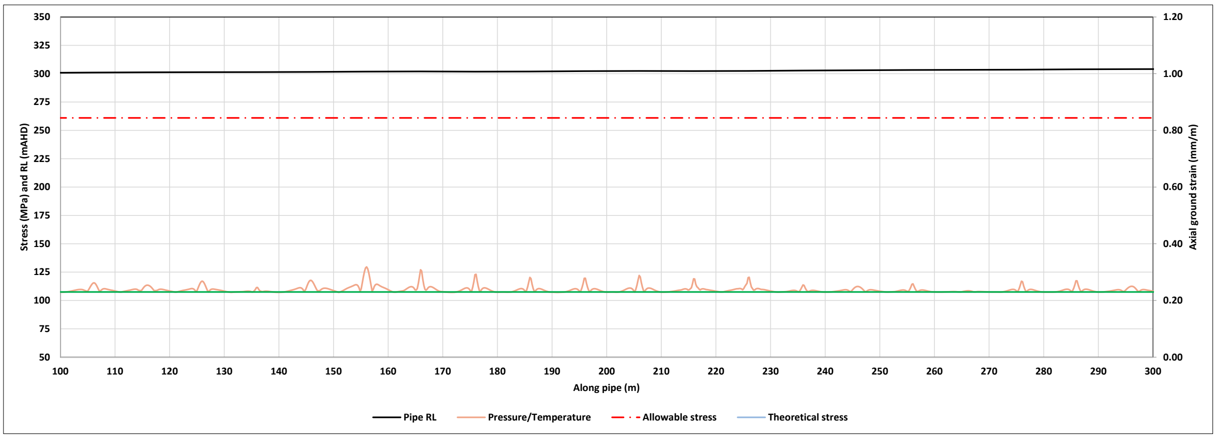

Figure 5-2: von Mises stress (IP = 1.05 MPa, dT = +44 deg C) – closer view between chainage 100 and 300.

5.2 LW S1A Subsidence Impact

For LW S1A, the predicted maximum settlement is 309 mm and the peak compressive ground strain along the pipe is -0.9 mm/m. This peak ground strain occurs at the location of maximum settlement. Note that the "worst" situation for the pipe is when it is operating at MAOP with a maximum positive temperature differential. The situation with a lower internal pressure (i.e. 300 kPa) with a maximum negative temperature differential will result in lesser pipe stress.

Figure 5-3 and Figure 5-4 show the pipe stress (von Mises) distribution at the end of LW S1A mining. It can be seen that the peak pipe stress occurs where the peak compressive ground strain is, and it also coincides with the settlement trough. The computed stresses and strains are summarized in Table 5-1. These values are all within their respective allowable limits.

Table 5-1: Pipe stress and strain results – end of LW S1A

Internal pressure (MPa)	Temperature differential (ºC)	Peak von Mises stress (MPa) [% SMYS]	Peak compressive stress (MPa) [% SMYS]	Peak compressive axial strain
1.05	+44	188 [65%]	177 [61%]	0.089%
1.05	+15	112 [39%]	110 [38%]	0.055%
0.3	+44	175 [60%]	175 [60%]	0.088%

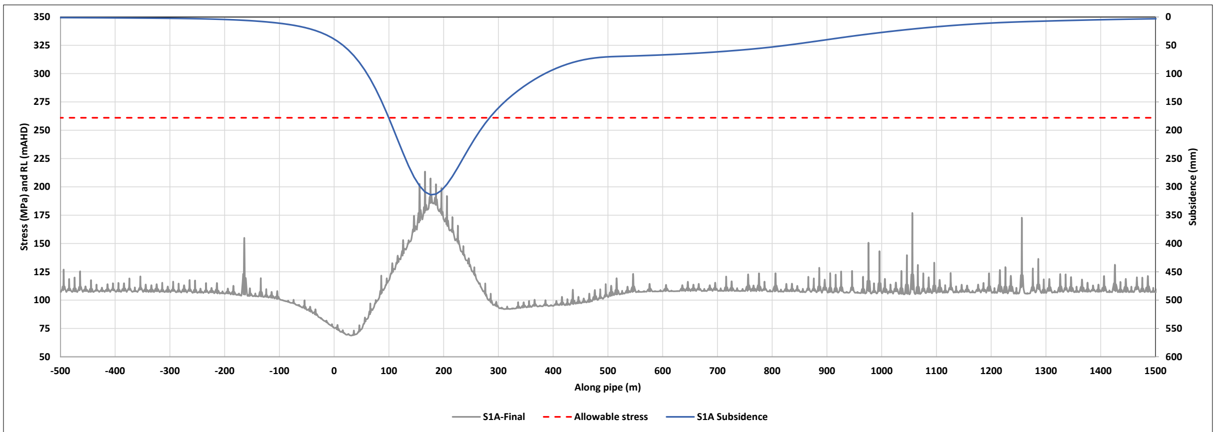

Figure 5-3: Pipe stress and predicted ground subsidence - end of LW S1A

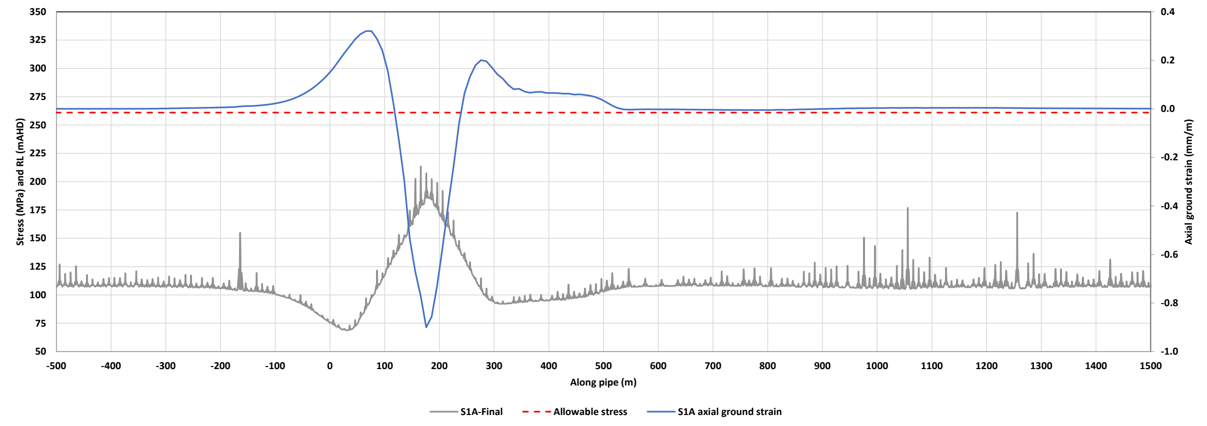

Figure 5-4: Pipe stress and predicted axial ground strains - end of LW S1A

5.3 LW S2A Subsidence Impact

For LW S2A, the predicted maximum settlement is 989 mm and the peak compressive ground strain along the pipe is -1.5 mm/m. This peak ground strain occurs at the location of maximum settlement. The settlement trough at approximate chainage 180 m, which occurs during LW S1A mining, subsided by a small amount. This is also true for the compressive ground strain at the location.

Figure 5-5 and Figure 5-6 show the pipe stress (von Mises) distributions during three longwall progressions: LW S2A-1560, LW S2A-1720 and end of LW S2A mining. The internal pressure is at MAOP with a temperature differential of +44ºC. It can be seen that the peak pipe stress occurs where the peak compressive ground strain is. That is, at approximately chainage 525m. The computed stresses and strains are summarized in . maximum pipe stress is 211 MPa (73% SMYS), the maximum compressive axial stress is -205 MPa (71% SMYS), and the maximum compressive axial strain is – 0.1%. These values are all within their respective allowable limits.

Table 5-2: Pipe stress and strain results – end of LW S2A

Internal pressure (MPa)	Temperature differential (ºC)	Peak von Mises stress (MPa) [% SMYS]	Peak compressive stress (MPa) [% SMYS]	Peak compressive axial strain
1.05	+44	211 [73%]	205 [71%]	0.10%
1.05	+15	140 [48%]	134 [46%]	0.067%
0.3	+44	203 [70%]	203 [70%]	0.10%

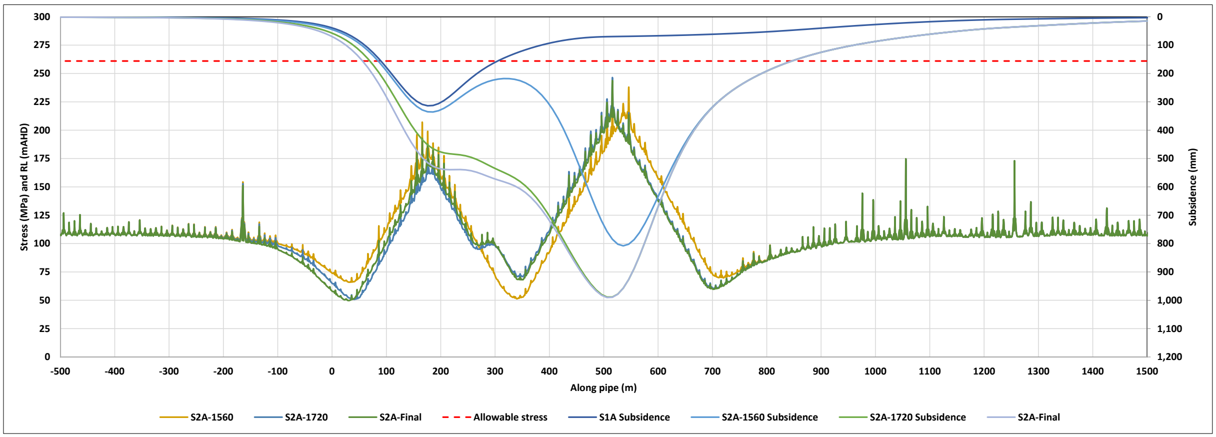

Figure 5-5: Pipe stress and predicted ground subsidence - LW S2A

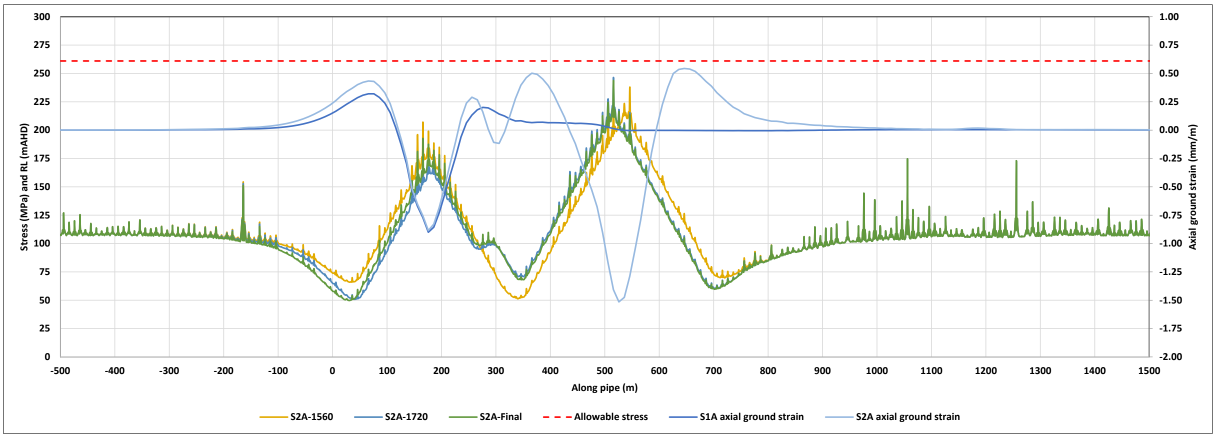

Figure 5-6: Pipe stress and predicted axial ground strains - LW S2A

5.4 Compressive axial ground strains

Further analyses were performed to track the development of pipe stress when the axial compressive ground strain increases while the subsidence remains unchanged. The pipe stress presented as percentage of SMYS as a function of compressive ground strains along the pipe is shown in Figure 5-7 and Figure 5-8 for LW S1A and LW S2A respectively. The values are summarized in Table Table 5-3.

It can be observed that for the same temperature differential, reducing the internal pressure has a minor effect on the pipe stress as it is dominated by the axial stress as shown in Figure 4-1.

The starting point has some influence on the amount of axial compressive ground strain the pipe can handle. For example, at the end of LW S1A mining for a temperature differential of +15ºC, the pipe stress is at 39% SMYS and the compressive ground strain is at 0.9 mm/m. The pipe reaches the allowable stress limit of 90% SMYS when the compressive ground strain increases to about 30 mm/m. However, at the end of LW S2A, the pipe stress is at 48% SMYS with a compressive ground strain of -1.5 mm/m and a higher settlement (and differential settlement) of just under 1 m. The pipe can only tolerate another 21.5 mm/m compressive ground strain before the stress reaches 90% SMYS. The reason the pipe can tolerate such high ground strain is that the hoop stress is small (only 6.3% SMYS at MAOP) and the von Mises stress prior to mine subsidence is also small. Therefore, it can handle a much higher longitudinal stress caused as ground strain increases.

The computed pipe compressive strains are below the critical compressive strains meaning local buckling is unlikely to occur. The pipe deformation results also indicate global buckling is not occurring.

Using the pipe stress results of LW S1A and LW S2A (MAOP and +15ºC temperature differential), the influence of the radius of ground curvature and ground compressive axial strain on pipe stress is shown in Figure 5-9. The radius of ground curvature for LW S1A and LW S2A is about 16 km and 11 km respectively. The pipe stress at lesser radius of ground curvature may be inferred by linear extrapolation as shown in the figure. The gradient of the 70% SMYS below 11 km is adjusted based on engineering judgement.

Table 5-3: Compressive axial ground strains as a function of pipe stress for the cases considered

S1A-final					
IP=MAOP dT=+44		**IP=300kPa dT=+44**		**IP=MAOP dT=+15**	
Strains (mm/m)	**Stress (% SMYS)**	**Strains (mm/m)**	**Stress (% SMYS)**	**Strains (mm/m)**	**Stress (% SMYS)**
-0.9	65%	-0.9	60%	-0.9	39%
-1.35	70%	-1.58	70%	-10.35	70%
-3.83	80%	-4.05	80%	-20.26	80%
-10.8	90%	-11.7	90%	-30.16	90%
-28.81	100%	-36.01	100%	-45.01	100%

S2A-final					
IP=MAOP dT=+44		**IP=300kPa dT=+44**		**IP=MAOP dT=+15**	
Strains (mm/m)	**Stress (% SMYS)**	**Strains (mm/m)**	**Stress (% SMYS)**	**Strains (mm/m)**	**Stress (% SMYS)**
-1.14	70%	-1.14	70%	-1.51	48%
-1.51	75%	-1.51	73%	-8.33	70%
-2.65	80%	-3.03	80%	-13.63	80%
-6.06	90%	-6.82	90%	-22.72	90%
-11.74	100%	-12.5	100%	-37.87	100%

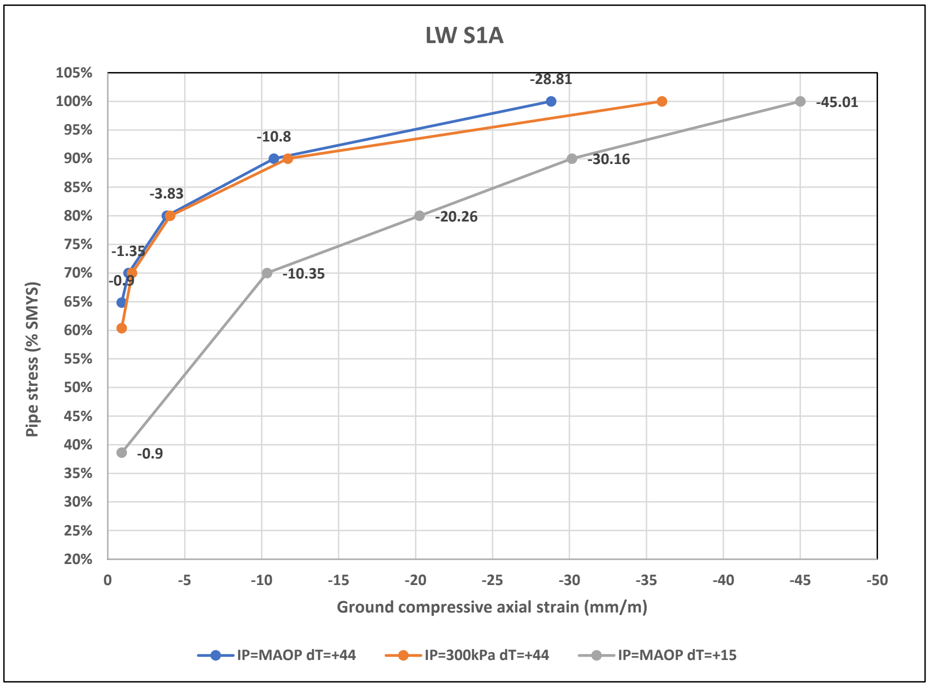

Figure 5-7: Pipe stress as a function of axial compressive ground strains with subsidence unchanged - LW S1A

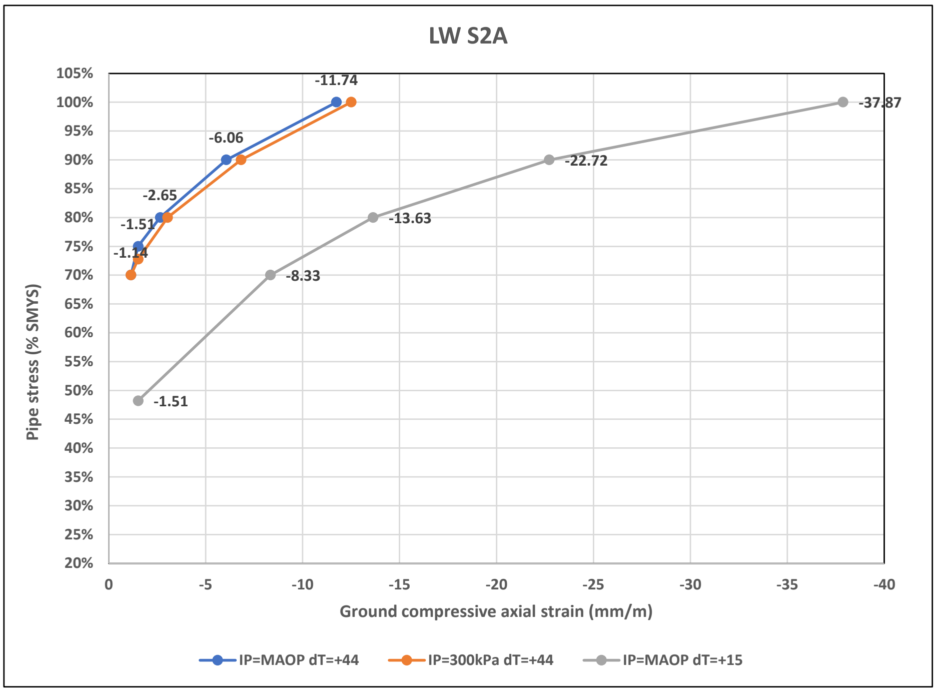

Figure 5-8: Pipe stress as a function of axial compressive ground strains with subsidence unchanged - LW S2A

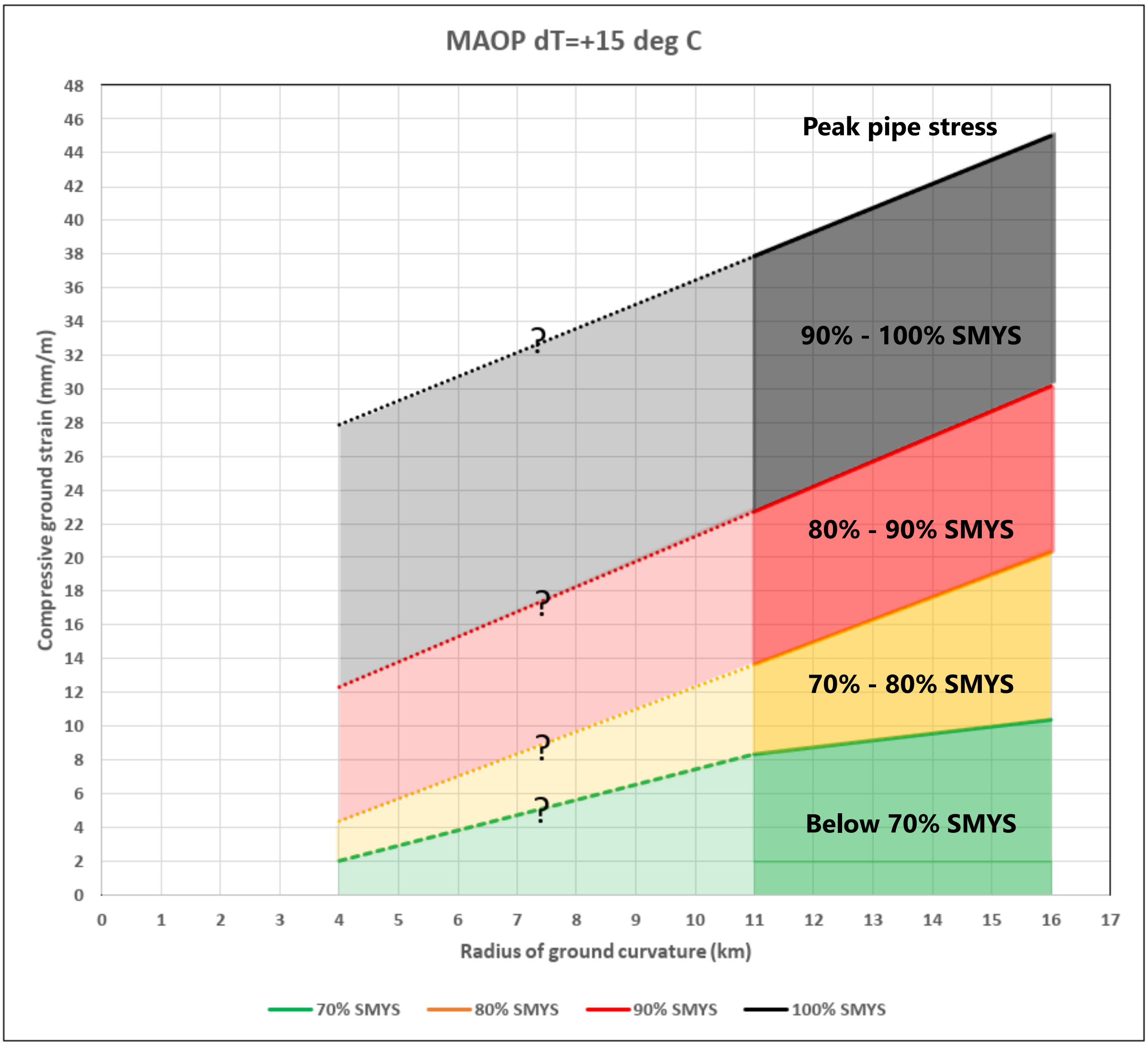

Figure 5-9: Pipe stress as a function of radius of ground curvature and compressive ground strain

5.5 Non-conventional Ground Movement

When there is a step change in the ground, bending and axial stresses develop in the pipe. Figure 5-10 shows the pipe stress as a function of vertical fault movement. Figure 5-11 shows the pipe vertical deflection and the von Mises stress distribution when the ground dropped by 100 mm across 0.25 m distance which is equivalent to a differential settlement of 400 mm over 1 m. Figure 5-12 shows the development of pipe stress as a function of lateral shear movement. Figure 5-13 shows the pipe lateral deflection and the von Mises stress distribution when the ground sheared laterally by 100 mm across 0.25 m distance which is equivalent to a differential lateral displacement of 400 mm over 1 m.

Table 5-4 summarises the step change magnitudes in the ground for the various pipe stress levels. It can be seen that the pipe stress reached the allowable code limit when the ground dropped by 85 mm (or 340 mm over 1 m), or when the ground sheared laterally by 93 mm (or 372 mm over 1 m).

Table 5-4: Pipe stress as a function of step ground movements

Pipe stress – von Mises stress		Vertical fault movement			Lateral shear movement		
(MPa)	(% SMYS)	(mm)	(mm/m)	Approx. Gradient	(mm)	(mm/m)	Approx. Gradient
203	70	57	228	1 : 4.4	65	260	1 : 3.8
232	80	70	280	1 : 3.6	78	312	1 : 3.2
261	90	85	340	1 : 2.9	93	372	1 : 2.7
290	100	100	400	1 : 2.5	110	440	1 : 2.3

Note: MAOP & +15ºC thermal differential

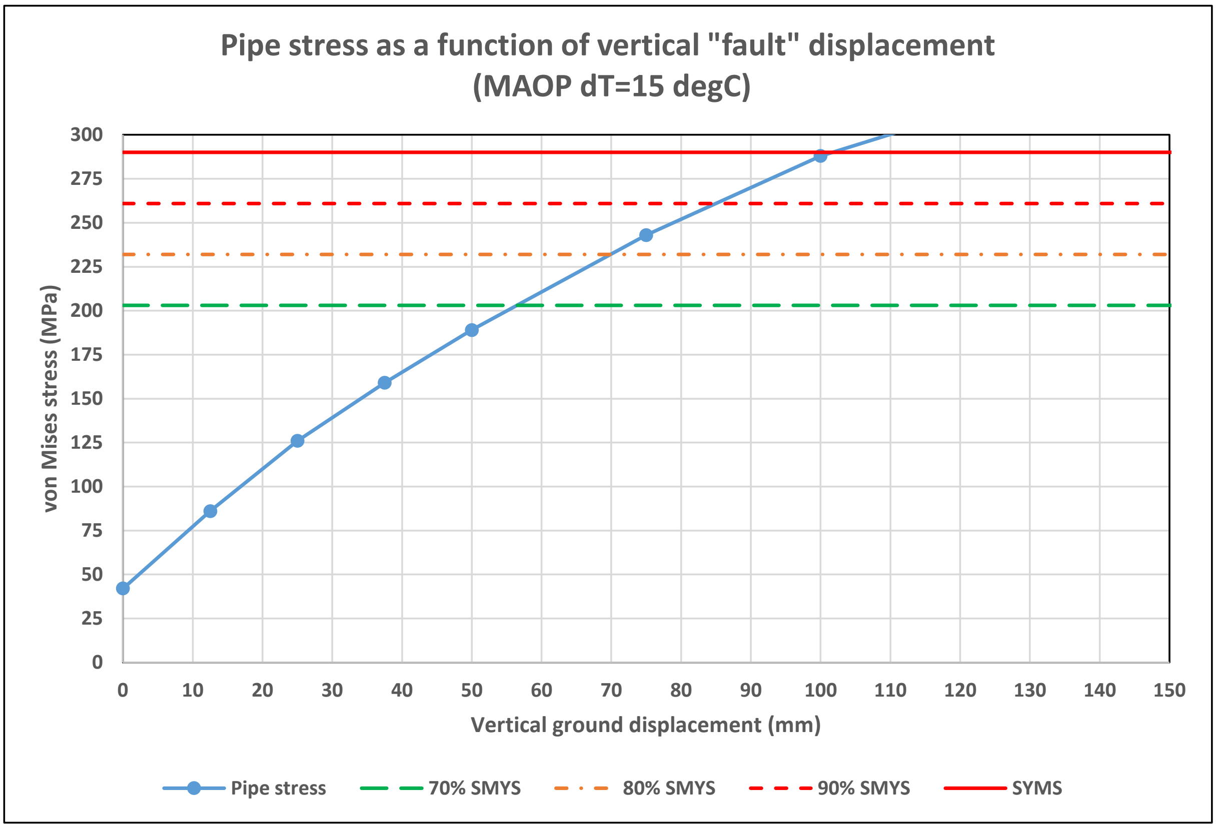

Figure 5-10: Pipe stress as a function of vertical fault displacement

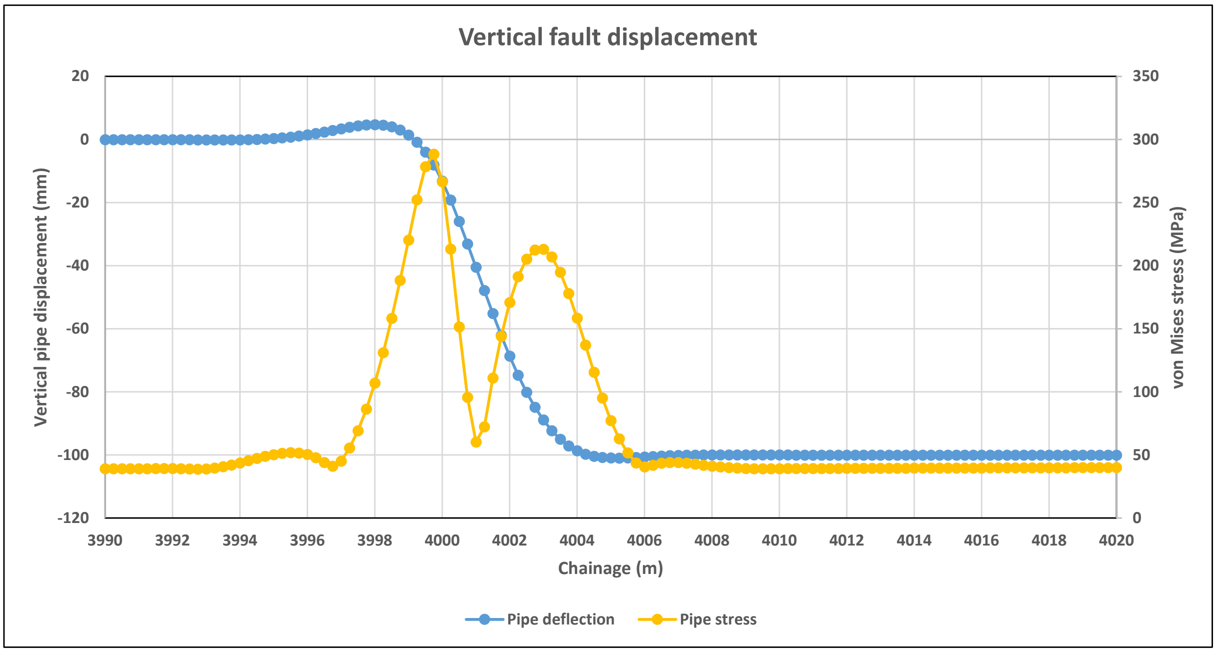

Figure 5-11: Pipe stress and deflection – 100 mm vertical fault movement

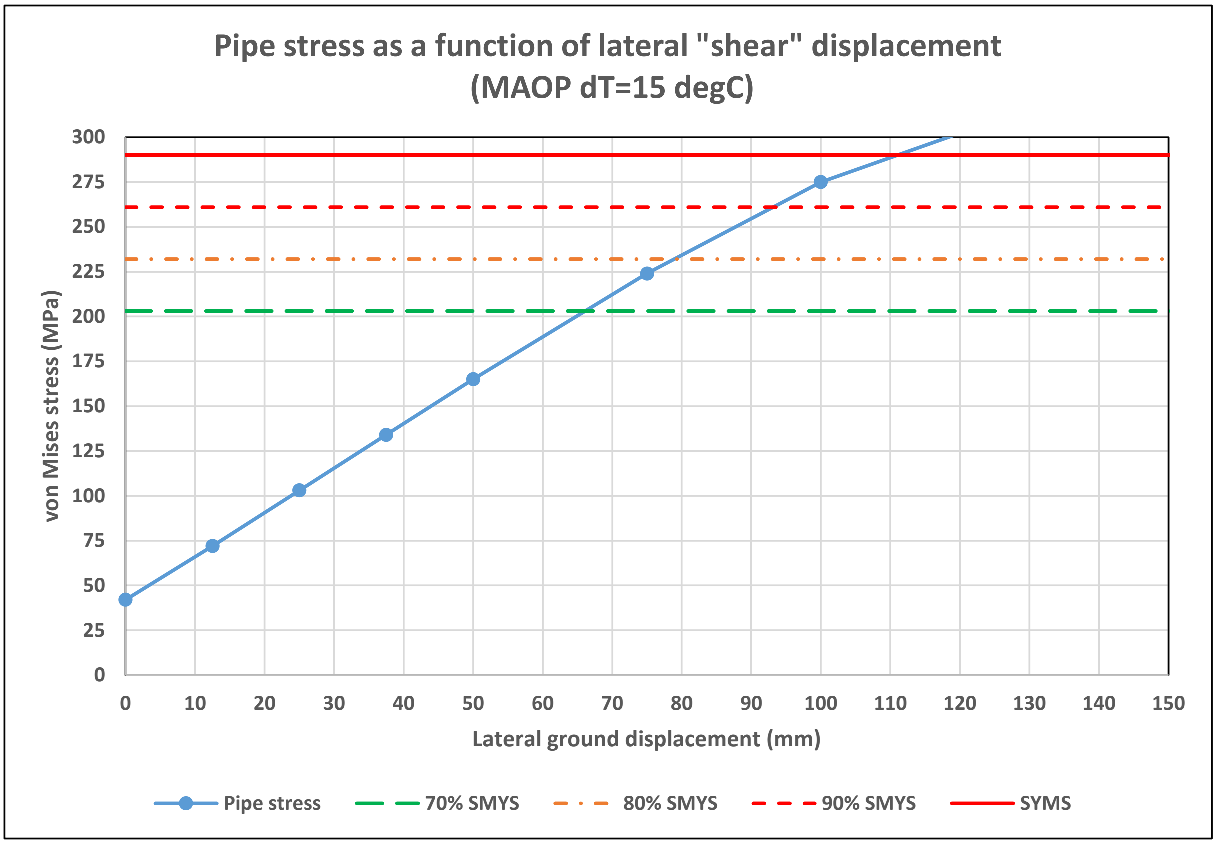

Figure 5-12: Pipe stress as a function of lateral shear displacement

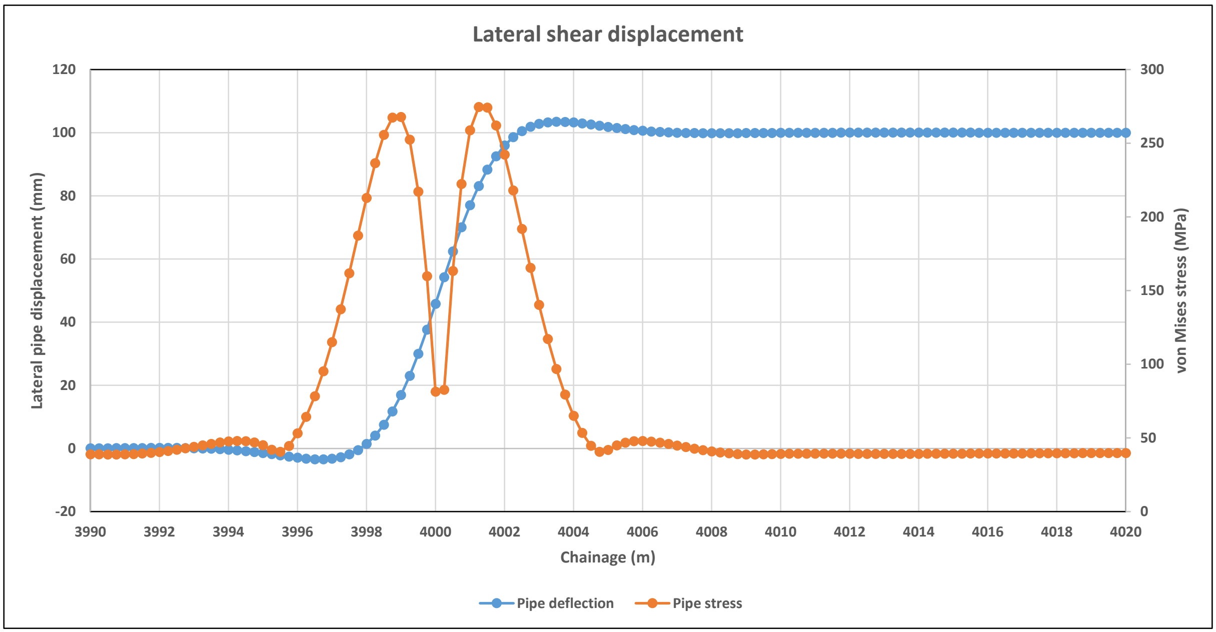

Figure 5-13: Pipe stress and deflection – 100 mm lateral shear movement

6 Risk Management and Mitigation Options

The analysis results indicate that the DN150 steel gas main will not be affected by the predicted subsidence of LW S1A and LW S2A. Survey of ground deformation along the pipe should be conducted as mining progresses. However, if the actual subsidence, in particular, the compressive ground strains, exceeds the prediction, then mitigation may be required. Note that reducing the operating pressure will not be an effective mitigation as it only reduces the hoop stress and not enough for the axial stress.

In order to manage the risk to the gas main cause by mine subsidence, a trigger action response plan should be developed. Table 6-1 shows a suggested plan. The green trigger corresponds to the pipe stress below 70% SMYS. The amber trigger is for pipe stress between 70% and 80% SMYS. The red trigger is when the compressive ground strain causes the pipe stress to reach 80% to 90% SMYS and beyond.

For conventional subsidence the zones indicated in Figure 5-9 can be used to define the ground strain triggers for a range of radius of ground curvature. We suggest the trigger levels for LW S2A should be re-evaluated after LW S1A is completed. If the survey data is significantly different from the prediction, then LW S2A subsidence to be re-predicted and the ground strain triggers to be determined from a revised pipe stress analysis.

For non-conventional subsidence a blue trigger of 2 mm/m ground strain is suggested so that a more frequent monitoring and a finer survey resolution to be implemented to confirm the presence of step change or valley closure/upsidence at creek crossings.

Table 6-1: Suggested trigger action response plan for LW S1A and LW S2A

	Blue	Green	Amber	Red
Pipe stress		**Less than 70% SMYS**	**Between 70 & 80% SMYS**	**Above 80% SMYS**
Conventional Subsidence **Compressive ground strain trigger for LW S1A**	-	Less than 10 mm/m Use Figure 5-9 for radius of curvature is less than 16 km	10 to 20 mm/m Use Figure 5-9 for radius of curvature is less than 16 km	20 to 30 mm/m and above 30 mm/m Use Figure 5-9 for radius of curvature is less than 16 km
Conventional Subsidence **Provisional compressive ground strain trigger for LW S2A**	-	Less than 8 mm/m Use Figure 5-9 for radius of curvature is less than 11 km	8 to 14 mm/m Use Figure 5-9 for radius of curvature is less than 11 km	14 to 23 mm/m and above 23 mm/m Use Figure 5-9 for radius of curvature is less than 11 km
Non-Conventional Subsidence: Vertical step change (fault) **Differential step movement**	Compressive ground strain approaching 2 mm/m	Less than 228 mm/m	228 to 280 mm/m	280 to 340 mm/m and above 340 mm/m
Non-Conventional Subsidence: Lateral step change (shear) **Differential step movement**	Compressive ground strain approaching 2 mm/m	Less than 260 mm/m	206 to 312 mm/m	312 to 372 mm/m and above 372 mm/m
Responses:	Review survey data to detect and confirm sustained irregularity in subsidence/ground deformation profile	Continue monitoring	Review survey data	Mining to stop
	If required, increase monitoring frequency in order to observe a trend and closing peg spacing to obtain a better movement resolution across the step change or irregularity	If required, increase monitoring frequency in order to observe a trend	Review and evaluate pipe performance	Review survey data and evaluate pipe performance
	Continue mining	Meeting with stakeholders to decide if further actions are required with respect to non-conventional subsidence	Meeting with stakeholders to decide if further actions are required	Meeting with stakeholders to decide if mitigation is required, and if so select the appropriate mitigation option
		Continue mining	Continue mining as per outcome of the meeting	Implementation of the selected mitigation
				Continue mining after the mitigation has been implemented

The following mitigation options should be considered:

1. Expose a section of the affected pipe in a trench such that it is decoupled from the ground strain
2. Shut off the gas main such that the internal pressure becomes zero

Further analysis will be required to determine the pipe length needs to be exposed. In addition, the exposed pipe will need to be properly supported such that it will not buckle as the ground compresses at both ends.

In the unlikely event where the ground movement suddenly exceeds the red trigger or an unexpected large differential settlement, the affected pipe should be isolate by closing valves on either ends. The condition of the pipe will then be assessed for damage to determine if repair is required.

Based on the Jemena Dial Before You Dig pipe network diagram Figure 6-1, there is a valve located at the beginning of the DN150 steel gas main along Hawthorne Road Figure 6-2 not far from the Moomba to Sydney Pipeline off-take. This valve will not affect the gas supply to Bargo. There is an above-ground valve at the off-take that can shut off the supply to the DN150 gas main as well as shown in Figure 6-3 and Figure 6-4. Further to the north of Bargo River, the DN150 steel gas main transitions to a DN160 PE line as shown in Figure 6-5 . This can be squeeze off and together with closing the valve upstream at Hawthorne Road, the affected steel gas main over the mine subsidence zone will be isolated and the affected pipe can be inspected and repaired.

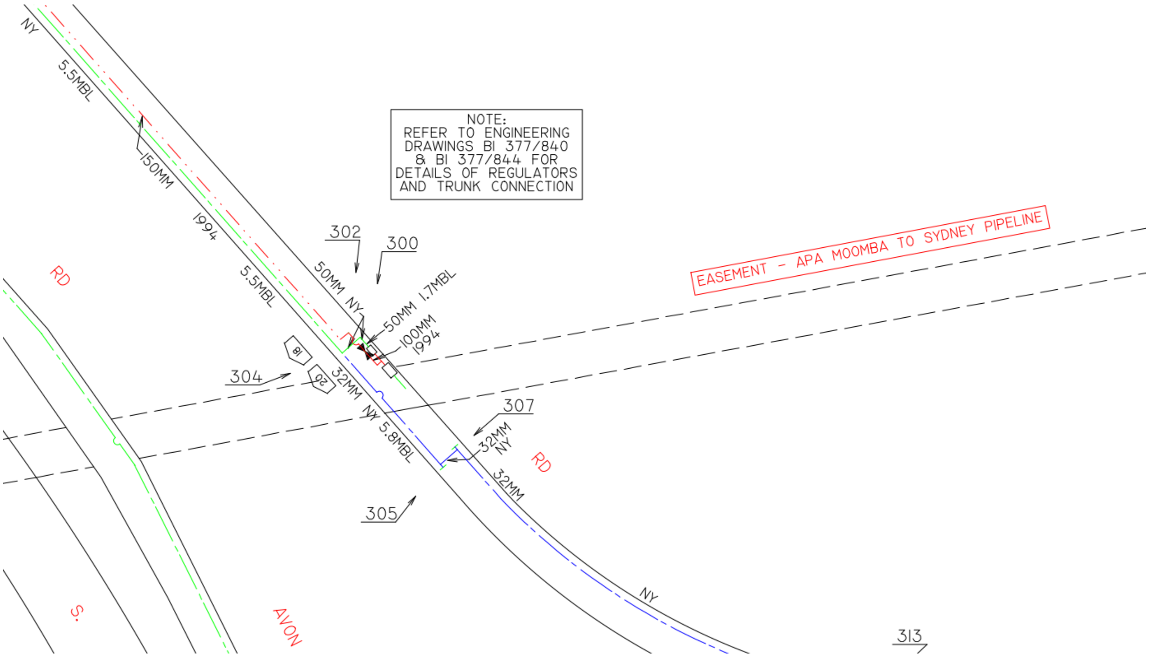

Figure 6-1: Pipe network close to the Moomba to Sydney Pipeline (Source: Jemena Dial Before You Dig).

Figure 6-2: Photo showing the below ground services at Hawthorne Road (Source: Google Street View).

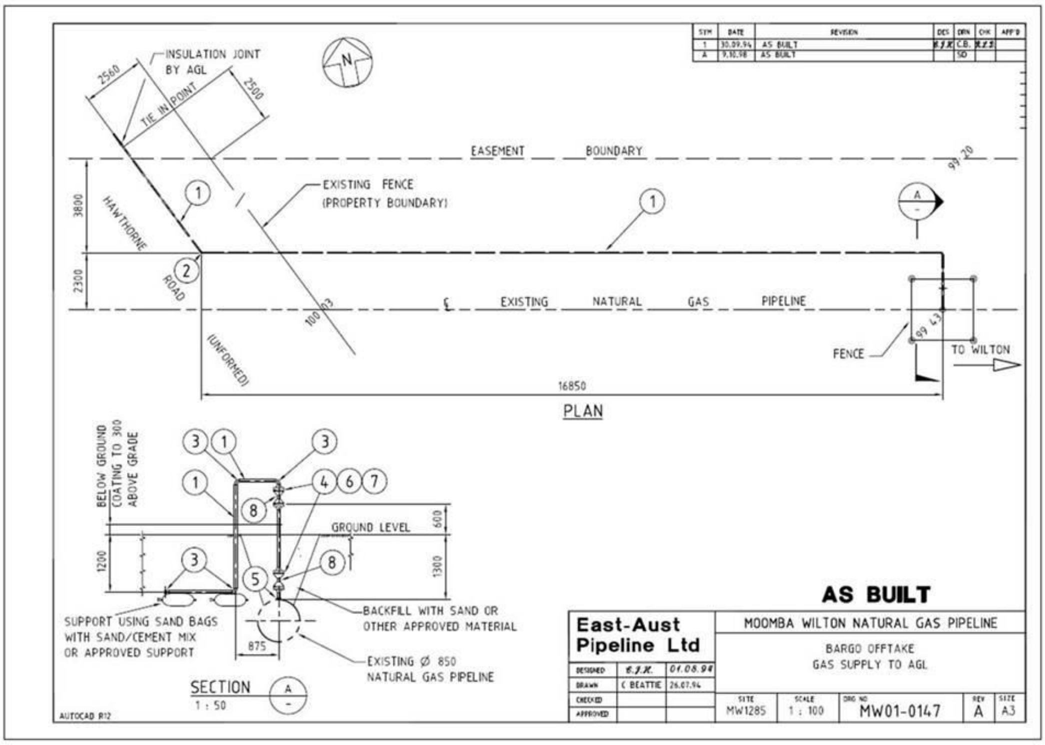

Figure 6-3: Diagram showing the Bargo offtake from the Moomba to Sydney Pipeline (Source: APA).

Figure 6-4: Photo of the Bargo offtake station at Hawthorne Road (Source: Google Street View).

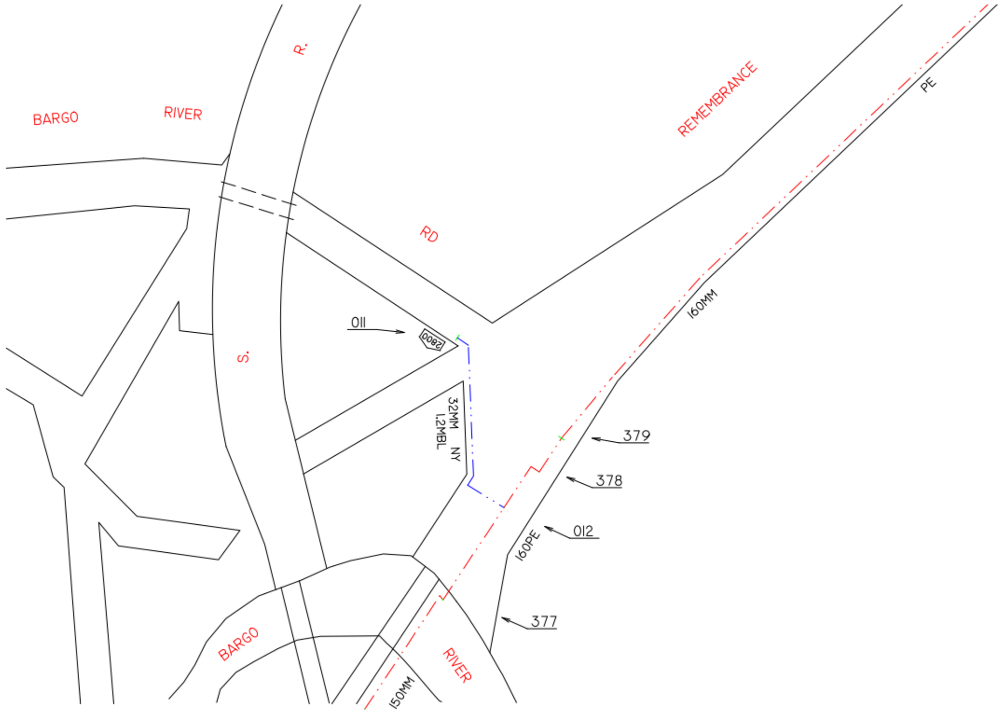

Figure 6-5: Pipe network north of Bargo River (Source: Jemena Dial Before You Dig).

7 Conclusions

Based on the findings of this study, the following conclusions are made:

1. The DN150 steel gas main when operates at the MAOP and a range of positive temperature differentials, the pipe stress and strains are within their respective allowable limits when subject to the predicted ground deformation caused by LW S1A and LW S2A mining.

2. The pipe stress is dominated by the axial compressive stress caused by the thermal effects and ground movements. Depending on the temperature differential, the internal pressure has no significant influence on the combined (von Mises) stress of the pipe.

3. When additional compressive strains by scaling up the predicted horizontal displacements uniformly are transferred to the pipe due to mine subsidence, for a reasonable temperature differential of +15°C, the pipe stress reaches the allowable limit when the compressive ground strain reaches 30 mm/m for LW S1A. For LW S2A, the compressive ground strain of 23 mm/m will cause the pipe to reach the allowable stress because of the reduce in radius of ground curvature effect.

4. For non-conventional subsidence such as a step change in the ground, the pipe reached the allowable stress limit when the ground settled by 85 mm over 1 m or the ground sheared laterally by 93 mm over 1 m.

8 Recommendations

The following recommendations should be considered:

1. The valve at the upstream end of the DN150 steel gas main located along Hawthorne Road can be closed to isolate the pipe within the mine subsidence zone so that gas can be shut off immediately when an unexpected ground deformation occurs that may lead to damage or rupture to the pipe. The DN160 PE gas main north of Bargo River can be squeeze off in an emergency and thus isolate the affected gas main over the mine subsidence zone. The damaged pipe can then be repaired.
2. Determine the actual depth of cover of the gas main within the mine subsidence zone. The present analysis assumed the depth of cover is 750 mm. If the actual depth of cover is much higher, then the pipe stress will be higher as the ground deforms. If the actual depth of cover is much less, there may be a potential for upheaval buckle to occur especially when the pipe is exposed in a trench to mitigate against step change or other non-conventional ground movement.
3. It will also be useful to check if the pipe is buried in a rock trench or not. It will have implications regarding the pipe responding to abrupt ground movement and trench excavation for mitigation purpose.
4. If there are faults/dykes that intersect the pipe alignment, relative movement across these discontinuities or weak zones may occur due to stress redistribution in the rock as coal extraction progresses. This would cause an abrupt ground deformation affecting the pipe stress. It is recommended that a geological mapping to be carried out along the pipe alignment to determine if the pipe intersects any of these geological features.
5. The present analysis assumed the pipe is defect free and no wall thickness loss. It will be prudent to check with Jemena regarding the current condition of the gas main.
6. Determine nearby buried and overhead services along the gas main within the mine subsidence zone in the event that the pipe needs to be exposed in a trench to uncoupled from ground deformation. Overhead power lines will limit the headroom for excavator/crane boom, and nearby buried services may affect the extent of trench.
7. Further pipe stress analysis can be performed to determine the length of pipe to be uncoupled from the ground. The exposed pipe will need to be properly supported to prevent buckling.

9 References

1. *American Lifelines Alliance (2001) Guidelines for the Design of Buried Steel Pipe.*
2. *AS/NZS 4645.2: 2018. Gas distribution networks Part 2: Steel pipe systems. Standards Australia.*
3. *AS 2885.1: 2018 – Pipelines – Gas and liquid petroleum Part 1: Design and construction. Standards Australia.*
4. *Gresnigt, A.M. (1986) Plastic Design of Buried Steel Pipelines in Settlement Areas. HERON, Vol. 31, No. 4, pp. 1-113.*

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Mine Subsidence Impact

Jemena DN150 Steel Gas Pipe

Tahmoor Coal Pty Ltd - SIMEC

18 August 2023

Project 311023-40903

Advisian
Worley Group

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PROJECT 311023-40903-AAG-REP-002: Mine Subsidence Impact Jemena DN150 Steel Gas Pipe

Rev	Description	Author	Review	Advisian approval	Revision date	Client approval	Approval date
0	For client review	DKH/ECKL D Ho/E Lo	PGD G Dominish	CWT C W Tan	18 Aug 23	N/A N/A	N/A

Table of contents

1 Executive summary

A 3D finite element model of the DN150 steel gas main was used to compute the pipe response caused by the predicted conventional mine subsidence of LW S1A to LW S6A at Tahmoor Mine. The peak pipe stress (von Mises) and longitudinal stress under the maximum allowable operating pressure of 1.05 MPa with a probable conservative temperature differential of +15°C and -16°C were computed using a revised pipeline model which has a more accurate geometric alignment and depth of cover based on potholing survey done in July 2022.

The pipe's Specified Minimum Yield Strength (SMYS) is used for assessment purpose. The allowable hoop stress is 20% SMYS (AS 4645.2:2018), the allowable combined stress (von Mises stress) is 90% SMYS (AS 2885.1:2018), and the allowable longitudinal or axial stress is 75% SMYS (AS 2885.1:2018).

The peak stress is caused by a combination of hoop stress and axial compressive stress in the affected section of the pipe where the maximum settlement or compressive ground strain occurs. It should be noted that the pipe stress is more sensitive to the axial compressive stress than to the hoop stress. The analysis showed for predicted conventional and non-conventional subsidence the hoop stress is well below the allowable limit.

A summary of the findings and suggested mitigations are provided in

Table 1-1. The trigger action response plan is provided in Table 8-1. The trigger levels in terms of the ground strain or differential ground movement corresponding to three levels of pipe stress (% SMYS) are provided in Table 8-1. The three pipe stress levels are: below 70% SMYS (green), between 70% and 80% SMYS (amber), and above 80% SMYS (red). The appropriate actions corresponding to each stress level are recommended in the table.

It is recommended that a "blue" trigger of 2 mm/m ground strain be used as an early warning that the ground at a particular location may undergo non-conventional ground movement such as a step change or valley closure/upsidence at creek crossings. More frequent and closer peg spacing may be required to confirm if the discontinuity is real and continue to deform. Mitigation measure such as exposing the pipe in a trench may be required.

The analysis results indicated that the pipe complied with the allowable stress and strain limits for the following predicted mining-induced ground movement:

- LW S1A to S2A conventional subsidence
- LW S4A to S6A conventional subsidence
- Total closure at Creek 1, Creek 2 and Creek 3. (see Figure 3-9 for their locations)

Mitigation is required for the following:

- LW S3A conventional subsidence – Sharp bend north of Teatree Hollow (expose pipe in a 50m (min) long trench)
- Total closure at Teatree Hollow – Expose pipe in a 50m (min) long trench)

Further analysis would be required at the creek crossings (i.e. Teatree Hollow, Creeks 1, 2 and 3) for the combined ground movement due to:

- Closure at the creek
- Upsidence at the creek
- Conventional subsidence

The above is to ensure the suggested trench mitigation for the sharp bend north of and at Teatree Hollow is adequate as upsidence has not been considered. For the other three creek crossings, the above analysis using the combined ground displacement would confirm if mitigation is required.

It is recommended that consideration be given to isolate the pipe section in the subsidence zone based on the operational requirements for the pipeline. This would allow isolation if the ground deforms significantly more than predicted or there is an unexpected abrupt ground movement such as a sinkhole or a shear fault deformation. Based on the "Dial Before You Dig" information, currently there is a shutoff valve at Hawthorne Road downstream of the Moomba to Sydney Pipeline off-take location which can be used for emergency shut down purpose. Note that this valve does not affect gas supply to Bargo. North of Bargo River, the DN150 steel gas main transitions to a DN160 PE pipe. This pipe can be squeezed off in an emergency thus isolating the affected gas main over the mining subsidence zone. Note that gas supply to Picton will be affected when the valve is closed and/or the PE pipe is squeezed off. An alternate gas supply will be required to avoid prolonged outage to customers while the affected section of the gas main is repaired.

If there are faults/dykes that intersect the pipe alignment, relative movement across these discontinuities or weak zones may occur due to stress redistribution in the rock as coal extraction progresses. This would cause an abrupt ground deformation affecting the pipe stress. It is recommended that a geological mapping along the pipe alignment to be carried out to determine if the pipe intersects any of these geological features.

The present analysis assumed the pipe is defect free and no wall thickness loss. The material used at the welds is stronger than the line pipe material. It will be prudent to check with Jemena regarding the current condition of the gas main and the welding procedure/specification.

It is recommended nearby below ground and above ground services along the pipe alignment be located. Their presence can affect the excavation size and procedure if trenching to expose the pipe is required to mitigate the pipe stress.

Alternative mitigation options should be considered if the trench width is limited by other constraints. For example, not sufficient width along the crest of the road embankment at Teatree Hollow.

Table 1-1: Summary of findings

Longwall subsidence [1]	Pipe stress compliance	Mitigation required?	Mitigation description	Comments
S1A conventional	Y	N	-	-
S1A-S2A non-conventional[2]	TBD	TBD	Compression hump to be considered. Mitigation details to be covered in a separate report	To be covered in a separate report
S2A conventional	Y	N	-	-
S3A conventional	N – sharp bend north of Teatree Hollow	Y	Expose pipeline in a 50m (min) trench south of the bend. Trench at least 1.4m wide to accommodate sideway pipe deflection. This trench may be required for creek closure and upsidence at Teatree Hollow.	Issues to address include but not limit to; proximity to road, trench width constraints, trench stability, flood prevention, upheaval buckling and reburial
S4A to S6A conventional	Y	N	-	As long as the high stress at the sharp bend north of Teatree Hollow has been mitigated
S2A to S6A Sudden step change	Refer to trigger levels in Table 8-1	Refer to response plan in Table 8-1	-	-
S2A to S6A Creek closure only (predicted total closure)[3]	N – Teatree Hollow	Y	Expose pipeline in a 50m (min) long trench at least 1.5m wide to accommodate pipe sideway deflection.	Issues to address include but not limit to; proximity to road, trench width constraints, trench stability, flood prevention, upheaval buckling and reburial Combined upsidence and conventional subsidence to be considered.
	Y - Creek 1	N	-	Combined upsidence and conventional subsidence to be considered.
	Y – Creek 2	N	-	Combined upsidence and conventional subsidence to be considered.
	Y – Creek 3	N	-	Combined upsidence and conventional subsidence to be considered.

Notes:
1 Based on predicted conventional subsidence and total creek closure provided by MSEC.
2 Road compression hump discovered at the end of LW S1A will be considered in a separate report.
3 Combined closure/upsidence/conventional subsidence to be analysed once a reasonable profile prediction is made by MSEC.

2 Introduction

Tahmoor Coal Pty Ltd (SIMEC Group) has requested Advisian (Worley Group) to carry out an investigation of the mine subsidence impact on the Jemena's DN150 steel gas main at Bargo, NSW, which will be undermined by LW S1A to S6A as shown in Figure 2-1. The ground movement associated with the mined longwalls can potentially affect the structural integrity of the pipe.

The main objectives of the investigation are to:

- Perform stress analysis of the buried steel gas main under the design operating condition and subjected to the predicted ground movement
- Assess the pipe stress against the code (AS/NZS 4652.2: 2018) requirements
- Provide potential mitigation solutions if the pipe stress exceeds the code requirement
- Provide input such as trigger levels in the Mine Plan which is being prepared by MSEC
- Provide technical advice to the Gas Team for risk assessment purposes

This report provides results of the gas main due to LW S1A to LW S6A mining. A limited cases of non-conventional mine subsidence were investigated.

The pipeline alignment and the depth of cover were surveyed and have been incorporated in the analysis model.

This report presents details of the methodology, inputs, assumptions, results, discussion, conclusions and recommendations.

This report supersedes the previous findings in Advisian's 2022 report.

The effect of the road compression hump on Remembrance Drive which occurred at the end of LW S1A mining on the gas main will be covered in a separate report.

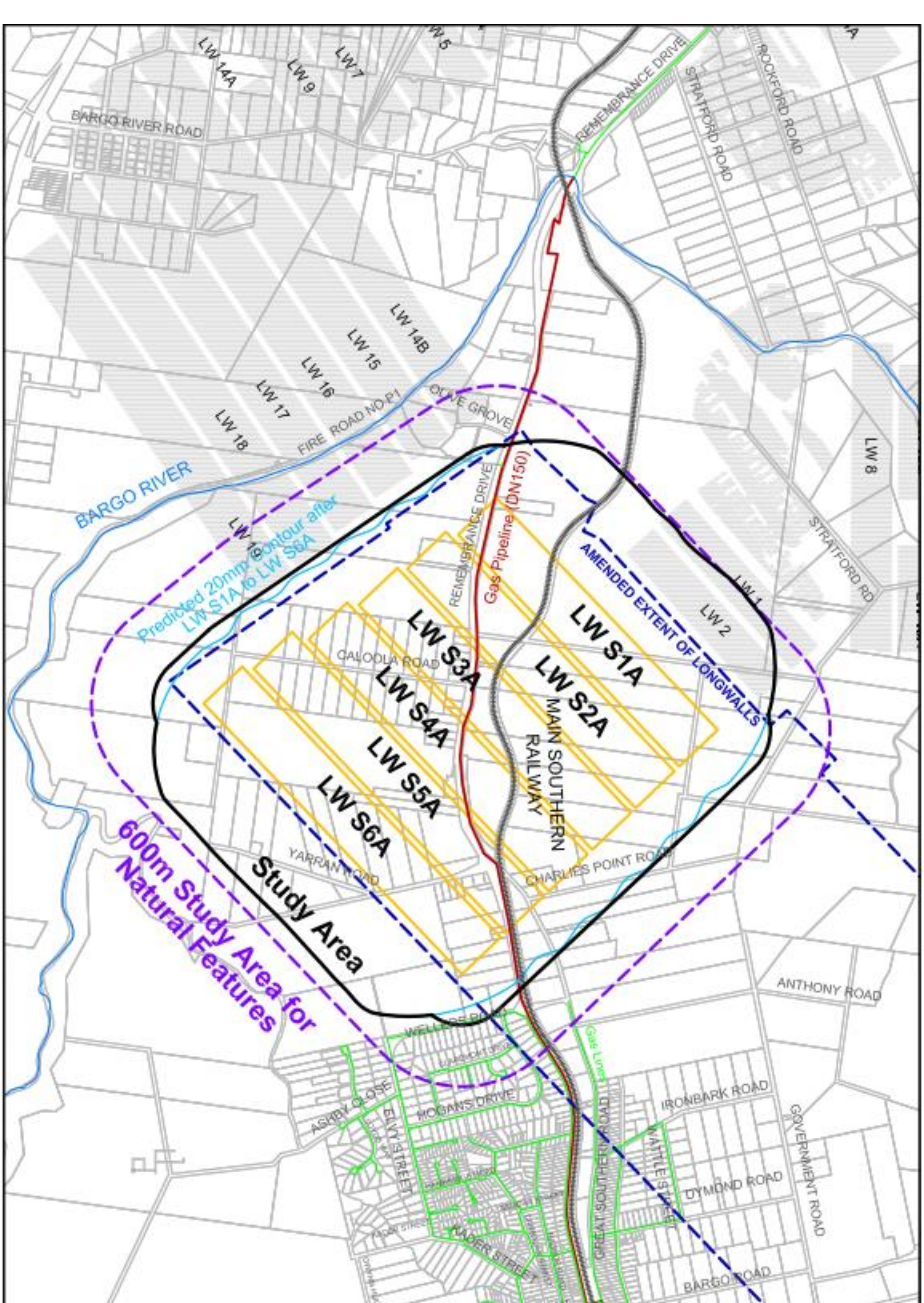


Figure 2-1: Proposed longwall layout. The DN150 gas mine is along Remembrance Drive (Source: MSEC)

3 Scope of Work and Methodology

The following tasks were carried out for the investigation:

1. Gather and review supplied information
2. Set up the DN150 pipe model over the mine subsidence region
3. Perform a series of pipe stress analyses based on the predicted 3D ground movements
4. Assess pipe stress against the relevant requirements in AS/NZS 4652.2: 2018.
5. Recommend mitigation solutions if pipe stress exceeds code allowable limit
6. Implement mitigation solutions in the pipe model for proof of concept
7. Provide technical information to the Mine Plan and the Gas Team to manage the risk

The modelling and pipe stress analysis will be performed using the finite element software, Abaqus, which is licensed to Advisian. Consistent SI units were used in the software: that is, length (m), mass (kg), time (s), force (N), temperature (°C), pressure and stress (Pa).

3.1 Information review

3.1.1 Pipe data

The following information was supplied by Jemena:

- Route layout
- Pipe data (e.g. dimensions, wall thickness and operating pressure)
- Pipe trench
- Pipe bends

The pipe data is summarized in Table 3-1. The provided information was used to create the finite element piping model.

Further information was provided by Tahmoor Coal based on a more accurate survey of the pipeline alignment and depth of cover along the route. They have been incorporated in the pipeline model for analysis.

Table 3-1: Pipe Data

Item	Units	Values
Design code	-	AS/NZS 4645.2
Nominal Size	DN	150
Pipe Outer Diameter	mm	168.3
Year Constructed	-	1994
Product Transported	-	Natural Gas
Maximum Allowable Operating Pressure (MAOP)	kPa.g	1050
Current Maximum Operating Pressure (MOP)	kPa.g	300
Pipe Material	-	API 5L X42
Specified Minimum Yield Strength (SMYS)	MPa	290
Ultimate Tensile Strength (UTS)	MPa	415
Thickness	mm	4.8
Pipe Coating	-	Yellow jacket
Location Class	-	Rural/Residential
Depth of Cover	mm	750 (minimum)
Corrosion Allowance	mm	0
Temperature range covered by AS 4652.2	°C	-30 to 60

3.1.2 Reference temperature

The reference temperature is used to calculate the longitudinal pipe stress when the buried pipe undergoes thermal expansion or contraction caused by thermal effect due to temperature change. The temperature change is the difference between the content temperature and the temperature of the pipe when it was first installed.

The average monthly air temperature data at the nearest weather station (Picton) was obtained from the Bureau of Meteorology (BOM). This was to estimate the reference temperature of the pipe when it was constructed in 1994. Unfortunately, the BOM data did not have data for that year. Nevertheless, from all the recorded data, the mean annual temperature is 16.2°C which is calculated from the mean annual maximum temperature of 23.5°C and the mean annual minimum temperature of 8.8°C. Considered the relatively shallow depth of cover of the pipe, the reference temperature of the pipe can be similar to the air temperature. Since the duration and season of the pipe installation is not known (except for the year), the mean annual temperature of 16°C was adopted as the reference temperature.

3.1.3 Operating temperature

The steel gas main is designed to AS 4645.2 which covers operating temperature range of the materials from -30ºC to 60ºC. A positive temperature differential will result in a high pipe stress. It is unlikely the gas temperature will be at 60ºC because the Moomba to Sydney Pipeline has a normal operating pressure of 6.5 MPa and an operating temperature of about 20ºC. Note that the nearest compressor station is at Young more than 200 km west of Bargo. It is reasonable to assume the gas temperature at Bargo will be similar to the soil temperature. Furthermore, the regulator at the off-take reduces the pressure from 6.5 MPa to a maximum pressure of 1.05 MPa (note that the current maximum operating pressure is 300 kPa), this pressure reduction process means the gas temperature in the gas main will be lower than the temperature in the transmission line.

If a reference temperature of 16ºC is assumed, then the positive temperature differential will only be about +5ºC or so. Considering the temperature uncertainties, it is reasonable to assume a +15ºC temperature differential in the study. Note that a negative temperature differential will cause longitudinal tension in the pipe which is not critical for the combined stress. However, the tensile longitudinal stress in the pipe will also be assessed.

The reduction in pressure at the off-take would lower the gas temperature. For this study, it was assumed the gas temperature could be as low as 0ºC. This gives a negative temperature differential of -16ºC.

The following temperature differentials were considered in the analysis:

- Positive thermal load: +15ºC temperature differential
- Negative thermal load: -16ºC temperature differential

3.1.4 Pipeline alignment and depth of cover

Pipeline route coordinates and depth of cover were provided by SIMEC). The pipeline model was modified accordingly. Plan views of the pipeline alignment are shown in Figure 3-1 to Figure 3-3. There are three locations where there are sharp bends:

- Location 1 (Approximate Northing 6206326 north of Teatree Hollow): bends connecting pipeline along the road crest and the pipeline along the base of the road embankment (see Figure 3-2)
- Location 2 (Approximate Northing 6205557, near "Creek 1" Figure 3-9) (see Figure 3-4)
- Location 3 (Approximate Northing 6205324, just south of Yarran Road) (see Figure 3-4)

The depth of cover along the pipeline is shown in Figure 3-5. It is higher than 750 mm which was assumed in the previous pipeline model. In general, the depth of cover is above 1 m. The maximum depth of cover is about 2.2 m.

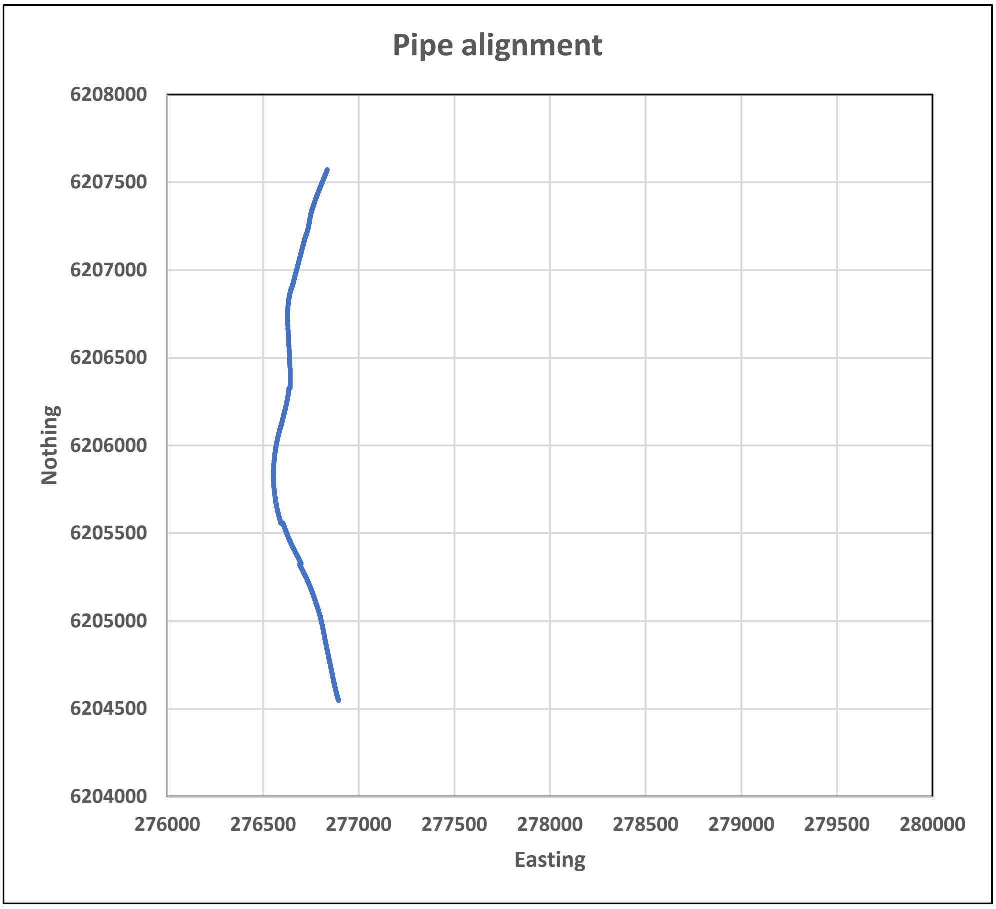


Figure 3-1: Plan view of the overall pipeline model

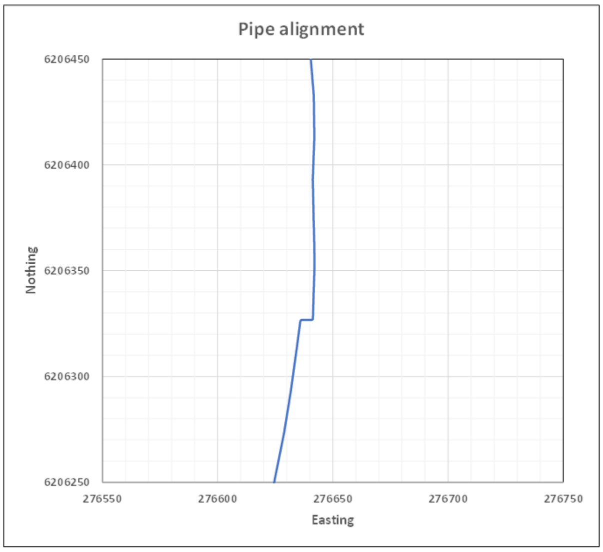


Figure 3-2: Plan view showing the sharp bends north of Teatree Hollow. Aerial photo showing Potholes #1267 and #1268 at the bends. Photo (below right) showing the buried pipe change in direction in the road embankment

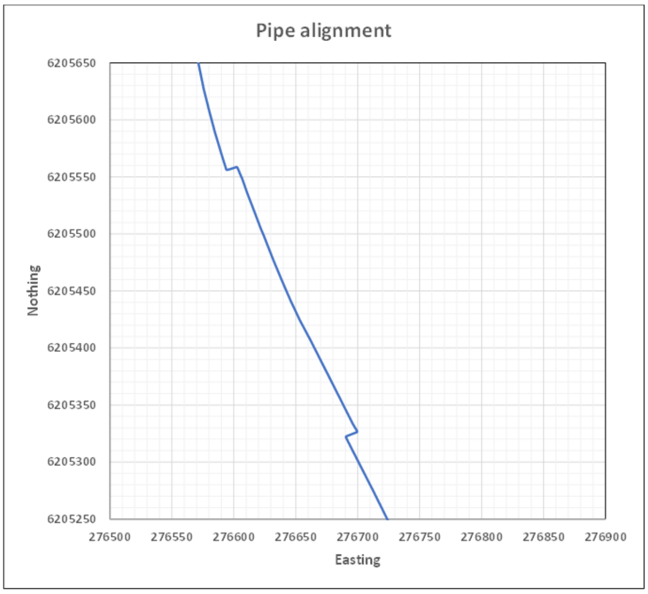


Figure 3-3: Plan view showing the sharp bend locations further south

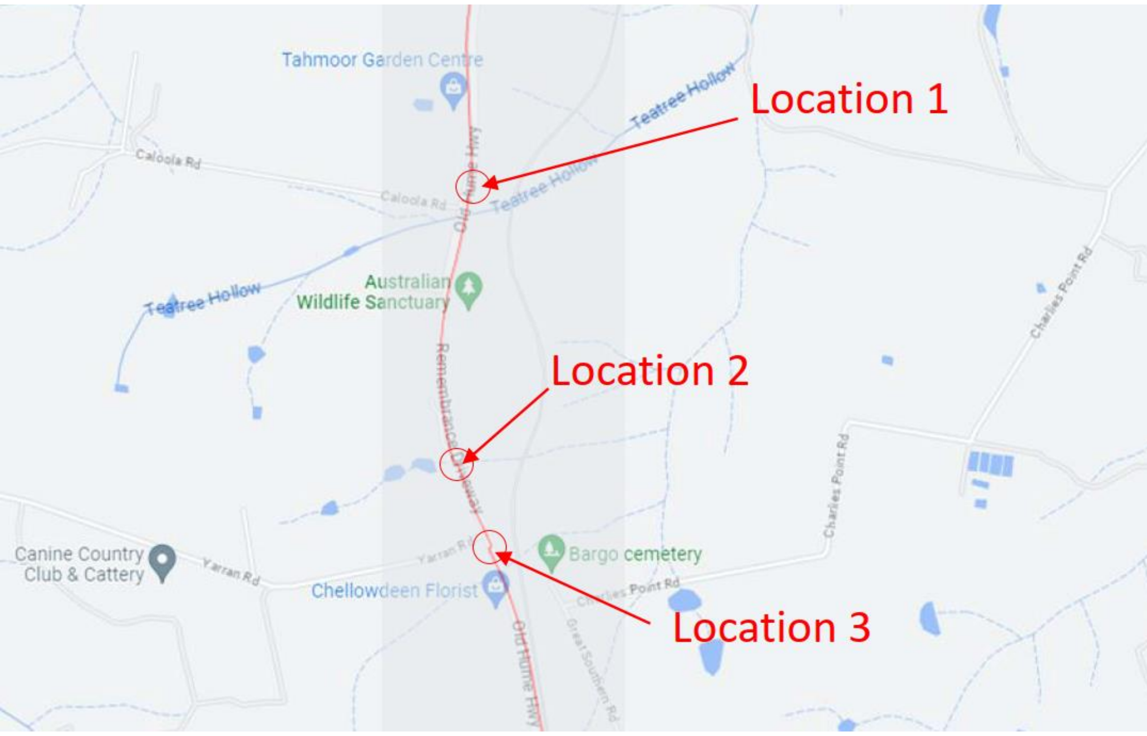


Figure 3-4: Plan view showing the sharp bend locations

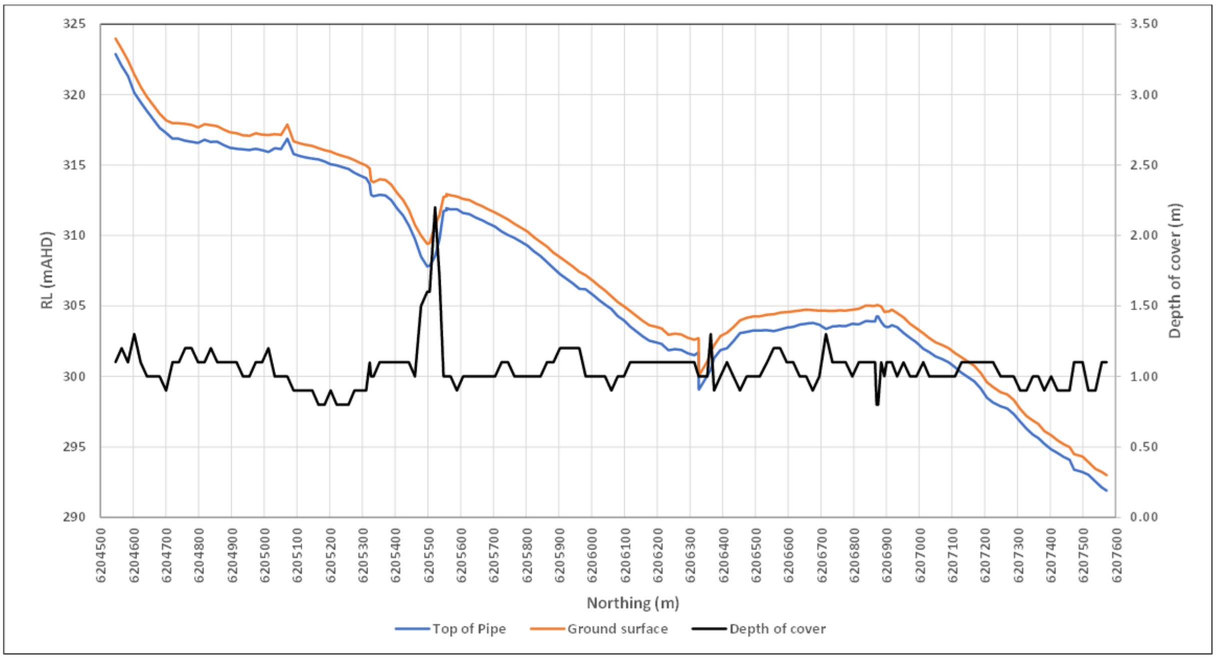


Figure 3-5: Top of pipeline, ground surface profiles and depth of cover along the pipeline

3.1.5 Predicted ground subsidence

3.1.5.1 Conventional mine subsidence

Mine Subsidence Engineering Consultants (MSEC) provided updated conventional subsidence ground displacement predictions along the pipeline alignment for LW S1A to LW S6A. They are plotted in the graphs in Figure 3-6 to Figure 3-8.

The predicted 3D ground displacements were progressively applied to the pipeline model to calculate the stress in the pipeline when it being undermined by LW S1A to LW S6A.

3.1.5.2 Non-conventional mine subsidence

At this stage, as the non-conventional subsidence or ground movement is not known, only limited analysis was performed on a straight and horizontal pipeline that was subject to a step ground deformation, that is:

- A vertical drop – a fault type ground deformation
- A lateral shear

The pipe stress was computed as a function of the ground movement. The ground movements corresponding to various pipe stress levels can be used as trigger levels in the Mine Plan.

3.1.5.3 Closure at creek crossings

The pipeline crosses four creeks (Figure 3-9) that could exhibit closure when undermined. An idealized ground displacement profile used in the analysis is shown in Figure 3-10. The maximum predicted total closure at each creek crossing is provided by MSEC as follows:

1. Teatree Hollow: 150 mm (Figure 3-11)
2. Tributary to Teatree Hollow (Referred to as Creek 1 in this study): 100 mm (Figure 3-12)
3. Tributary to Teatree Hollow (Yarran Road) (Referred to as Creek 2 in this study): 75 mm (Figure 3-13)
4. Tributary to Teatree Hollow (Wellers Road) (Referred to as Creek 3 in this study): 25 mm (Figure 3-14)

At each creek crossing, three different closure orientations (or bearings) were analysed to check sensitivity.

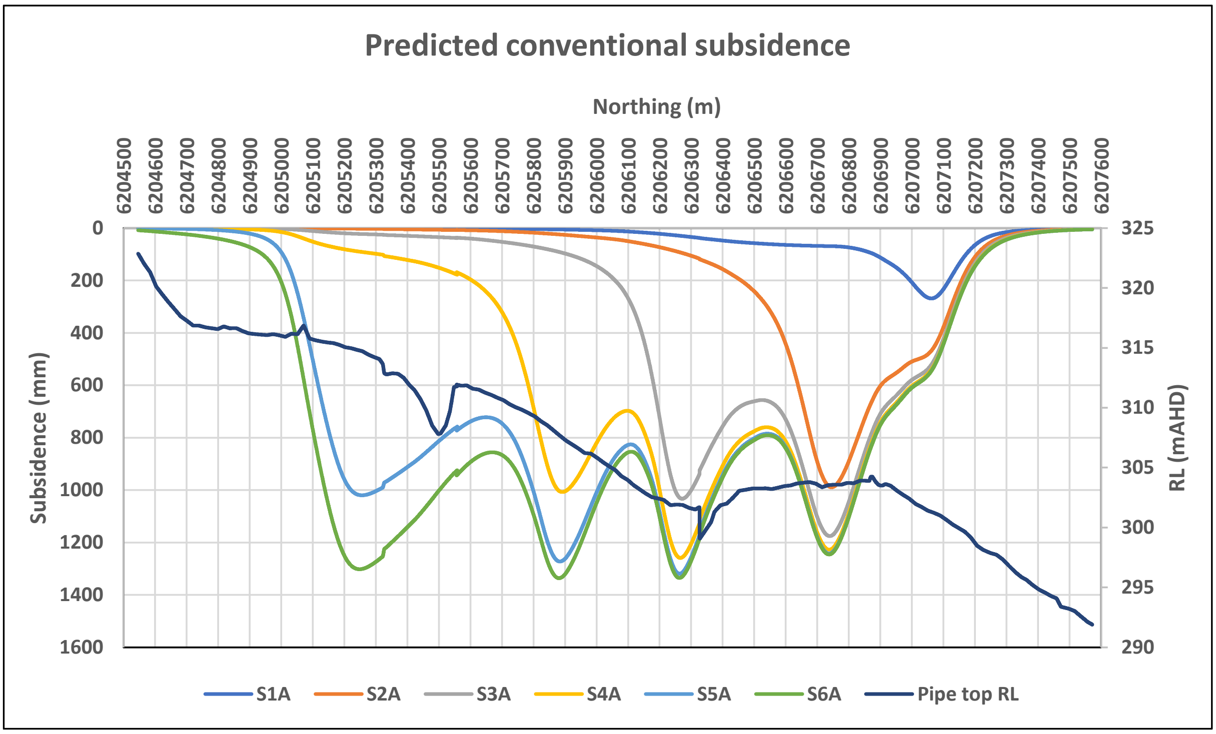


Figure 3-6: Predicted subsidence along DN150 gas main (Source: MSEC)

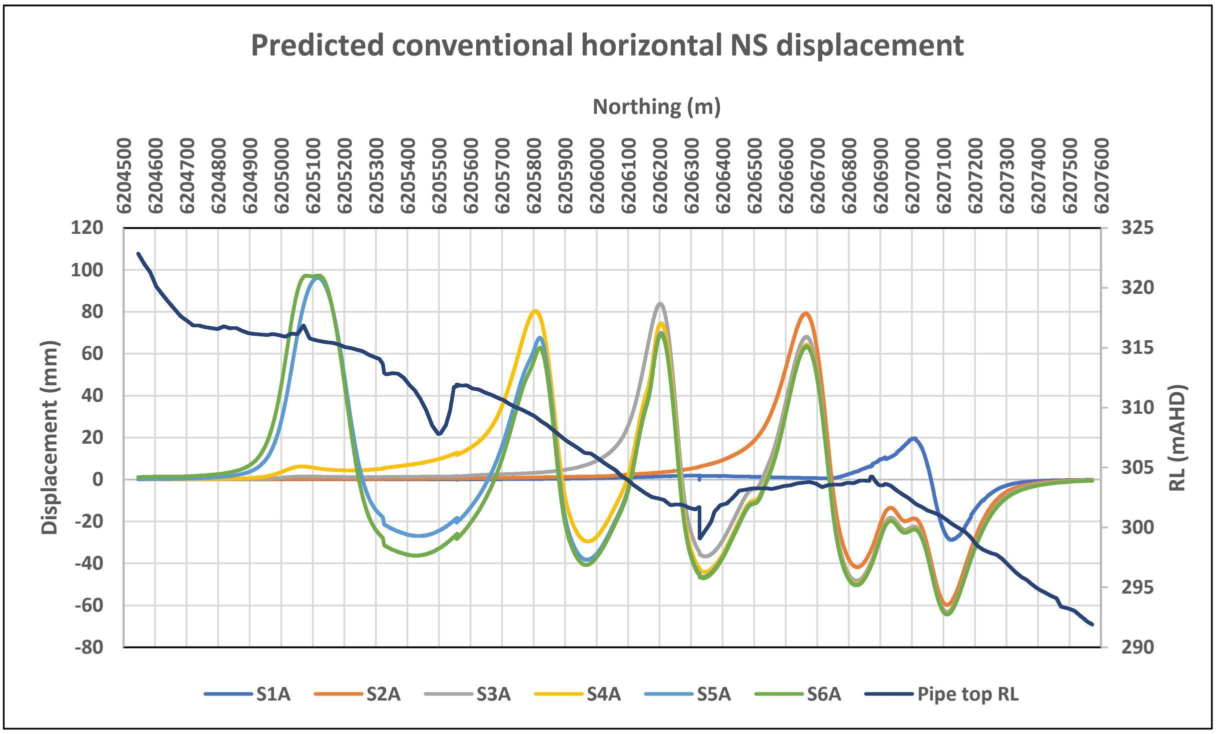


Figure 3-7: Predicted horizontal displacement in the north-south direction along DN150 gas main (Source: MSEC)

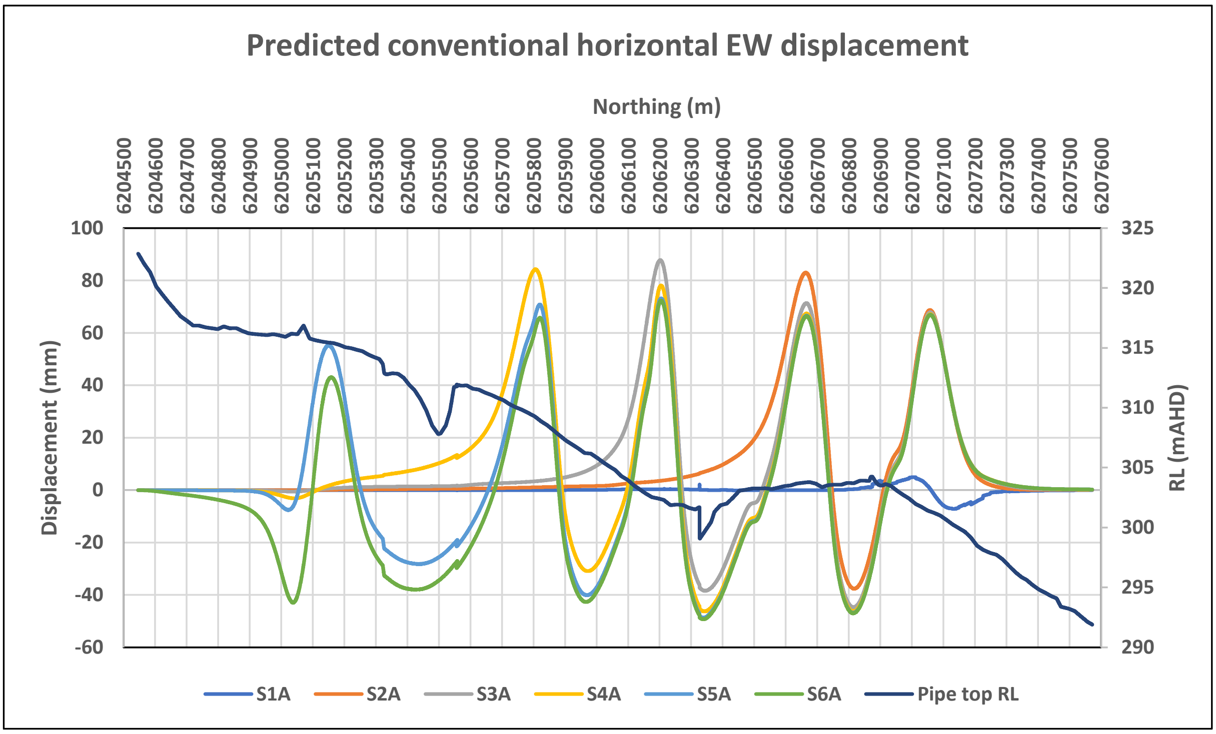


Figure 3-8: Predicted horizontal displacement in the east-west direction along DN150 gas main (Source: MSEC)

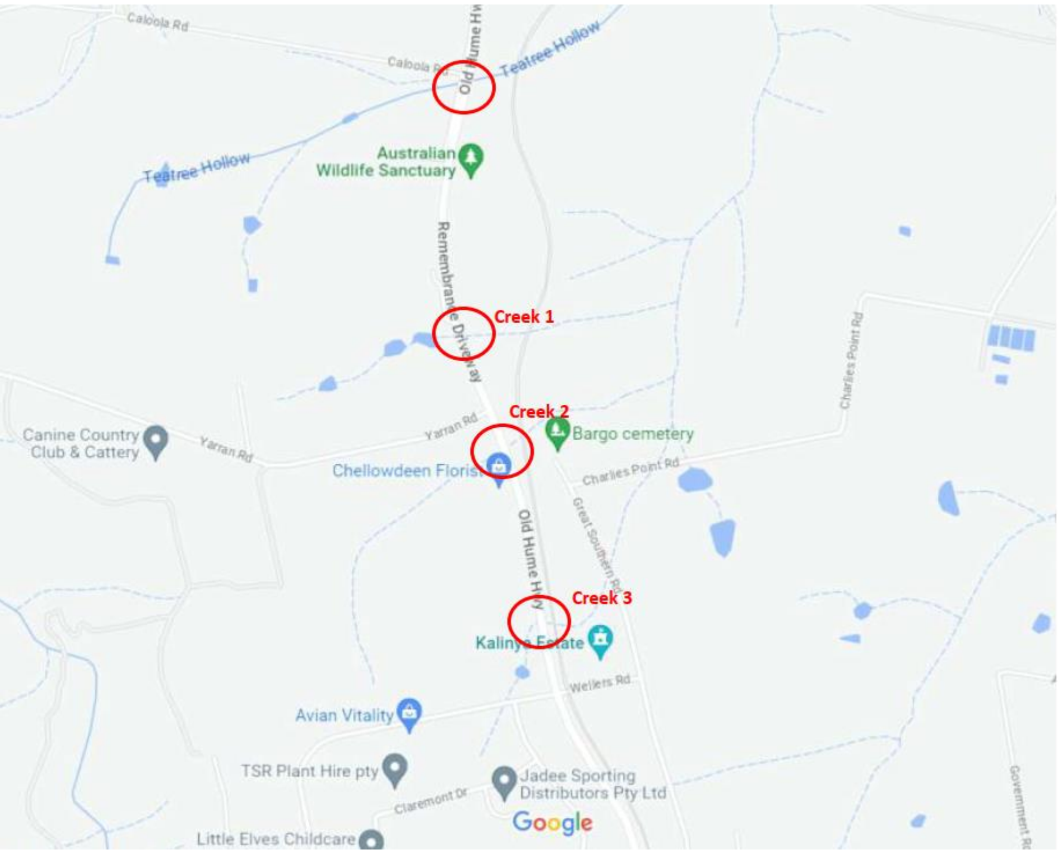


Figure 3-9: Creek crossing locations

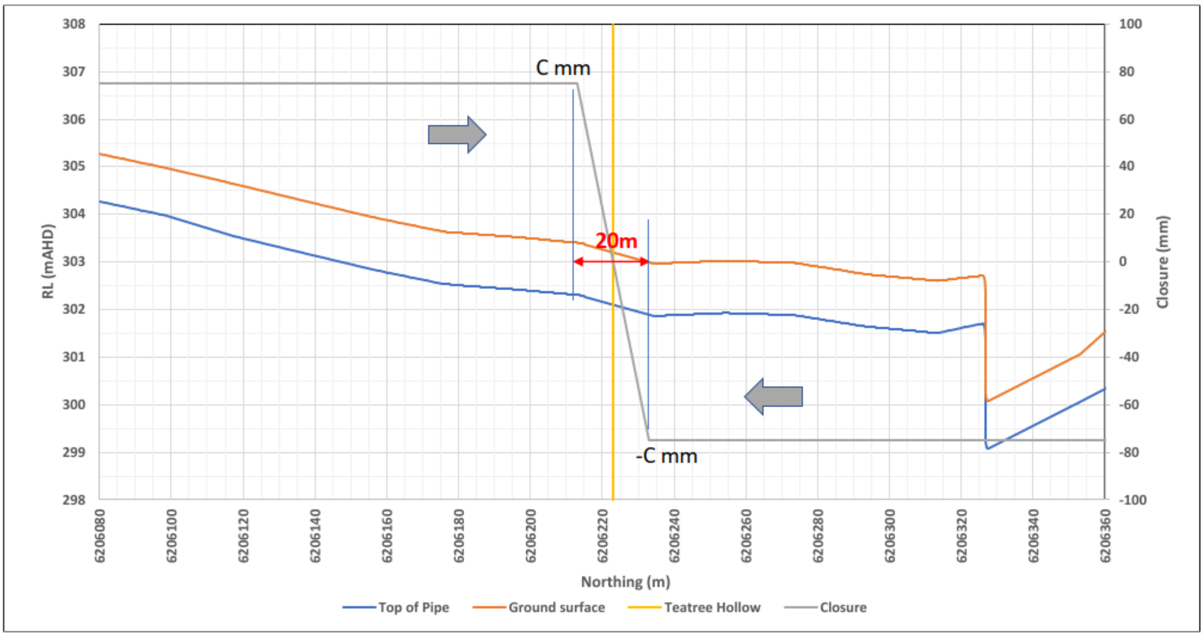


Figure 3-10: Idealised ground displacement profile for creek closure

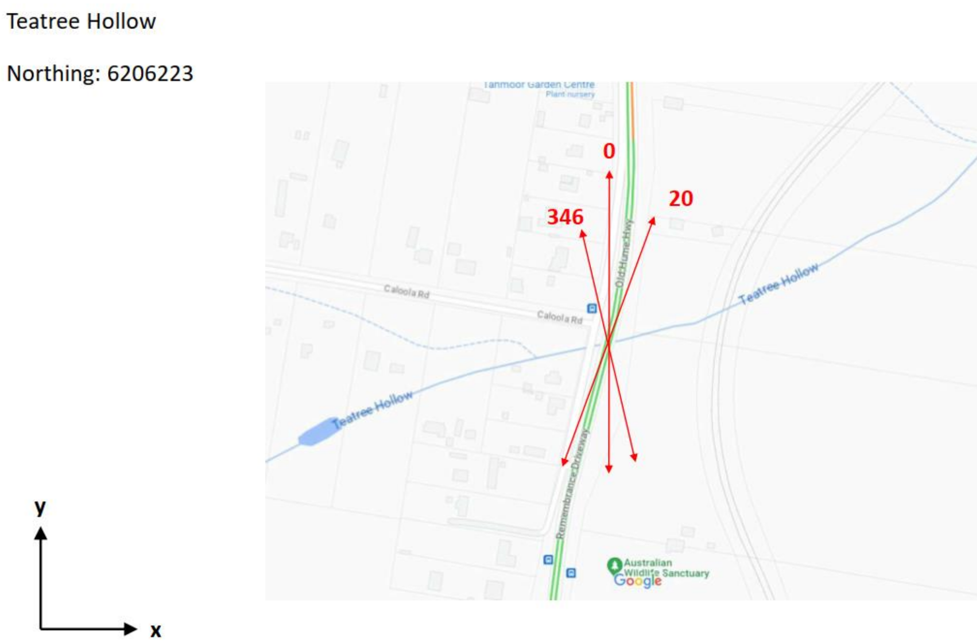


Figure 3-11: Teatree Hollow crossing

Creek 1

Northing: 6205509

Figure 3-12: Creek 1 crossing

Creek 2

Northing: 6205198

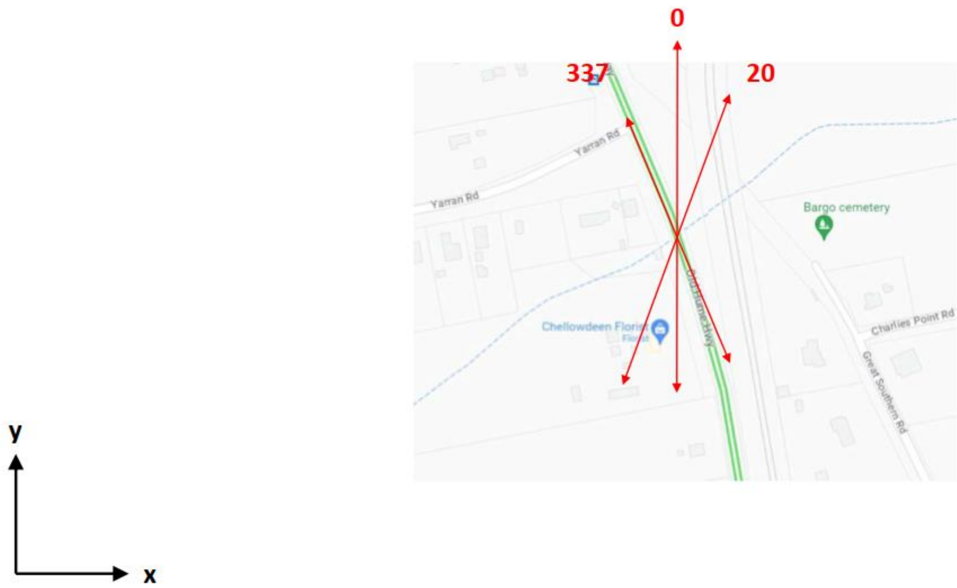


Figure 3-13: Creek 2 crossing

Creek 3

Northing: 6204717

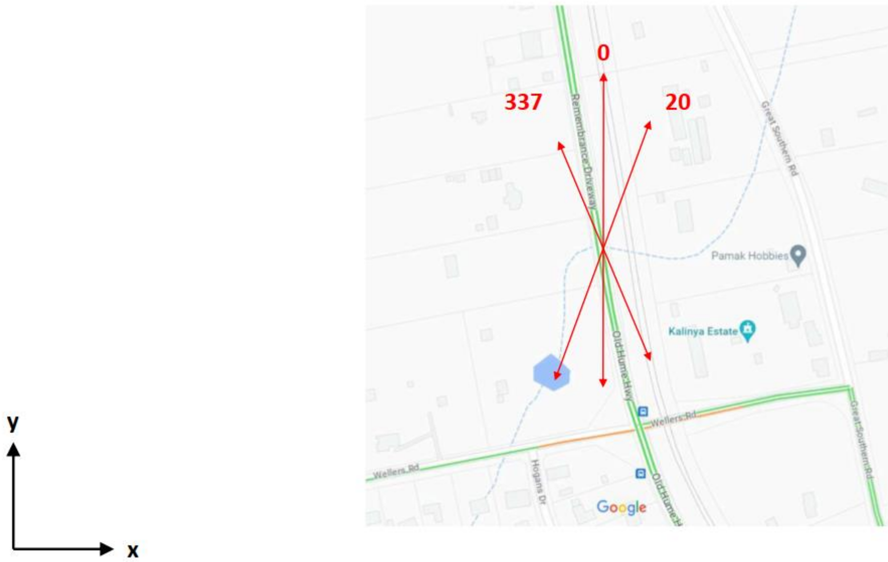


Figure 3-14: Creek 3 crossing

3.2 Pipe Stress Analysis

The pipe stress analysis of the DN150 steel gas main was performed in two parts: (1) manual calculations, and (2) finite element analysis.

The manual calculations were to determine the stress state for a long straight pipe operating under internal pressure and a temperature differential. The manual calculation results were also used to validate the finite element analysis results.

The finite element model considered the geometric layout of the pipeline (i.e. pipe bends and direction changes), the nonlinear pipe-soil interaction, 3D ground deformation in addition to the internal pressure and temperature effect. Note that the pipe was assumed to be defect free and no wall thickness loss.

3.2.1 Manual Calculations

A preliminary assessment using manual calculations has been performed for the affected pipeline. The total stress in the pipe is contributed by the following mechanisms that were considered in the calculations:

1. Internal pressure
2. Temperature effects

The manual calculation was performed using the design condition of the pipe. Details are provided in the following sections.

3.2.1.1 Stresses caused by internal pressure

The hoop or circumferential stress, σ_{hoop}, caused by internal pressure is given by:

$$\sigma_{hoop} = P\,(D/2t) \quad (1)$$

where P = internal pressure = MAOP = 1.05 MPa

D = outer diameter of pipe

and t = wall thickness

For a buried pipe being constrained by soil, the axial or longitudinal stress, σ_L, caused by Poisson's ratio effect is:

$$\sigma_L = \nu\,\sigma_{hoop} \quad (2)$$

where ν = Poisson's ratio = 0.3.

3.2.1.2 Temperature effects

The longitudinal stress, $\sigma_{L\theta}$, caused by temperature effects on a buried pipe is calculated by:

$$\sigma_{L\theta} = E\,\alpha\,(\theta_1 - \theta_0) \quad (3)$$

where E = pipe stiffness

α = coefficient = of thermal expansion

θ_1 = operating temperature

and θ_0 = reference temperature

3.2.1.3 Combined stress

The above equations will be combined to give the total longitudinal stress and hoop stress at the location of interest. The von Mises stress, σ_{vm}, which will be used for assessment later, can then be calculated by:

$$\sigma_{vm}=\sqrt{\{½[(\sigma_h - \sigma_L)^2+(\sigma_L - \sigma_r)^2+(\sigma_r-\sigma_h)^2]\}} \qquad (4)$$

where σ_h = total hoop stress

σ_L = total longitudinal stress

and σ_r = radial stress.

The radial stress on the inner surface is the internal pressure (compressive). The radial stress on the outer surface of the pipe can assume to be practically zero.

3.2.2 Finite Element Analysis

The 5.8 km of the DN150 pipe over the mine subsidence zone and beyond was modelled. The pipe was represented by a series of 2-node pipe elements of about 0.2 m in length. The depth of cover was modelled using the Pipe-Soil Interface (PSI) elements which represent a series of soil springs along the length of the pipeline. These PSI elements are provided in the Abaqus software for modelling nonlinear pipe-soil interaction in accordance with the methodology provided in the American Lifeline Alliance (2001). The potholing survey indicated the backfill did not consists of sand. The exact description of the backfill was not provided. Based on the provided photos, the backfill is likely to be a mixture of clayey sand and sandy clay. For pipe stress analysis purpose, it is conservative to assume the backfill to be a dense sand as it provides a higher restraint to the pipeline. When the ground subsides, a higher pipe stress would result. The assumed backfill properties for the pipe trench are as follows:

- Unit weight of fill = 20 kN/m^3
- Friction angle = 35° (assumed a dense sand which is a conservative assumption)
- Cohesion = 0 kPa
- Coating factor = 0.6 (polyethylene)

The pipe stress analysis involved nonlinear geometry effects and nonlinear soil springs. The pipe material was assumed to be linear elastic. This can be modelled with nonlinear stress-strain behaviour to consider yielding and strain-hardening if required after examining the computed pipe stresses.

The pipe material properties adopted in the study are shown in Table 3-2. In the model, the pipeline was assumed to be defect free and there is no metal loss both internally and externally. The pipeline geometry and depth of cover in the model were based on the information provided by Tahmoor Coal.

The transient ground movements along the pipeline predicted by MSEC were mapped to the corresponding soil nodes in the model.

The following analysis steps were performed:

1. Apply gravity
2. Apply internal pressure
3. Apply temperature effect (maximum or minimum effects)
4. Apply the predicated ground movement in a series of ground movement profiles corresponding to the coal extraction of LW S1A to LW S6A.

Where the pipe stress is found to be at its peak but not exceeding the allowable limit, the ground movement for that instance will be increased gradually until the pipe stress reached or exceeded the allowable limit.

If the pipe stress is found to exceed the allowable stress, then the following typical mitigations can be analysed using the model:

- Reduce the internal pressure
- Reduce the depth of cover along the affected section of the pipe
- Exposed the pipe to decouple the ground strain from the pipe along the affected length

The mitigation will depend on how the pipeline behaved when subject to the predicted ground movement.

Table 3-2: Pipe material properties

Properties	Units	Values
Young's modulus	MPa	200,000
Poisson's ratio	-	0.3
Density	Kg/m^3	7850
Coefficient of thermal expansion	/C	0.0000117

3.3 Assessment Criteria

3.3.1 Allowable Stress

The pipe was designed to AS 4645.2 which states that the hoop stress shall not be greater than 20% SMYS of the pipe. In this case, SMYS = 290 MPa, and 20% SMYS = 58 MPa. The code does not provide guidance on the longitudinal stress or the combined stress (i.e. von Mises stress).

When the pipe is deformed by the ground, the stress state should consider the change in longitudinal stress in addition to the hoop stress. Although AS 4645.2 only considers the allowable limit for hoop stress, it mentions that "*steel piping systems for gas outside these limits are generally covered by the AS 2885 suite of Standards and for some jurisdictions*". The longitudinal stress in the restrained pipe can be caused by a combination of thermal effect, Poisson's ratio effect, longitudinal bending and strain caused by ground deformation.

In accordance to AS 2885.1 the stress limits for an axially restrained pipe are:

- Longitudinal stress: 90% SMYS (i.e. 261 MPa)
- Combined stress: 90% SMYS (i.e. 261 MPa)

In the event where the pipeline deflection is dominated by bending, the pipe is no longer considered to be axially restrained, then the stress limit for longitudinal stress would be:

- Longitudinal stress: 75% SMYS (i.e. 218 MPa)

The allowable stress limits in Table 3-3 are used to assess the pipe stress subject to subsidence.

Table 3-3: Allow stress limits

Stress	Allowable (% SMYS)	Allowable (MPa)	Reference
Hoop	20	58	AS 4645.2
Longitudinal (axially restrained)	90	± 261	AS 2885.1
Longitudinal (not axially restrained)	75	± 218	AS 2885.1
Combined (von Mises)	90	261	AS 2885.1

3.3.2 Allowable Compressive Strains

When the pipe undergoes differential settlement, the pipe will bend and compressive strains will develop at the location. Local buckling (wrinkle) can occur if the compressive strain is large enough. In order to prevent local buckling failure from occurring, the longitudinal compressive strain is limited to the following ALA (2001) critical strain equation:

$$\varepsilon_{cr} = 0.5\frac{t}{D'} - 0.0025 + 3000\left(\frac{pD}{2Et}\right)^2 \qquad (5)$$

where ε_{cr} = critical compressive strain

t = wall thickness = 4.8 mm

p = internal pressure

E = elastic modulus of the steel pipe material = 200,000 MPa

D = outer pipe diameter = 168.3 mm

and D′ = imperfection factor for ovalisation and it is given by:

$$D' = \frac{D}{1 - \frac{3}{D}(D - D_{min})} \qquad (6)$$

where D_{min} = minimum outer diameter of an ovalized pipe cross-section.

The above equation was proposed by Gresnigt (1986) that was based on available experimental results, and valid for local buckling failure mode with small or insignificant external pressure. The effect of ovalisation on the equation is relatively minor and D_{min} = D is often assumed.

If D_{min} = D is assumed, the critical compressive strains for the various internal pressures are shown in Table 3-4. It can be seen that the critical compressive strains are not too sensitive to the internal pressure. The values in the table will be used for assessment purposes.

Table 3-4: Critical compressive strains

Internal pressure (MPa g)	Critical compressive strains (%)
0 (empty)	1.1760
0.3 (current MOP)	1.1762
1.05 (MAOP)	1.1786

3.4 Assumptions

In this study the following assumptions were made:

- Linear elastic model
- Static stress analysis
- Pipeline is defect free (metal loss and cracks at welds)
- Pipeline coating is not damaged and defect free
- Backfill is a dense sand (a conservative assumption for pipe stress)
- Ignore water table (a conservative assumption for pipe stress)

- Welds not explicitly modelled and analysed (assumed weld material is the same as the line pipe material for analysis purpose)

3.5 Exclusions

The following items were excluded in the present study:

- Assessment of pipe protection design
- Vibration and load effects on the pipeline and coating associated with construction works
- Accidental impact loads
- Earthquake loads
- Assessment of the pipe coating and corrosion protection
- Analysis and assessment of the welds (including fatigue assessment)
- Design, analysis and verification of any pipeline protection structure
- Assessment and verification of the predicted ground movement magnitude and profile
- Pipeline beyond the study area has not been analysed and assessed
- Any nearby existing and future services that may be affected by mining-induced ground movement and their mitigation works, and how they interact with the gas pipeline have been excluded from this study

4 Manual Calculation Results

The component stresses for the different internal pressures and temperature effects are summarized in Table 4-1. Note that no ground movement has been considered in the calculations and the effects of pipe bends have been ignored. These results are to show the baseline condition for a long straight length of the buried pipe prior to any mine subsidence effect.

When the pipe is operating at MAOP, the hoop stress is well below the allowable limit of 20% SMYS. The longitudinal stress is mainly influenced by the thermal effects. The compressive longitudinal stress gives the highest von Mises stress. However, they are both below 90% SMYS for all the temperature differentials considered.

When the pipe is operating at 0.3 MPa, the hoop stress is much reduced. However, the thermal effect can still cause a high longitudinal stress resulting in a high von Mises stress. Both stresses are below 90% SMYS.

The internal pressure needs to increase to 3.308 MPa to cause the hoop stress to reach 20% SMYS. Note that this is a fictious case because the gas main was designed and operated not to exceed 1.05 MPa internal pressure.

Table 4-1: Pipe stress results - manual calculation

Internal pressure (MPa)	Hoop stress (MPa) [% SMYS]	Longitudinal stress (MPa) [% SMYS]			Radial stress (MPa)	Von Mises stress (MPa) [% SMYS]	Comments
		Poisson's ratio effect	Temperature effect	Total			
1.05	18.41 [6.3%]	5.52 [1.9%]	-35.10 [12.1%]	-29.58 [10.2%]	-1.05	41.80 [14.4%]	MAOP with dT=+15°C
1.05	18.41 [6.3%]	5.52 [1.9%]	37.44 [12.9%]	42.96 [14.8%]	-1.05	38.20 [13.2%]	MAOP with dT=-16°C
0.3	5.26 [1.8%]	1.58 [0.5%]	-35.10 [12.1%]	-33.52 [11.6%]	-0.3	36.32 [12.5%]	Operating pressure with dT=+15°C
0.3	5.26 [1.8%]	1.58 [0.5%]	37.44 [12.9%]	39.02 [13.5%]	-0.3	36.85 [12.7%]	Operating pressure with dT=-16°C
3.308	58 [20%]	17.4 [6.0%]	-35.10 [12.1%]	-17.7 [6.1%]	-3.308	69.62 [24.0%]	Pressure that caused hoop stress to reach 20% SMYS, dT = +15°C

Notes:

1. -ve stress is compressive stress.
2. No pipe bends considered.

5 FEA Results and Assessment

5.1 Prior to Mine Subsidence

The maximum von Mises and longitudinal stress for internal pressure of 1.05 MPa (MAOP) with the maximum positive and negative temperature differentials prior to mine subsidence are shown in Figure 5-1 and Figure 5-2 respectively. Three main stress spikes occurred at the sharp pipe bends as expected. All stresses are below their respectively code allowable limits. The other stress spikes are an artifact of the discretization of the geometry model. They can be reduced by further smoothing of the pipe alignment geometry if necessary.

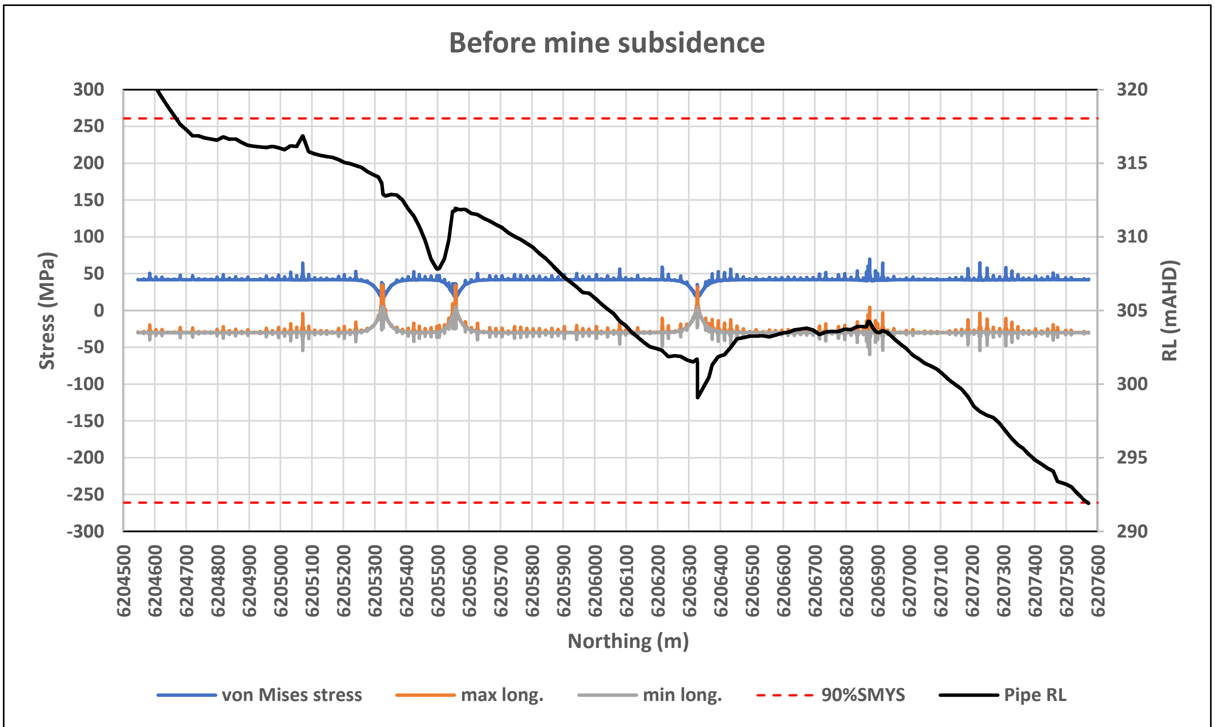


Figure 5-1: Peak pipe stress prior to mine subsidence (IP = 1.05 MPa, dT = +15 deg C)

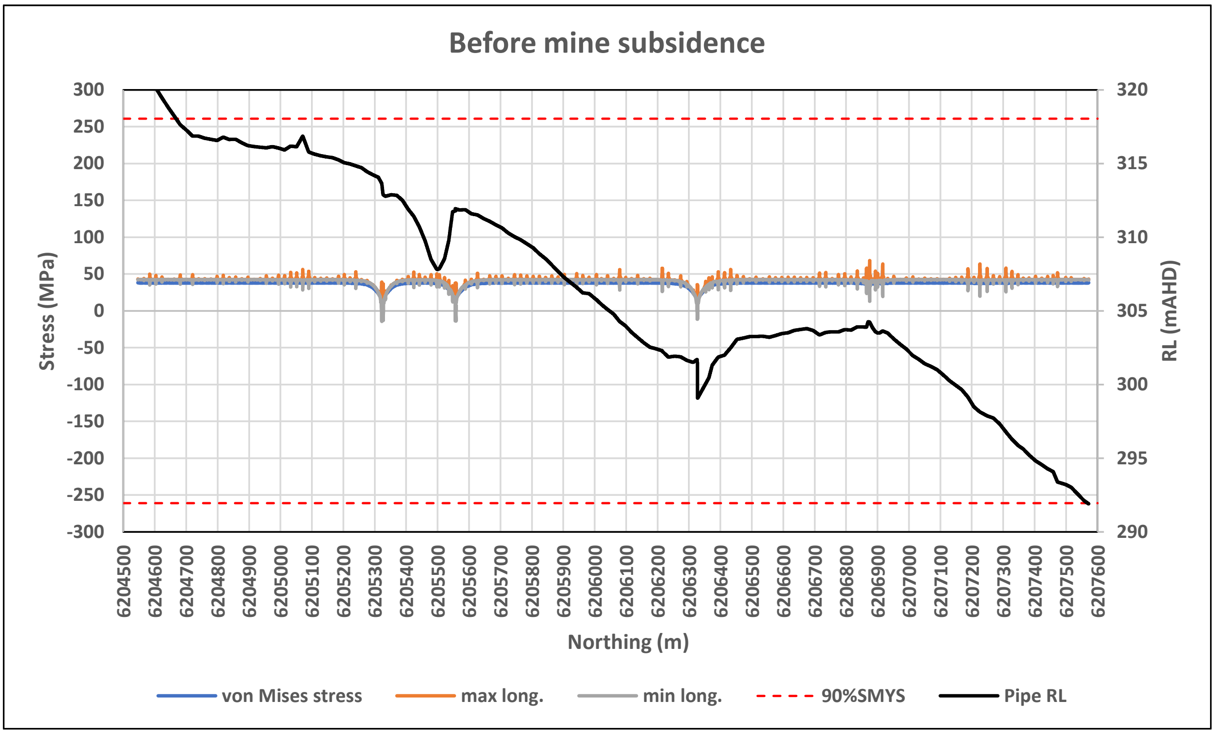


Figure 5-2: Peak pipe stress prior to mine subsidence (IP = 1.05 MPa, dT = -16 deg C)

5.2 LW S1A Subsidence Impact

For LW S1A, the predicted maximum settlement is 269 mm and the peak compressive ground strain along the pipe is -1.4 mm/m. This peak ground strain occurs at the location of maximum settlement. Note that the "worst" situation for the pipe is when it is operating at MAOP with a maximum positive temperature differential.

Figure 5-3 and Figure 5-4 show the peak pipe stress distributions at the end of LW S1A mining for the positive and negative temperature differential cases. It can be seen that the peak pipe stress occurs where the peak compressive ground strain is, and it also coincides with the settlement trough. The computed stresses and strains are summarized in Table 5-1. These values are all within their respective allowable limits.

Table 5-1: Pipe stress and strain results – end of LW S1A

Internal pressure (MPa)	Temperature differential (ºC)	Peak von Mises stress (MPa) [% SMYS]	Peak longitudinal stress (MPa) [% SMYS]	Peak compressive axial strain
1.05	+15	139 [48%]	-130 [45%]	0.065%
1.05	-16	64 [22%] at subsidence trough	-55 [38%]	0.028%

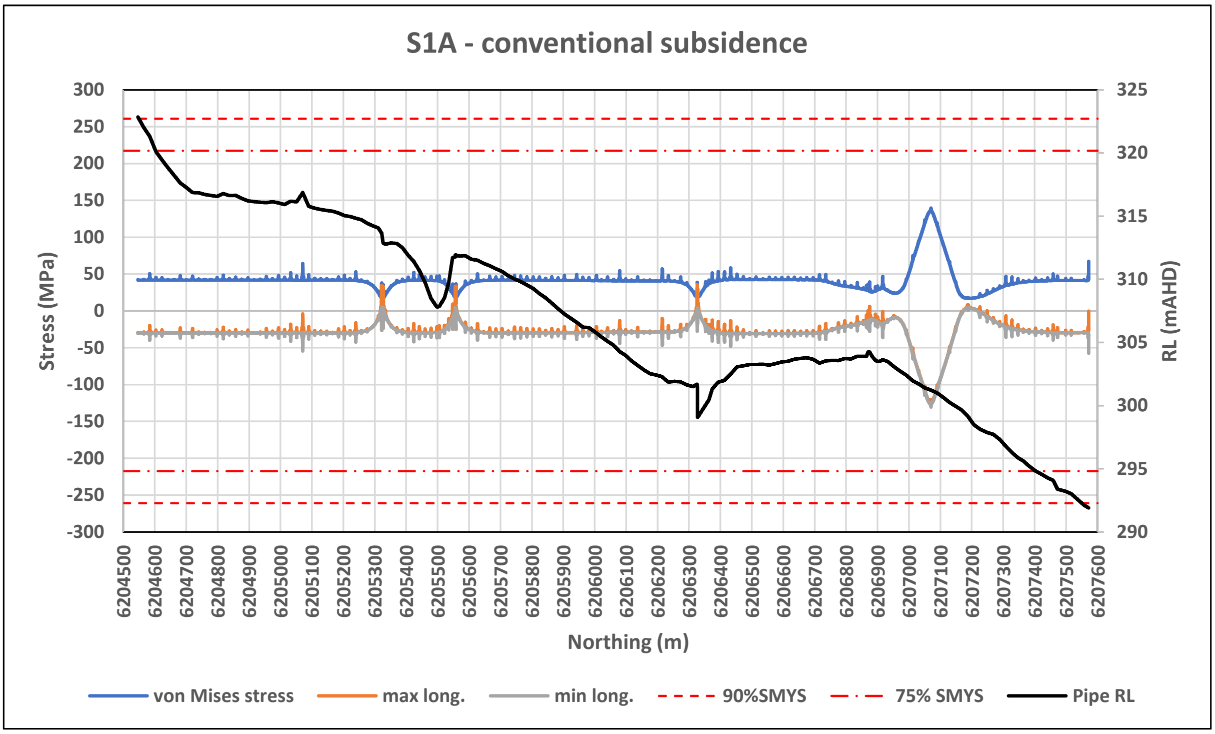


Figure 5-3: Peak pipe stress end of LW S1A (IP = 1.05 MPa, +15 deg C temp. diff.)

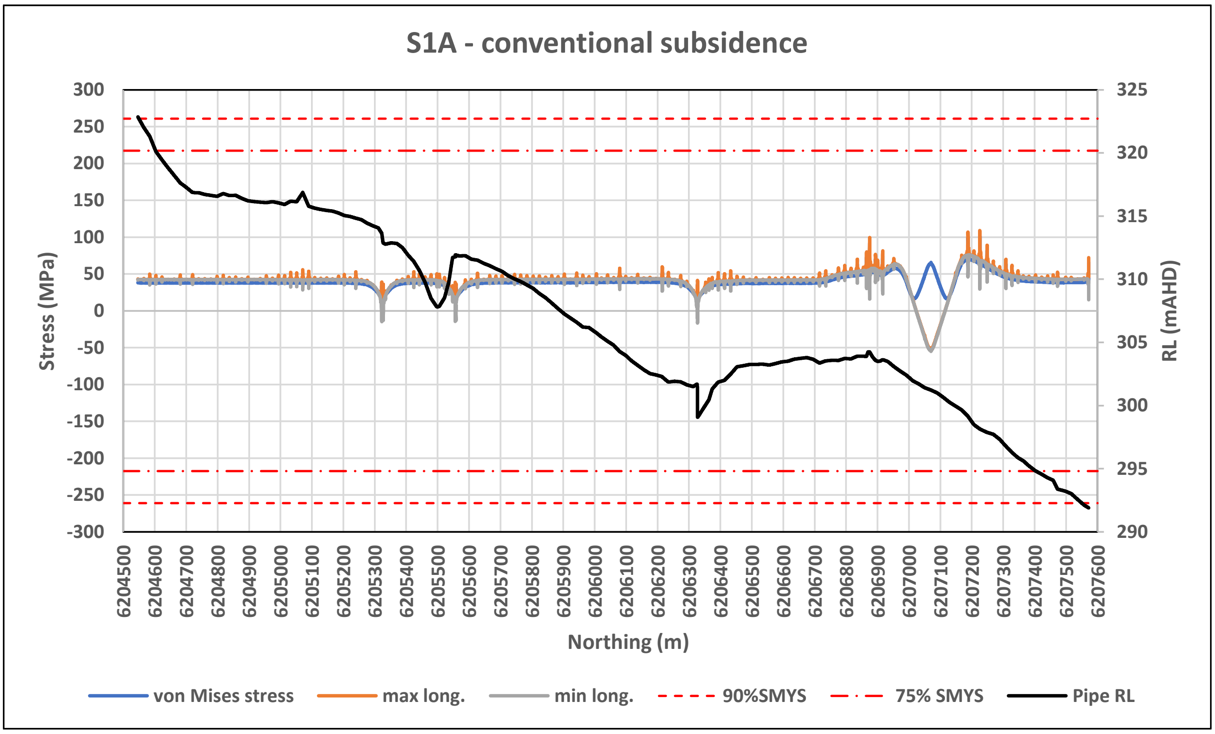


Figure 5-4: Peak pipe stress end of LW S1A (IP = 1.05 MPa, -16 deg C temp. diff.)

5.3 LW S2A Subsidence Impact

For LW S2A, the predicted maximum settlement is 989 mm and the peak compressive ground strain along the pipe is -1.7 mm/m. This peak ground strain occurs at the location of maximum settlement at approximate Northing 6206750.

Figure 5-5 and Figure 5-6 show the peak pipe stress distributions at the end of LW S2A mining for the positive and negative temperature differential cases. The peak stresses are summarized in Table 5-2. These values are within their respective allowable limits for an axially restrained pipe.

Table 5-2: Pipe stress and strain results – end of LW S2A

Internal pressure (MPa)	Temperature differential (°C)	Peak von Mises stress (MPa) [% SMYS]	Peak longitudinal stress (MPa) [% SMYS]	Peak compressive axial strain
1.05	+15	237 [82%]	-228 [79%]	0.114%
1.05	-16	139 [48%]	-131 [45%]	0.066%

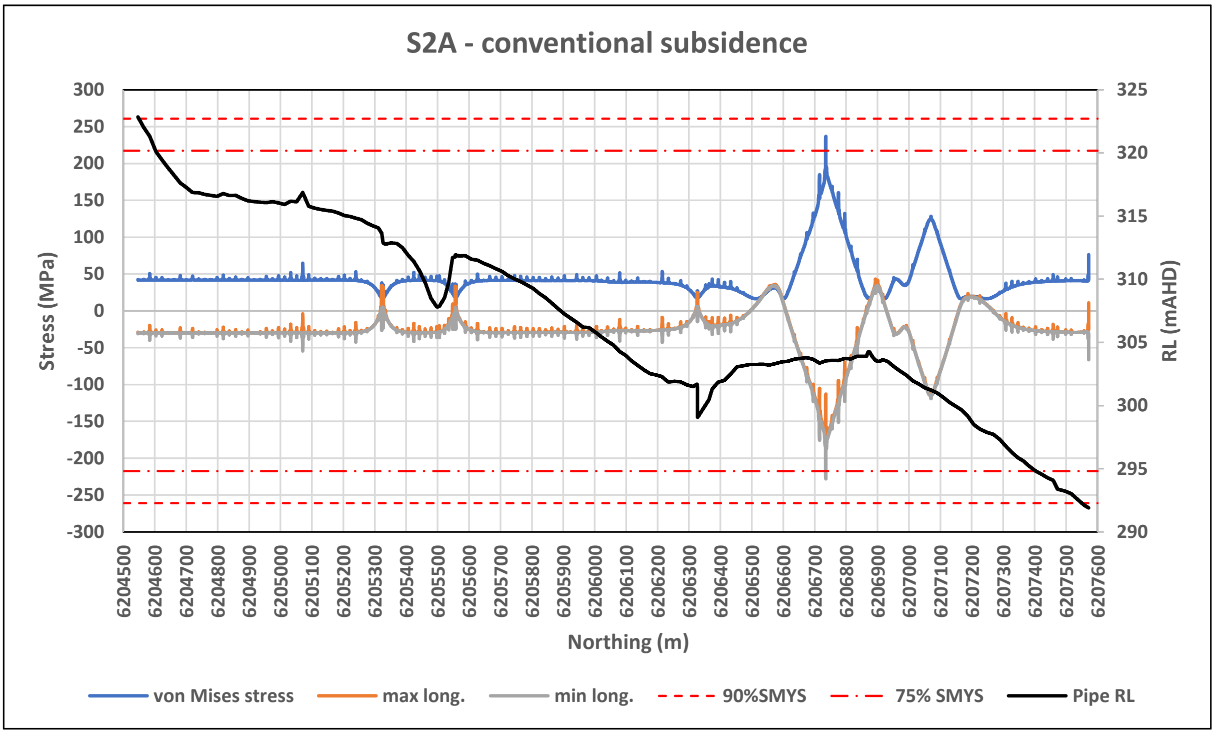


Figure 5-5: Peak pipe stress at the end of LW S2A (IP = 1.05 MPa, +15 deg C temp. diff.)

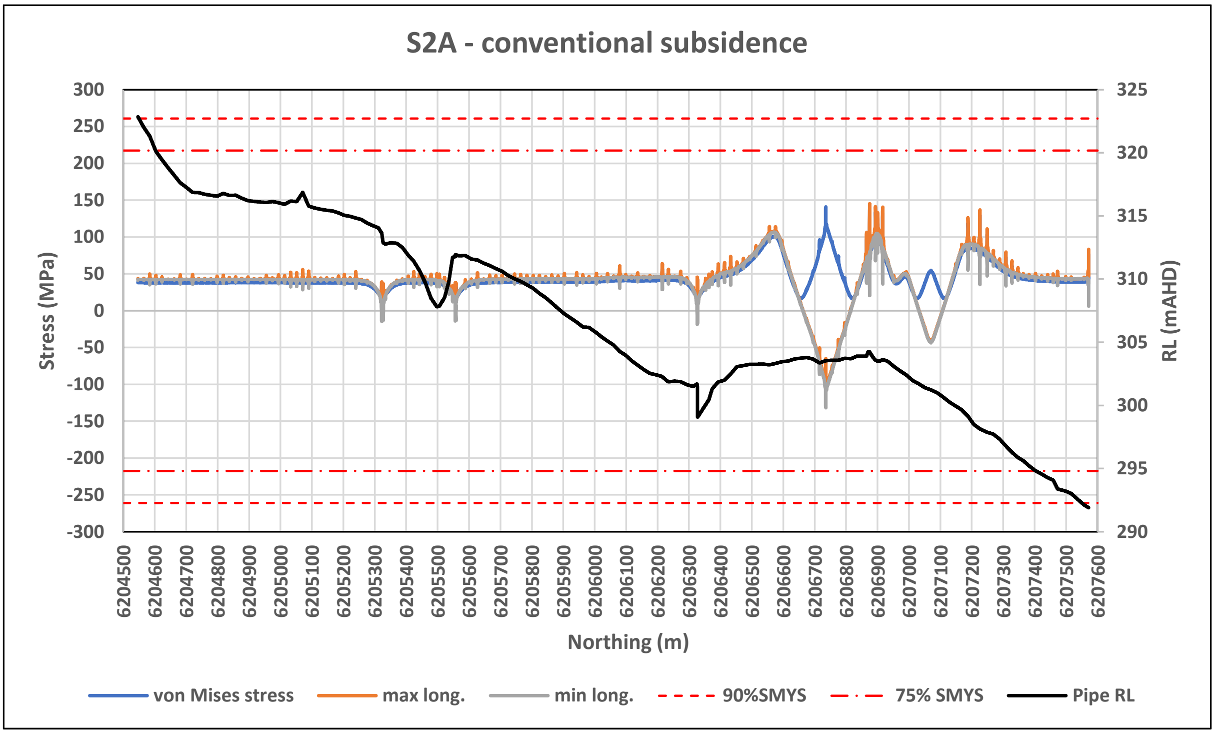


Figure 5-6: Peak pipe stress at the end of LW S2A (IP = 1.05 MPa, -16 deg C temp. diff.)

5.4 LW S3A Subsidence Impact

For LW S3A, the predicted maximum settlement is 1176 mm occurring at the settlement trough during LW S2A (Northing 6207600). The new settlement trough over LW S3A is 1031 mm and the compressive ground strain is -2.25 mm/m. This peak ground strain occurs at the location of maximum settlement at approximate Northing 6206255.

Figure 5-1 and Figure 5-2 show the peak pipe stress distributions at the end of LW S3A mining for the positive and negative temperature differential cases. The peak stresses are summarized in Table 5-3. The sharp bend at Location 1 has a peak von Mises stress of 337 MPa which exceeds the SMYS. The stresses along the rest of the pipeline are within the acceptable limit.

A zoomed-in view of the exaggerated deflected shape at the Location 1 sharp bend is shown in Figure 5-9. The subsidence of LW S3A is such that it puts the pipeline south of the bend into a compression and together with the thermal load, the bend at the top of the road embankment experiences a stress exceeding the allowable limit. Possible mitigation concepts to reduce the overstress to below the allowable limit are detailed in Section 6.

Table 5-3: Pipe stress and strain results – end of LW S3A

Internal pressure (MPa)	Temperature differential (°C)	Location	Peak von Mises stress (MPa) [% SMYS]	Peak longitudinal stress (MPa) [% SMYS]	Peak compressive axial strain
1.05	+15	~6206730	218 [75%]	-218 [75%]	0.109%
1.05	+15	~6206259	136 [47%]	-128 [44%]	0.064%
1.05	+15	~6206326 (Location 1 Sharp bends)	335 [116%]	267 [92%]	-
1.05	-16	~6206730	127 [44%]	-118 [41%]	0.059%
1.05	-16	~6206100	121 [42%]	-	-
1.05	-16	~6206326 (Location 1 Sharp bends)	141 [49%]	-	-

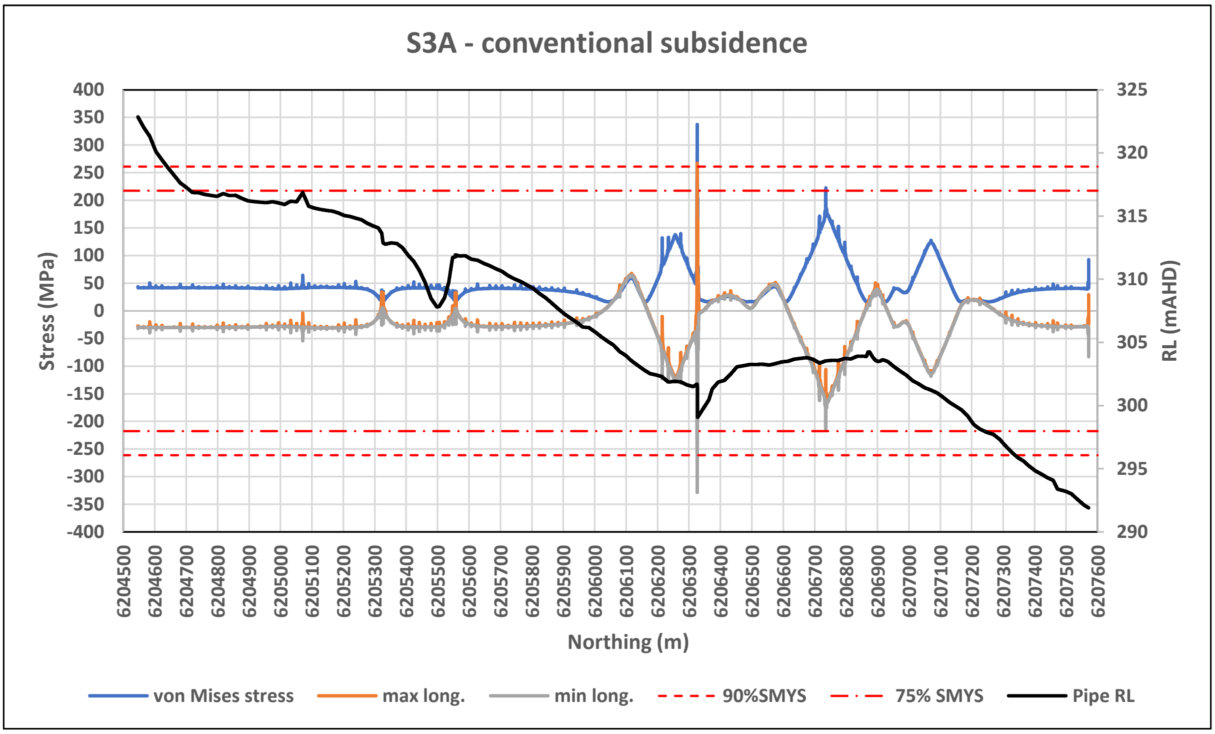


Figure 5-7: Peak pipe stress at the end of LW S3A (IP = 1.05 MPa, +15 deg C temp. diff.)

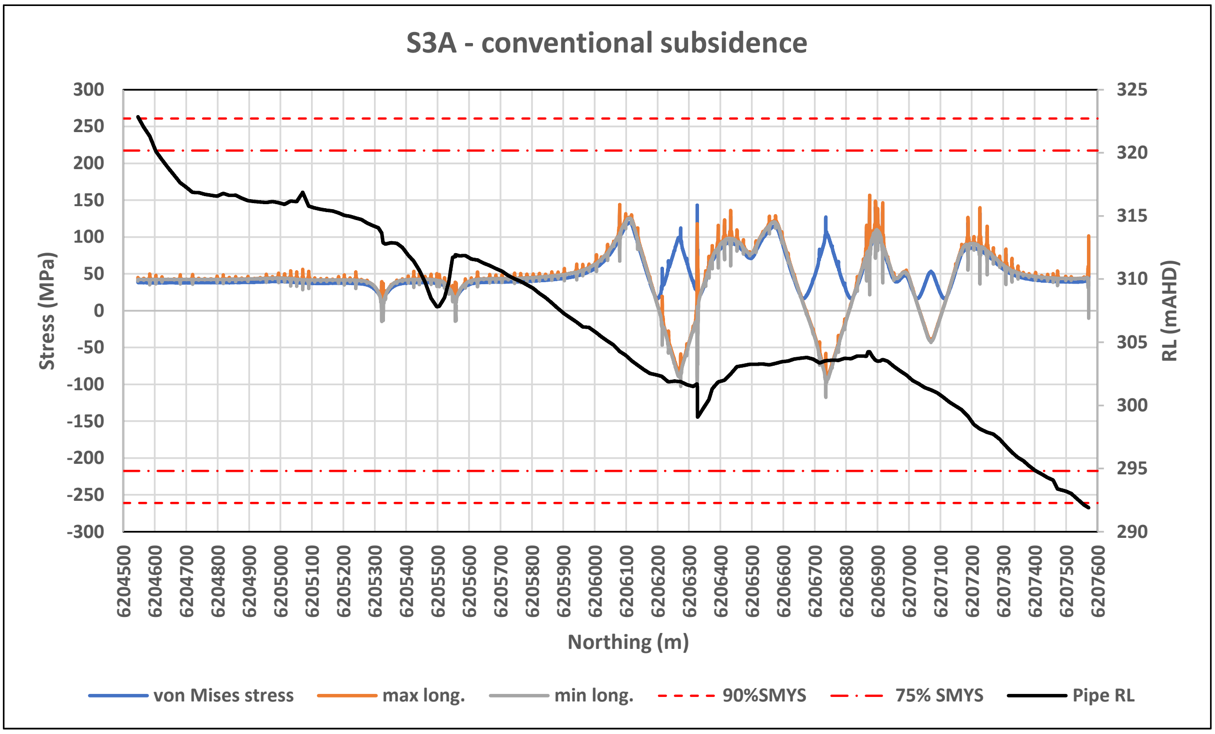


Figure 5-8: Peak pipe stress at the end of LW S3A (IP = 1.05 MPa, -16 deg C temp. diff.)

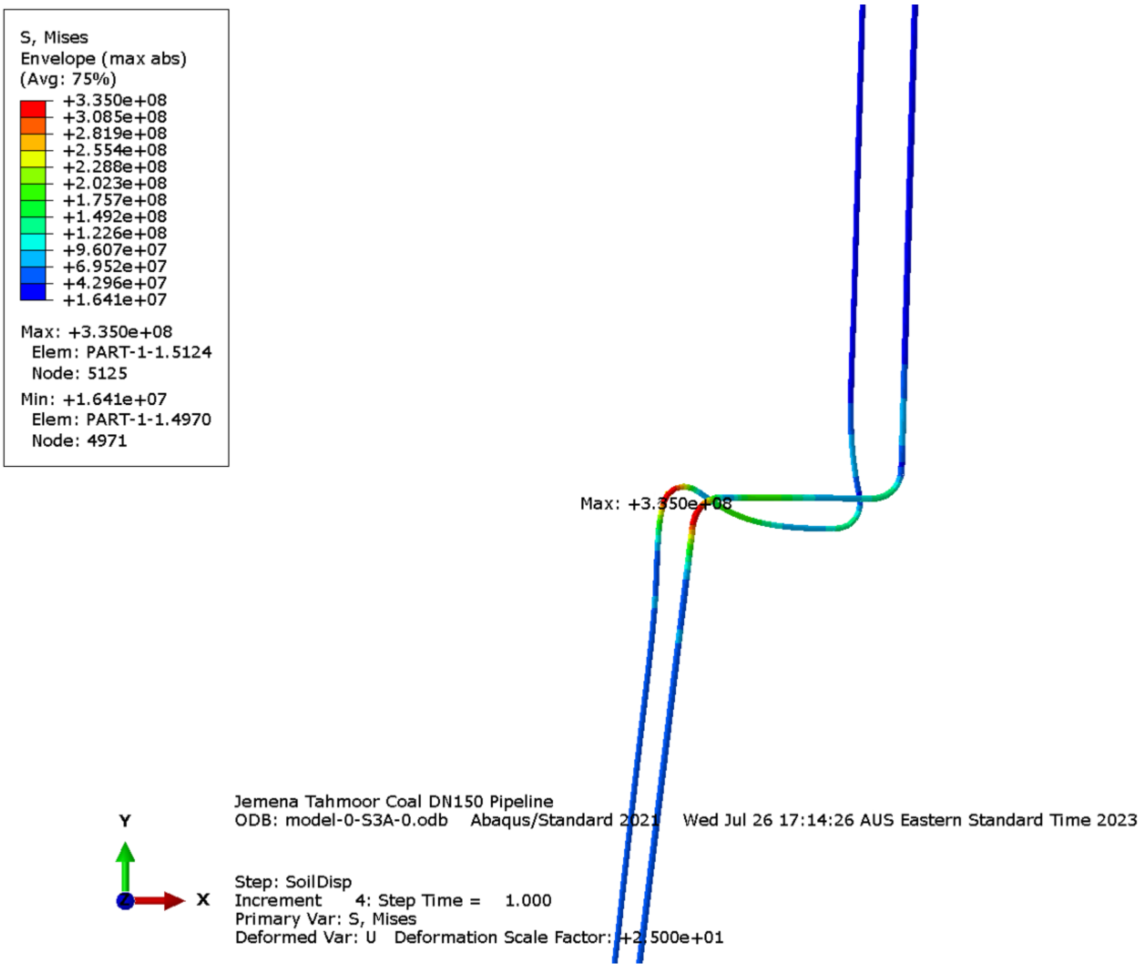


Figure 5-9: Peak pipe stress and exaggerated pipe deflection at Location 1 at the end of LW S3A (IP = 1.05 MPa, +15 deg C temp. diff.)

5.5 LW S4A Subsidence Impact

For LW S4A, the predicted maximum settlement is 1259 mm occurring at the settlement trough during LW S3A (Northing ~6206270). The new settlement trough over LW S4A is 1007 mm and the compressive ground strain is -1.78 mm/m. This peak ground strain occurs at the location of maximum settlement at approximate Northing 6205865.

Figure 5-10 and Figure 5-11 show the peak pipe stress distributions at the end of LW S4A mining for the positive and negative temperature differential cases. The peak stresses are summarized in Table 5-4. The stresses at the sharp bend at Location 1 remain above the acceptable limit. The stresses along the rest of the pipeline are within the acceptable limit.

Table 5-4: Pipe stress and strain results – end of LW S4A

Internal pressure (MPa)	Temperature differential (°C)	Location	Peak von Mises stress (MPa) [% SMYS]	Peak longitudinal stress (MPa) [% SMYS]	Peak compressive axial strain
1.05	+15	~6205903	195 [67%]	-194 [67%]	0.097%
1.05	+15	~6206326 (Location 1 Sharp bends)	318 [110%]	-310 [107%]	0.155%
1.05	-16	~6205903	116 [40%]	-112 [39%]	0.056%

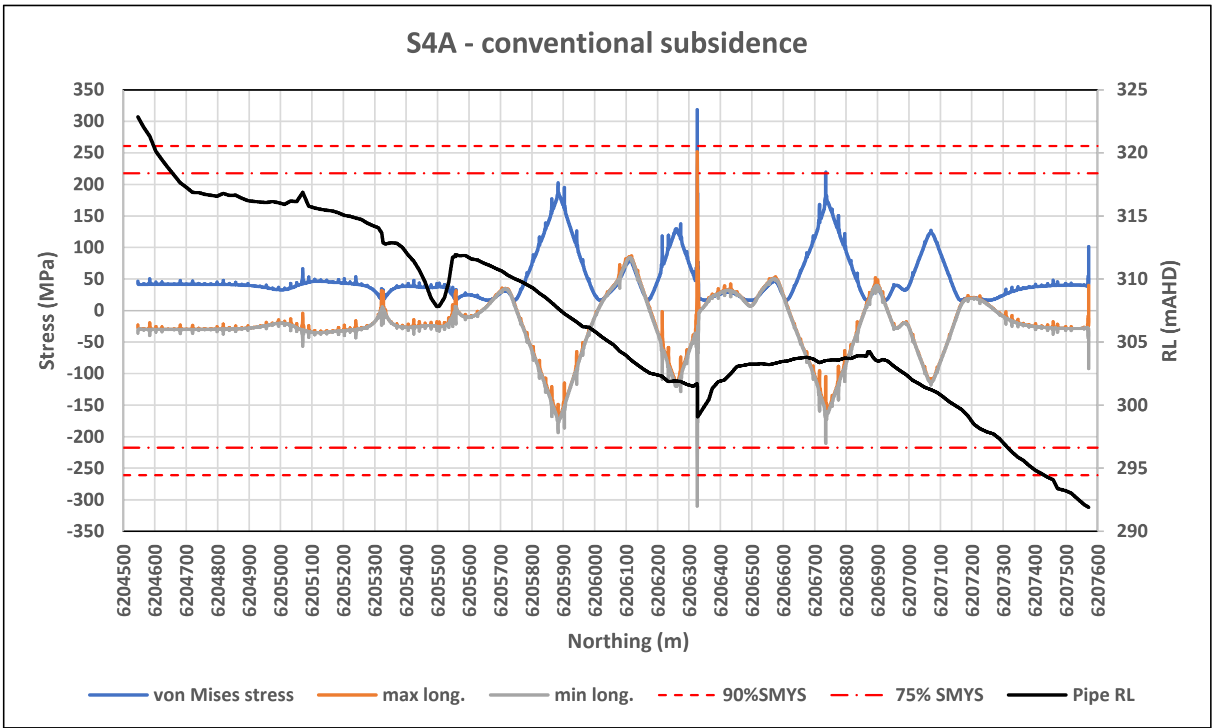


Figure 5-10: Peak pipe stress at the end of LW S4A (IP = 1.05 MPa, +15 deg C temp. diff.)

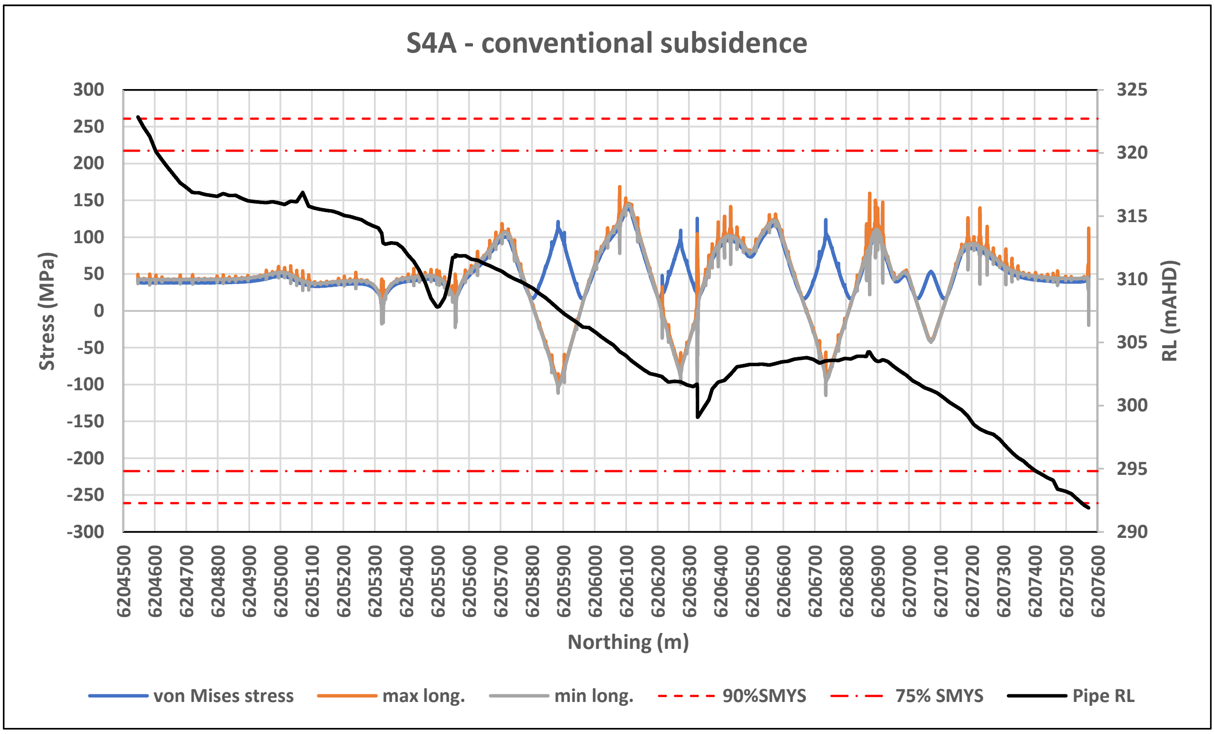


Figure 5-11: Peak pipe stress at the end of LW S4A (IP = 1.05 MPa, -16 deg C temp. diff.)

5.6 LW S5A Subsidence Impact

For LW S5A, the predicted maximum settlement is 1317 mm occurring at the settlement trough during LW S3A (Northing ~6206270). The new settlement trough over LW S5A is 1020 mm and the compressive ground strain is about -1.30 mm/m. This peak ground strain occurs at the location of maximum settlement at approximate Northing 6205255.

Figure 5-12 and Figure 5-13 show the peak pipe stress distributions at the end of LW S5A mining for the positive and negative temperature differential cases. The peak stresses are summarized in Table 5-5. The stresses at the sharp bend at Location 1 remain above the acceptable limit. The stresses along the rest of the pipeline are within the acceptable limit.

Table 5-5: Pipe stress and strain results – end of LW S5A

Internal pressure (MPa)	Temperature differential (°C)	Location	Peak von Mises stress (MPa) [% SMYS]	Peak longitudinal stress (MPa) [% SMYS]	Peak compressive axial strain
1.05	+15	~6205203	167 [58%]	-158 [54%]	0.079%
1.05	+15	~6206326 (Location 1 Sharp bends)	312 [108%]	-303 [104%]	0.152%

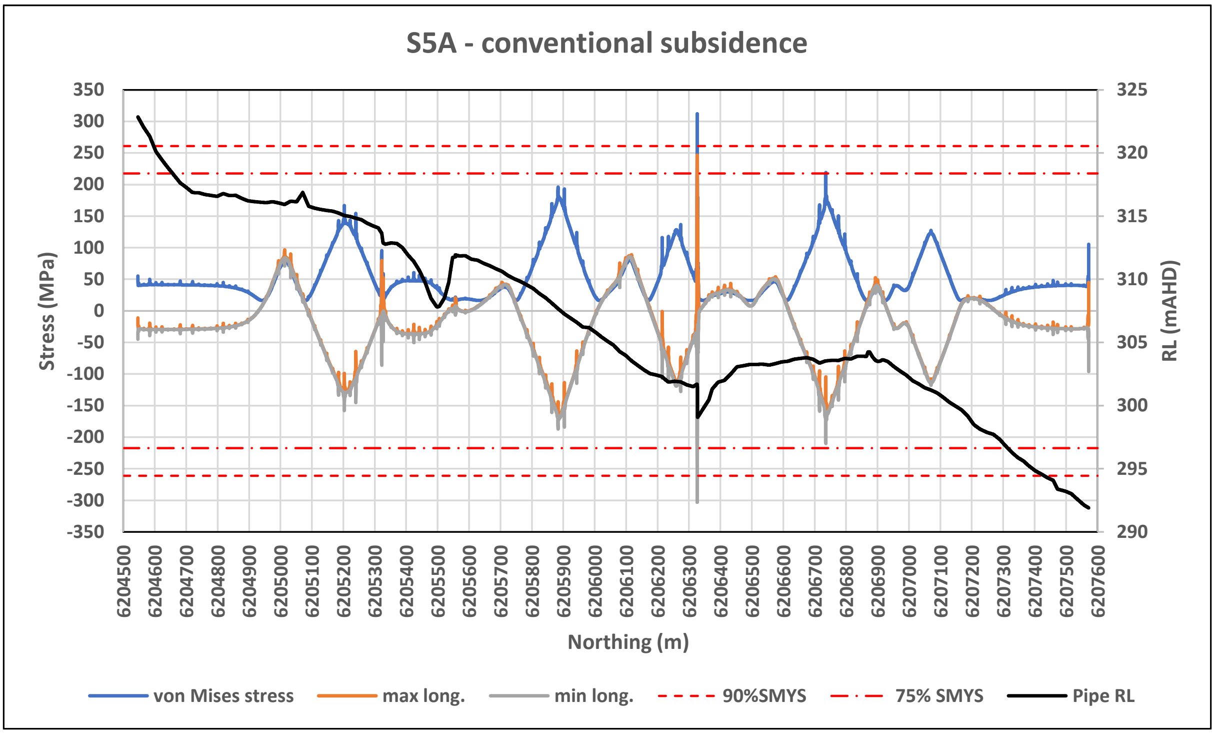


Figure 5-12: Peak pipe stress at the end of LW S5A (IP = 1.05 MPa, +15 deg C temp. diff.)

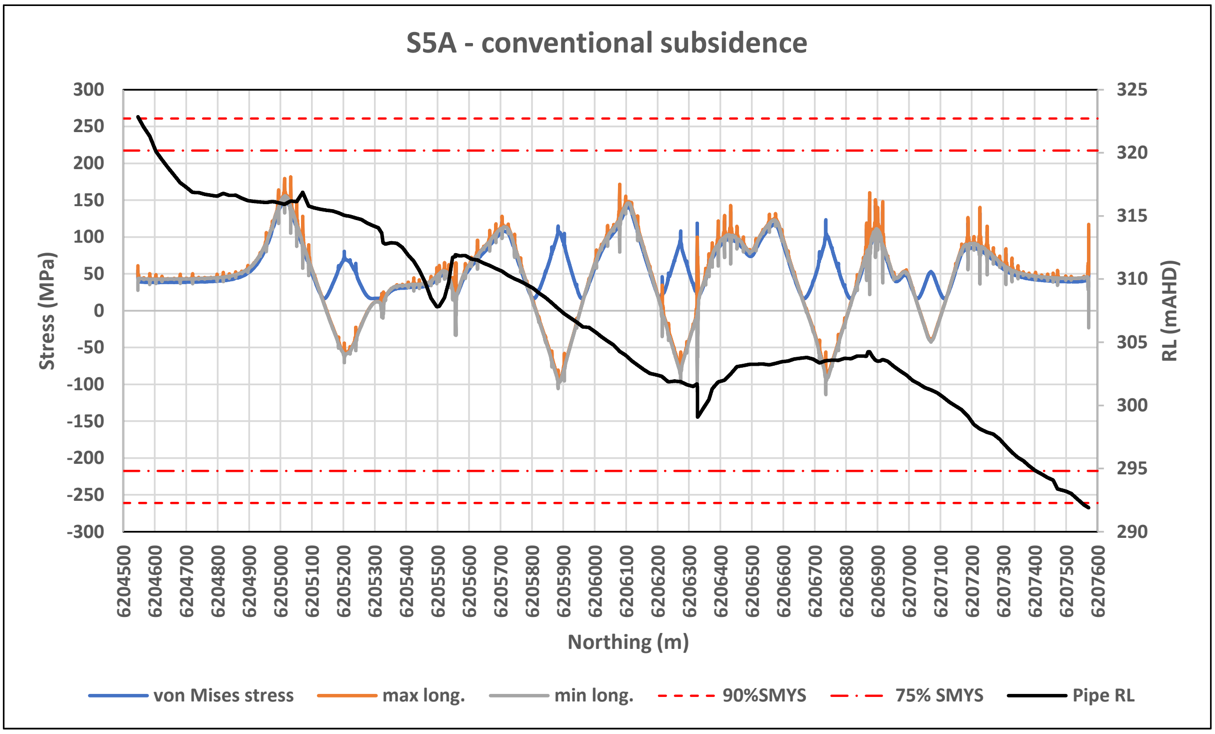


Figure 5-13: Peak pipe stress at the end of LW S5A (IP = 1.05 MPa, -16 deg C temp. diff.)

5.7 LW S6A Subsidence Impact

For LW S6A, the predicted maximum settlement is 1324 mm occurring at the settlement trough during LW S4A (Northing ~6205865). The settlement trough over LW S5A is 1301 mm and the compressive ground strain is about -1.30 mm/m.

Figure 5-14 and Figure 5-15 show the peak pipe stress distributions at the end of LW S6A mining for the positive and negative temperature differential cases. The peak stresses are summarized in Table 5-6Table 5-5. The stresses at the sharp bend at Location 1 remain above the acceptable limit. The stresses along the rest of the pipeline are within the acceptable limit.

Table 5-6: Pipe stress and strain results – end of LW S6A

Internal pressure (MPa)	Temperature differential (°C)	Location	Peak von Mises stress (MPa) [% SMYS]	Peak longitudinal stress (MPa) [% SMYS]	Peak compressive axial strain
1.05	+15	~6205203	167 [58%]	-158 [54%]	0.079%
1.05	+15	~6206326 (Location 1 Sharp bends)	312 [108%]	-303 [104%]	0.152%

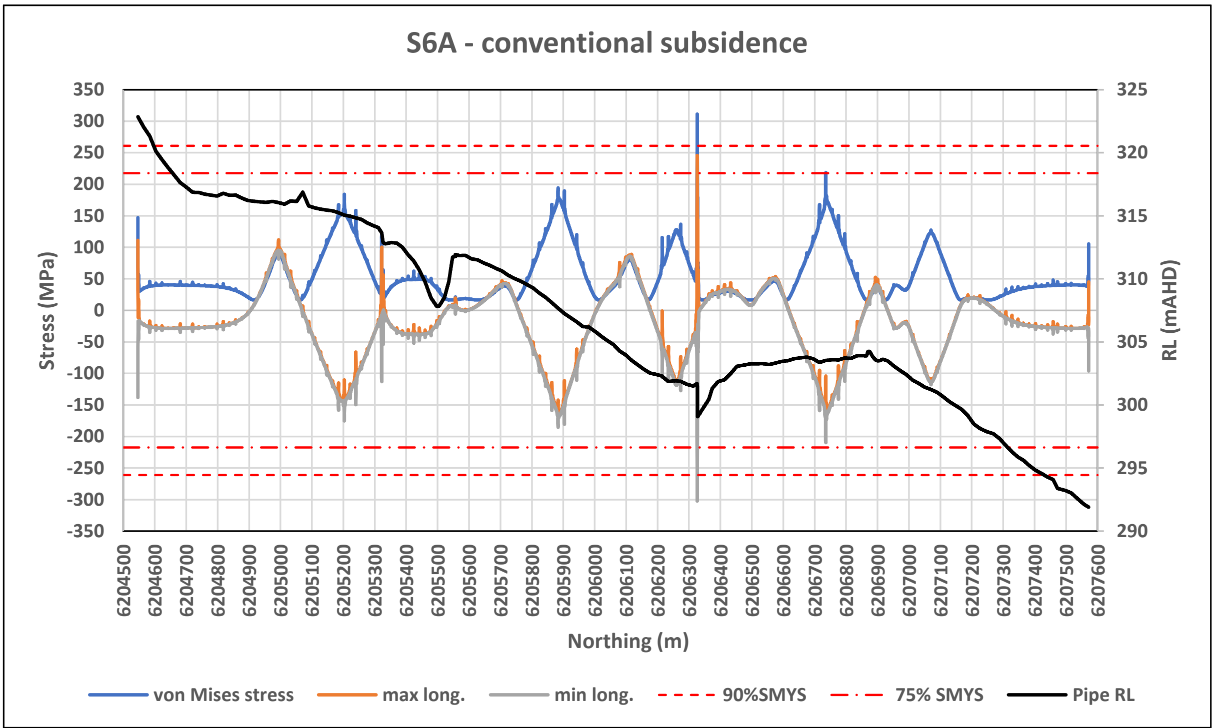


Figure 5-14: Peak pipe stress at the end of LW S5A (IP = 1.05 MPa, +15 deg C temp. diff.)

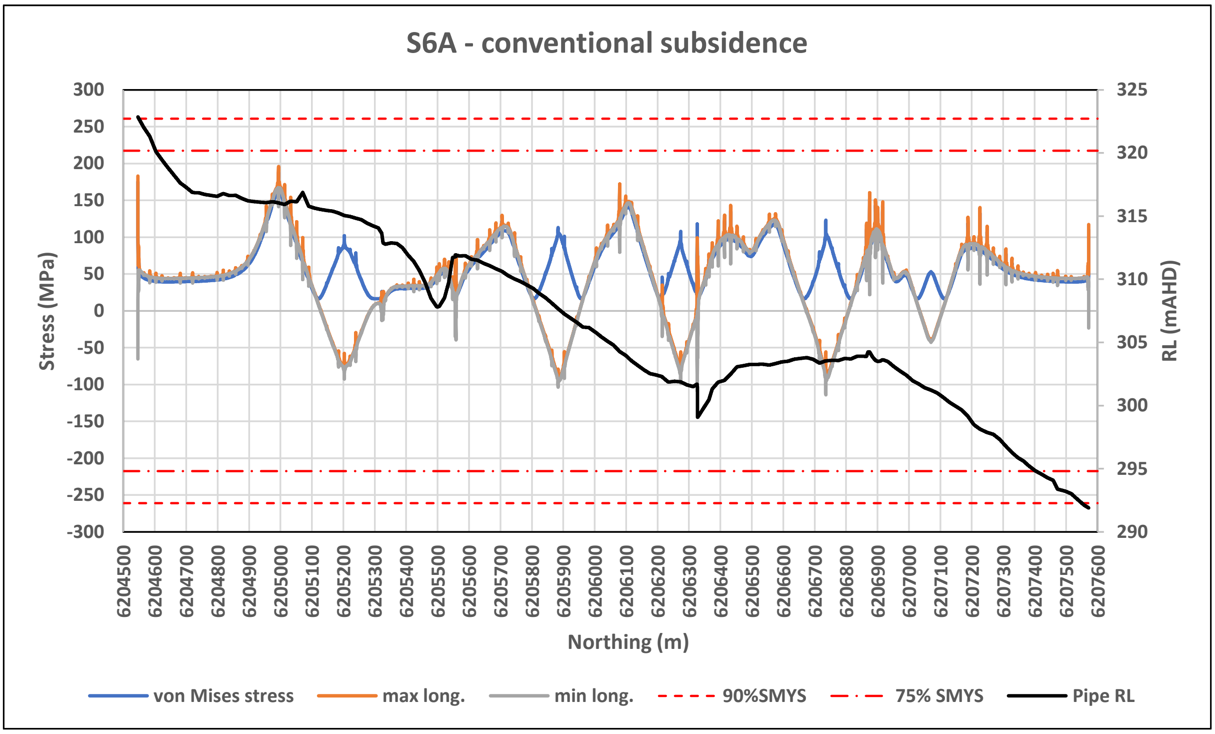


Figure 5-15: Peak pipe stress at the end of LW S5A (IP = 1.05 MPa, -16 deg C temp. diff.)

5.8 Compressive axial ground strains

Further analyses were performed to track the development of pipe stress when the axial compressive ground strain increases while the subsidence remains unchanged. Using the pipe stress results of LW S1A and LW S2A (MAOP and +15°C temperature differential), the influence of the radius of ground curvature and ground compressive axial strain on pipe stress is shown in Figure 5-16. The radius of ground curvature for LW S1A and LW S2A is about 16 km and 11 km respectively. The pipe stress at lesser radius of ground curvature may be inferred by linear extrapolation as shown in the figure. The closure ground strains for Teatree Hollow creek crossing were used for zero radius of ground curvature in the graph.

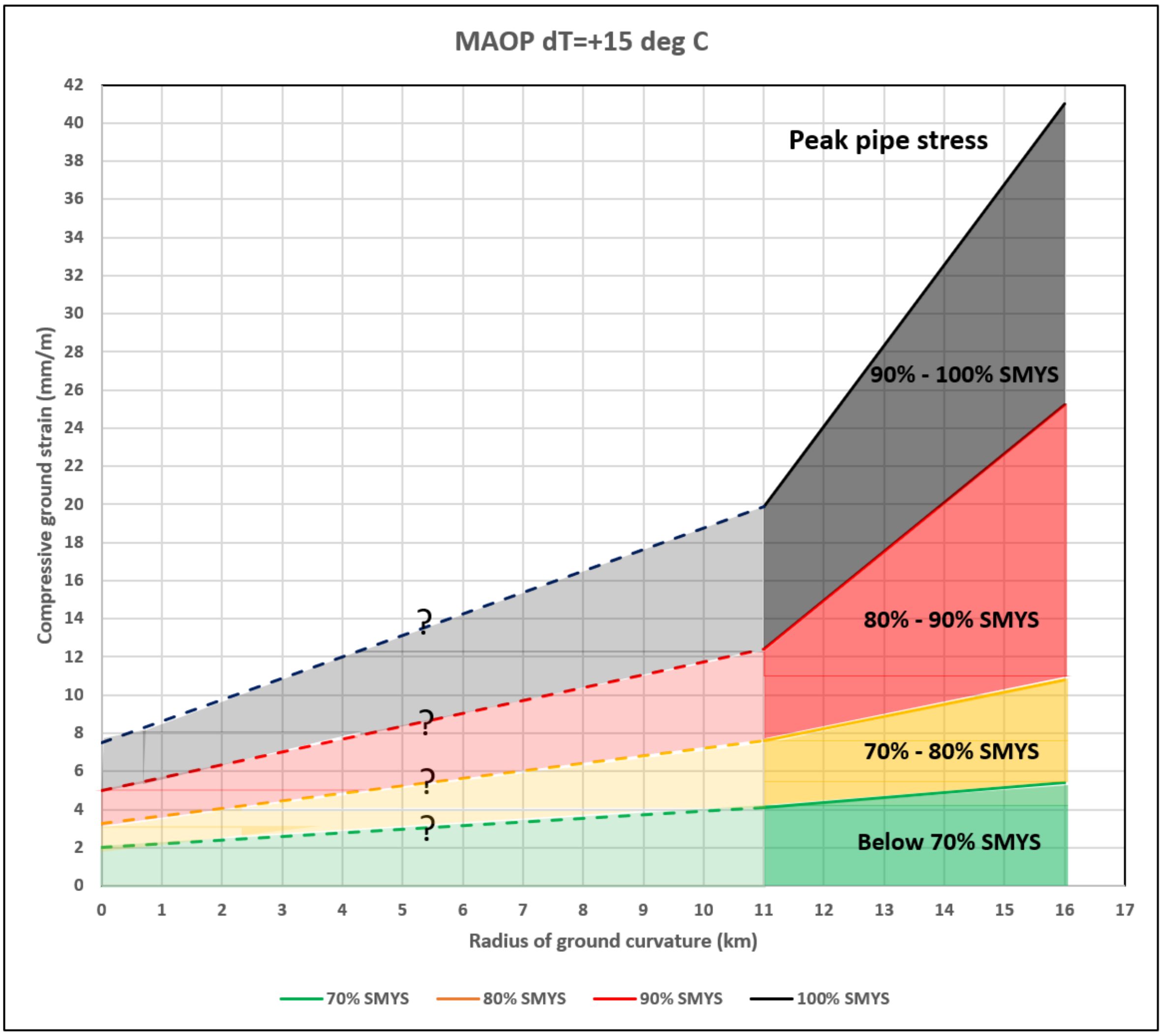


Figure 5-16: Pipe stress as a function of radius of ground curvature and compressive ground strain

5.9 Non-conventional Ground Movement

5.9.1 Step change

When there is a step change in the ground, bending and axial stresses develop in the pipe. A straight and horizontal pipeline model was used to investigate how a step change in the ground could affect the pipeline. Based on the pot-hole survey, the average depth of cover along the pipeline route is about 1m (see Figure 3-5), and this was assigned to the model.

Figure 5-17 shows the pipe stress as a function of vertical fault movement. Figure 5-18 shows the development of pipe stress as a function of lateral shear movement.

Table 5-7 summarises the step change magnitudes in the ground for the various pipe stress levels. It can be seen that the pipe stress reached the allowable code limit when the ground dropped by 59 mm (or 236 mm over 1 m), or when the ground sheared laterally by 82 mm (or 328 mm over 1 m).

Table 5-7: Pipe stress as a function of step ground movements

Pipe stress – von Mises stress		Vertical fault movement			Lateral shear movement		
(MPa)	(% SMYS)	(mm)	(mm/m)	Approx. Gradient	(mm)	(mm/m)	Approx. Gradient
203	70	40	160	1 : 6.3	60	240	1 : 4.2
232	80	49	196	1 : 5.1	71	284	1 : 3.5
261	90	59	236	1 : 4.2	82	328	1 : 3.0
290	100	69	276	1 : 3.6	93	372	1 : 2.7

Note: MAOP & +15^{o}C thermal differential

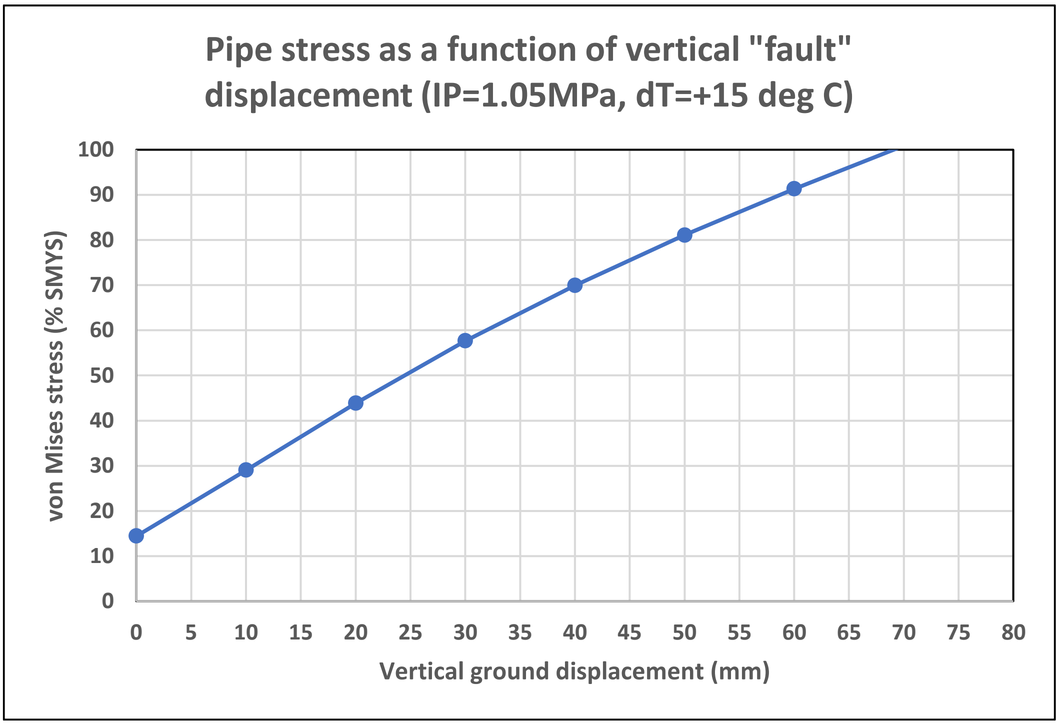


Figure 5-17: Pipe stress as a function of vertical fault displacement

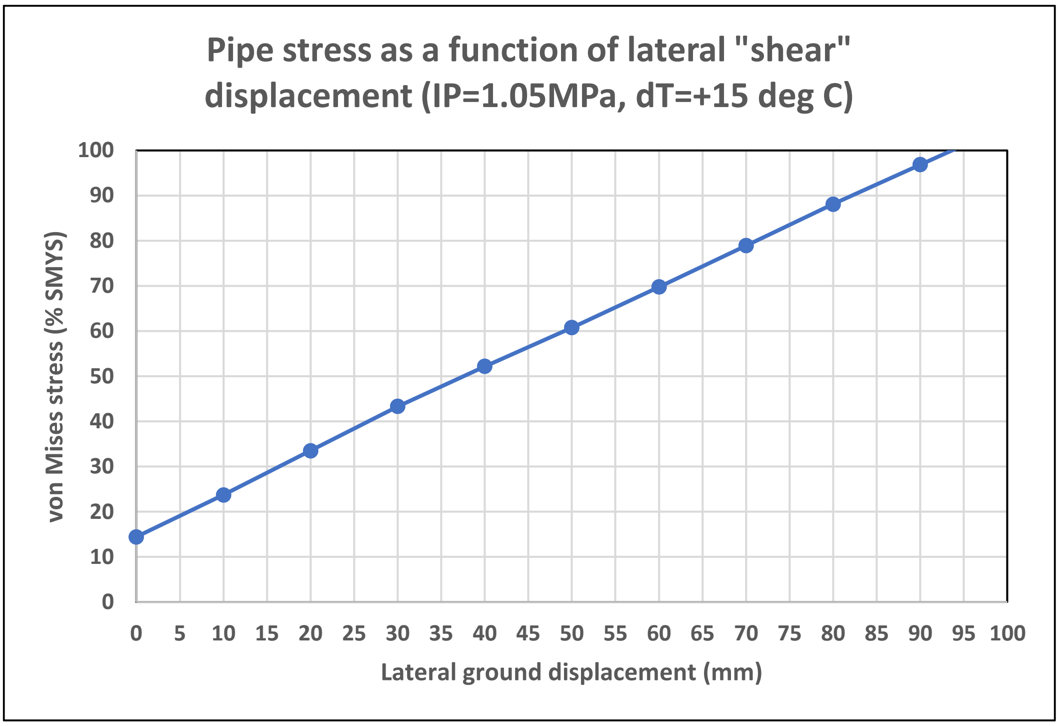


Figure 5-18: Pipe stress as a function of lateral shear displacement

5.9.2 Creek Closure

The peak pipe stress resulted in the predicted creek closure at the four locations are summarized in Table 5-8. At Teatree Hollow, the pipeline stress within the closure zone would exceed the allowable limit when subject to the maximum predicted total closure. However, the pipeline at the other three creek crossings can withstand the total predicted creek closure. The closure orientations considered have a minor effect on the pipe stress. The positive thermal load is more critical than the negative thermal load as the positive thermal load caused compression in the pipe and increased the combined (von Mises) stress. Figure 5-19 to Figure 5-22 show the von Mises stress distribution at the four creek crossings. Note that a stress spike is present at the sharp bend at Teatree Hollow and Creek 1. They may not represent the true behaviour at the bend because of the way the lateral ground movement was applied in the model.

Further closure displacement was applied to Creek 1 to Creek 3 until the pipe stress reached 90% SMYS. Figure 5-23 to Figure 5-26 show the peak von Mises stress as the total closure increases. For Creek 1 to Creek 3, an arbitrary linear extrapolation using stresses at the total closure values at 50mm and 100mm was used to estimate the closures corresponding to various stress levels. The closure trigger levels can be estimated from Table 5-9. Note that the positive thermal differential (i.e. +15°C) is the governing case.

At Teatree Hollow, the stress is governed by the small change in vertical direction of the pipeline within the closure compression zone. As such, it could only tolerate a total closure of about 95mm when the pipe stress reaches the code allowable limit of 90% SMYS. When the total closure reaches the predicted value of 150mm, the pipe stress will exceed the allowable limit. A possible mitigation is to expose the pipeline in a trench in the compression zone. See Section 7.

At the other creek crossings (i.e. Creek 1 to Creek 3), a much higher total closure up to 170 to 225 mm can be tolerated.

Table 5-8: Peak pipe stress caused by maximum predicted total closure

Creek	Bearing	Maximum predicted total closure	Pressure	Temperature differential	Peak von Mises stress	Peak von Mises stress	Code compliant
	(degrees)	**(mm)**	**(MPa)**	**(deg C)**	**(MPa)**	**(% SMYS)**	**(Y/N)**
Teatree Hollow	0	150	1.05	+15	296	102	N
	20				293	101	N
	346				292	101	N
	0	150	1.05	-16	246	85	Y
	20				244	84	Y
	346				239	82	Y
Creek 1	0	100	1.05	+15	187	64	Y
	20				180	62	Y
	337				189	65	Y
	0	100	1.05	-16	155	53	Y
	20				141	49	Y
	337				159	55	Y
Creek 2	0	75	1.05	+15	185	64	Y
	20				171	59	Y
	337				187	64	Y
	0	75	1.05	-16	101	35	Y
	20				85	29	Y
	337				105	36	Y
Creek 3	0	25	1.05	+15	130	45	Y
	20				124	43	Y
	337				130	45	Y
	0	25	1.05	-16	47	16	Y
	20				41	14	Y
	337				47	16	Y

Table 5-9: Peak pipe stress as a function of closure (IP = 1.05 MPa, dT = + 15 deg C)

Creek crossing	**Total closure (mm)**			
	Predicted	**70% SMYS**	**80% SMYS**	**90% SMYS**
Teatree Hollow	150	45	65	95
Creek 1	100	125	175	225
Creek 2	75	110	145	185
Creek 3	25	100	130	170

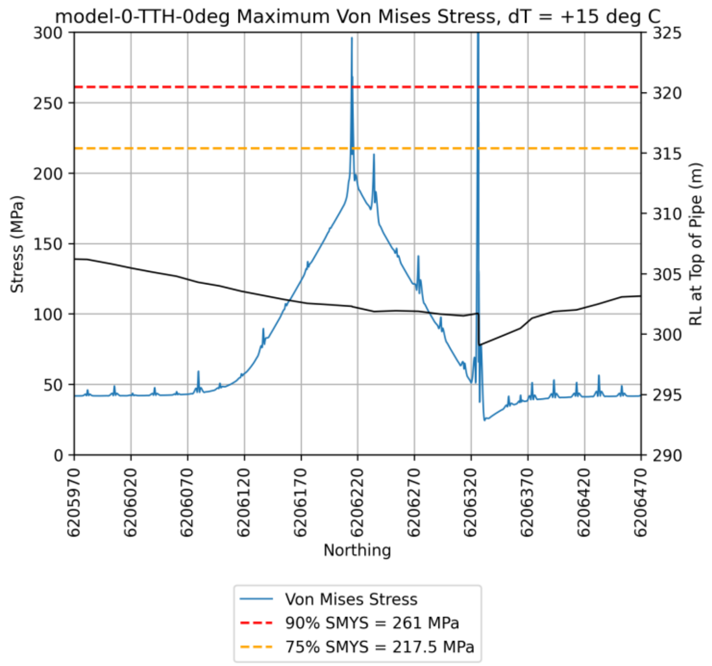


Figure 5-19: von Mises stress at Teatree Hollow due to the maximum predicted creek closure

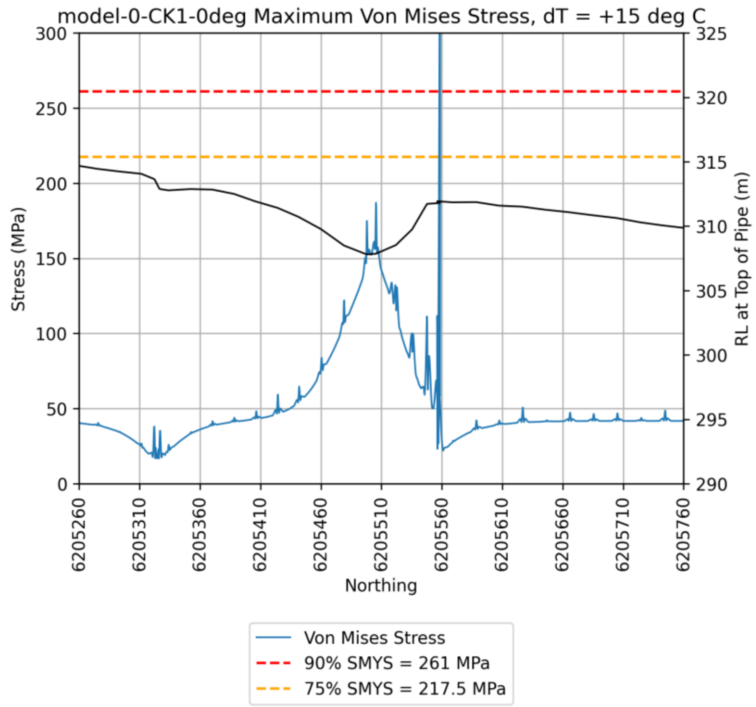


Figure 5-20: von Mises stress at Creek 1 due to the maximum predicted creek closure

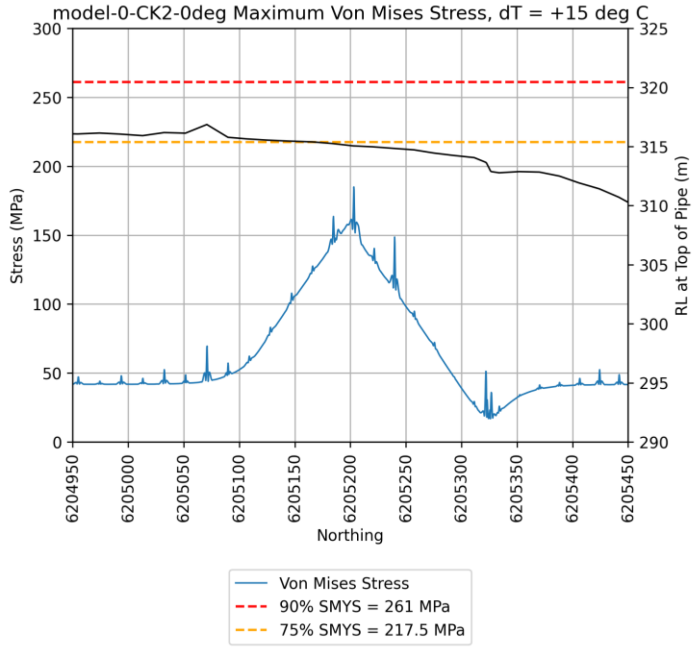


Figure 5-21: von Mises stress at Creek 2 due to the maximum predicted creek closure

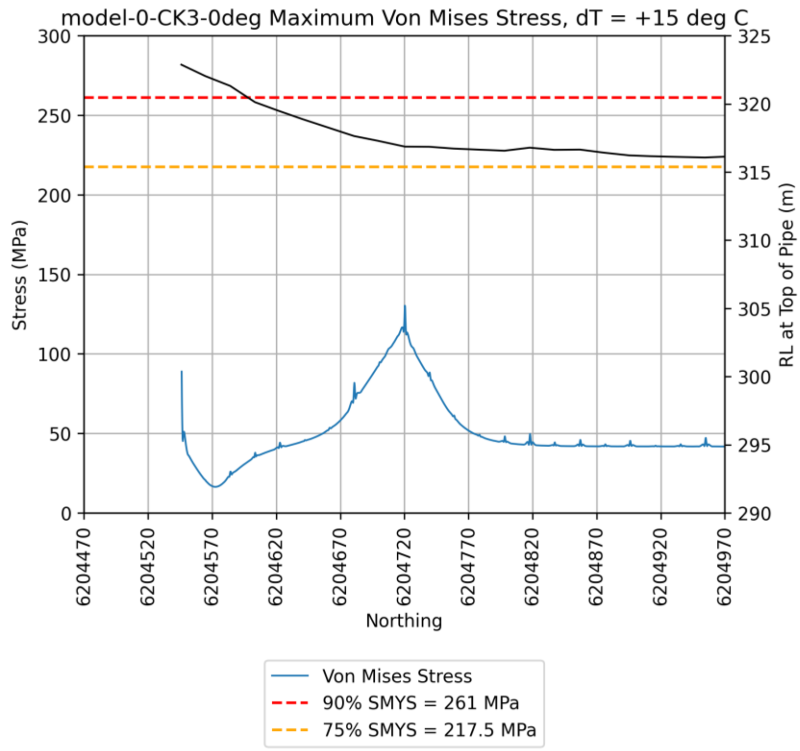


Figure 5-22: von Mises stress at Creek 3 due to the maximum predicted creek closure

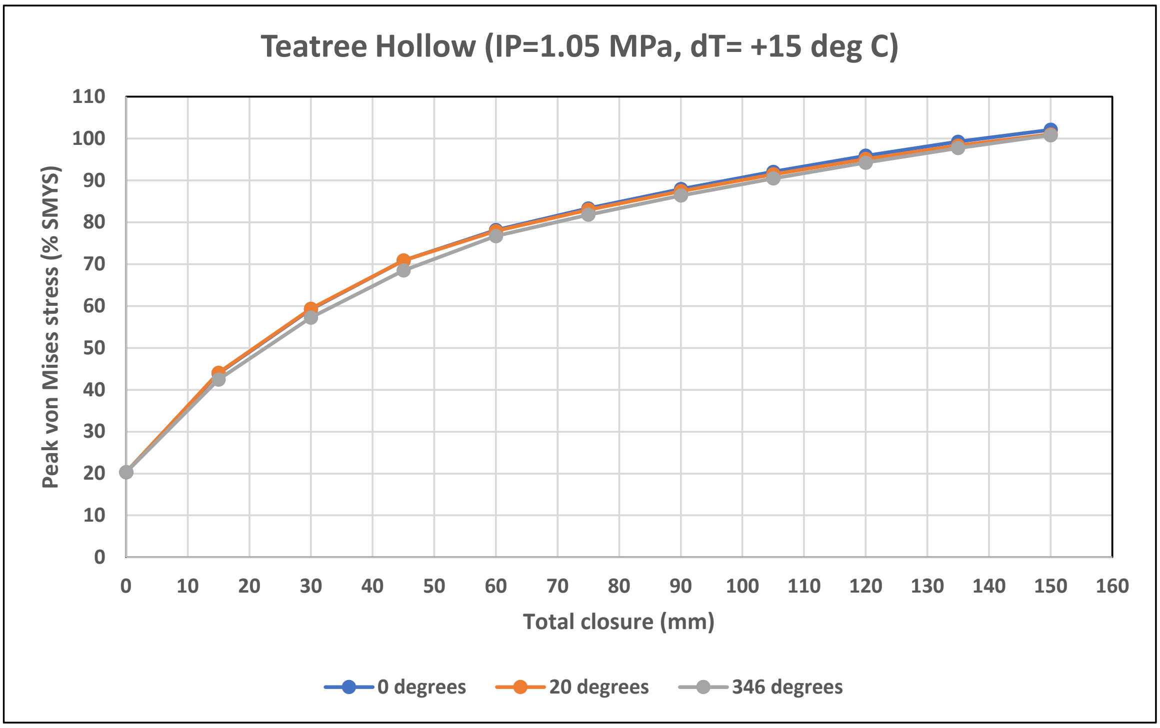


Figure 5-23: von Mises stress as a function of total closure – Teatree Hollow

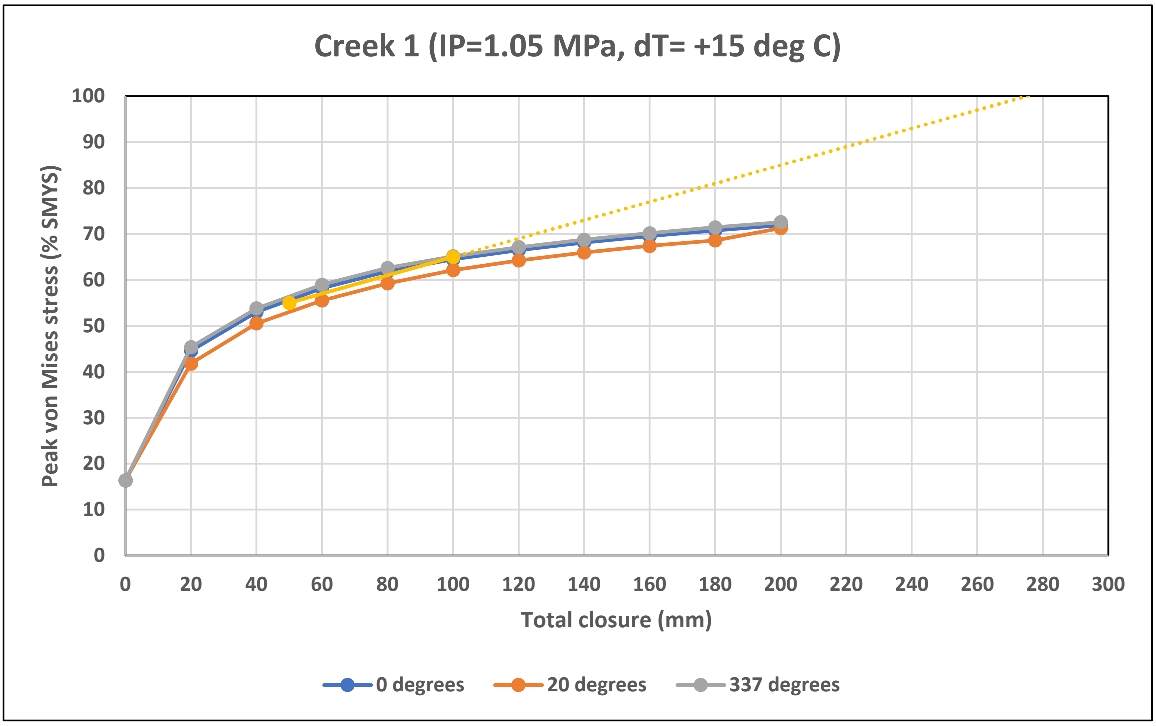


Figure 5-24: von Mises stress as a function of total closure – Creek 1

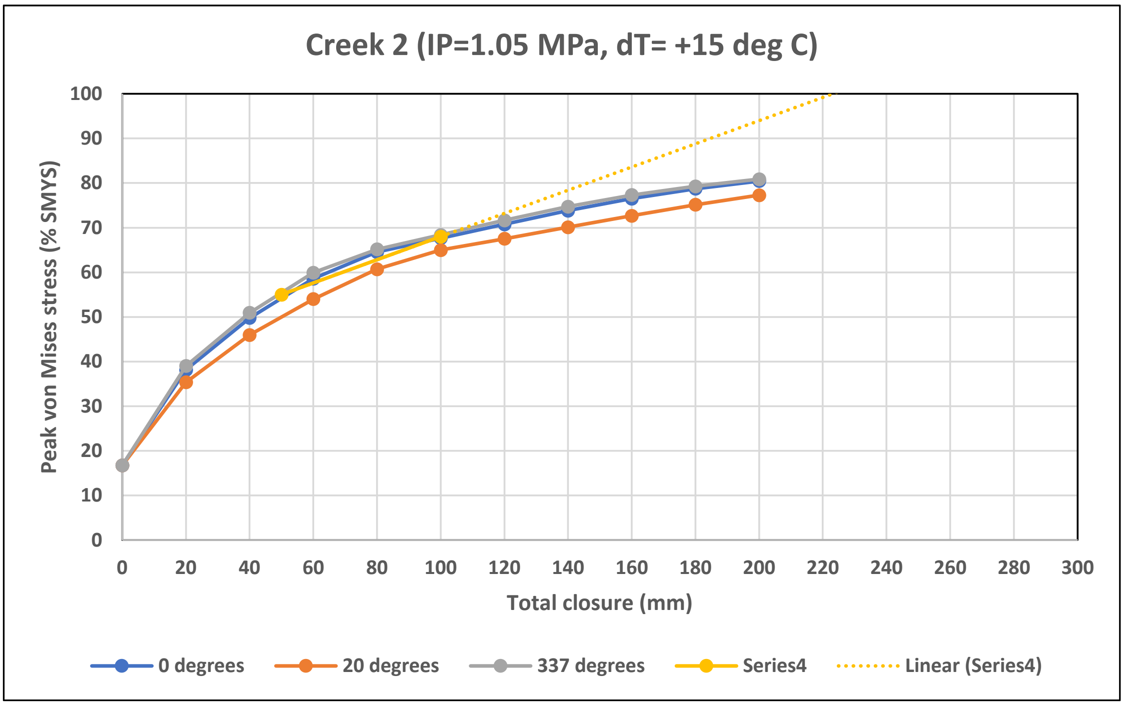


Figure 5-25: von Mises stress as a function of total closure – Creek 2

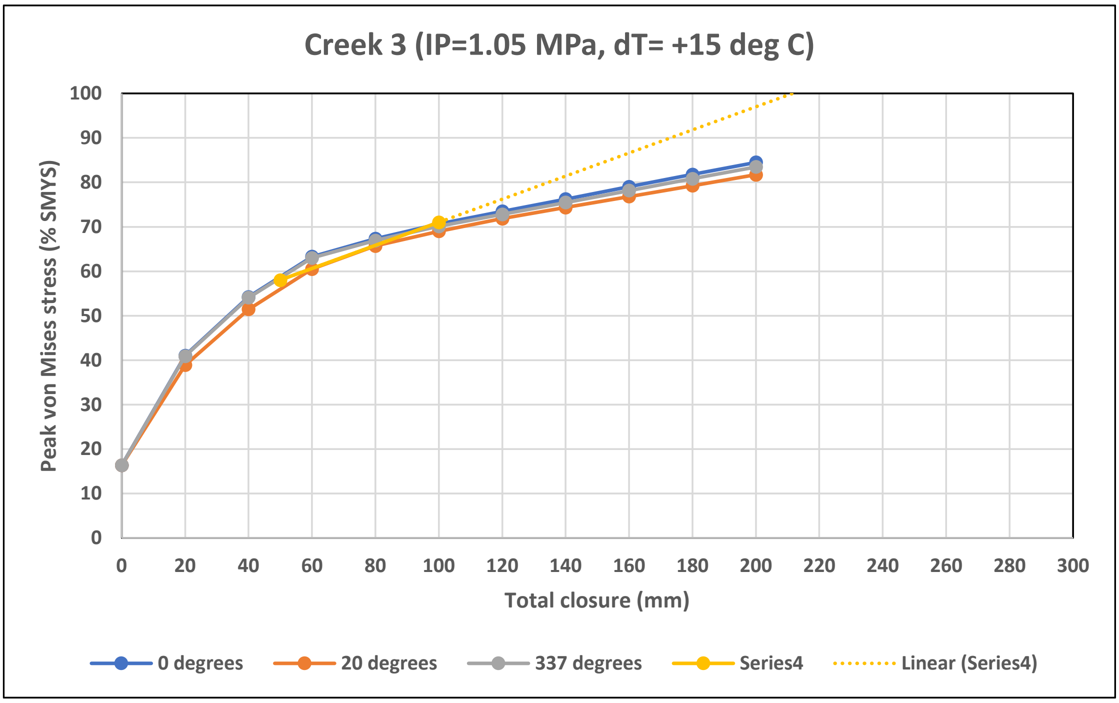


Figure 5-26: von Mises stress as a function of total closure – Creek 3

6 Mitigation Concepts at Sharp Bends

During LW S3A conventional subsidence, the pipe at the sharp bend at the top of the road embankment (Northing ~ 6206326) experienced high stresses that exceed the allowable limit (see Figure 5-9). Two mitigation concepts were investigated. They are: (1) an anchor south of the bend to provide addition axial restrain to the pipeline, and (2) expose the pipeline in a trench further south of the bend.

6.1 Anchor Block

An equivalent axial spring of 1E7 N/m representing an anchor block was attached to the pipe south of the bend as shown in Figure 6-1. The spring provided axial stiffness or resistance such that the relative displacement between the pipe and soil in the axial direction is reduced when the ground subsides.

The von Mises stress and longitudinal stresses (Figure 6-2 to Figure 6-3) at the bend when subject to S3A conventional subsidence are well below the respective allowable limits. The peak stresses shown in the figure occur further north in the region corresponds to the trough caused by S2A subsidence. Note that they are also below the allowable limits.

The disadvantage of this mitigation is that the required stiffness is difficult to quantify for design purpose.

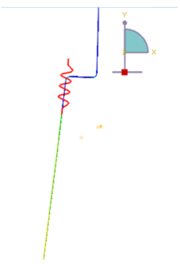


Figure 6-1: Axial spring representing an axial anchor just south of the sharp bend

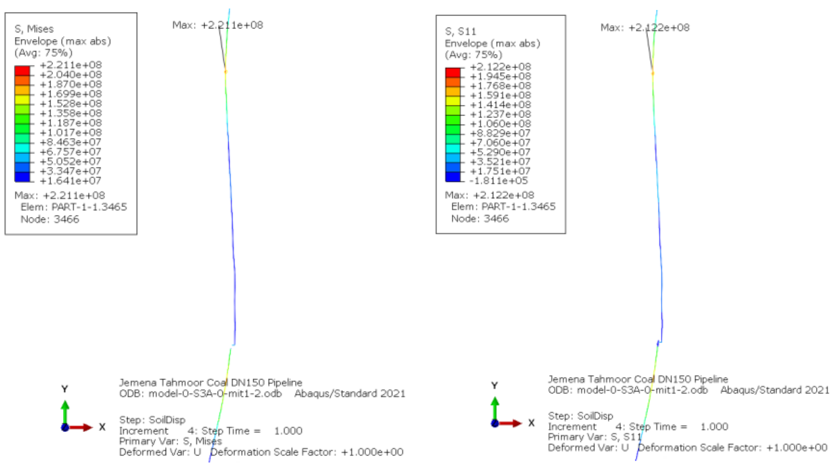
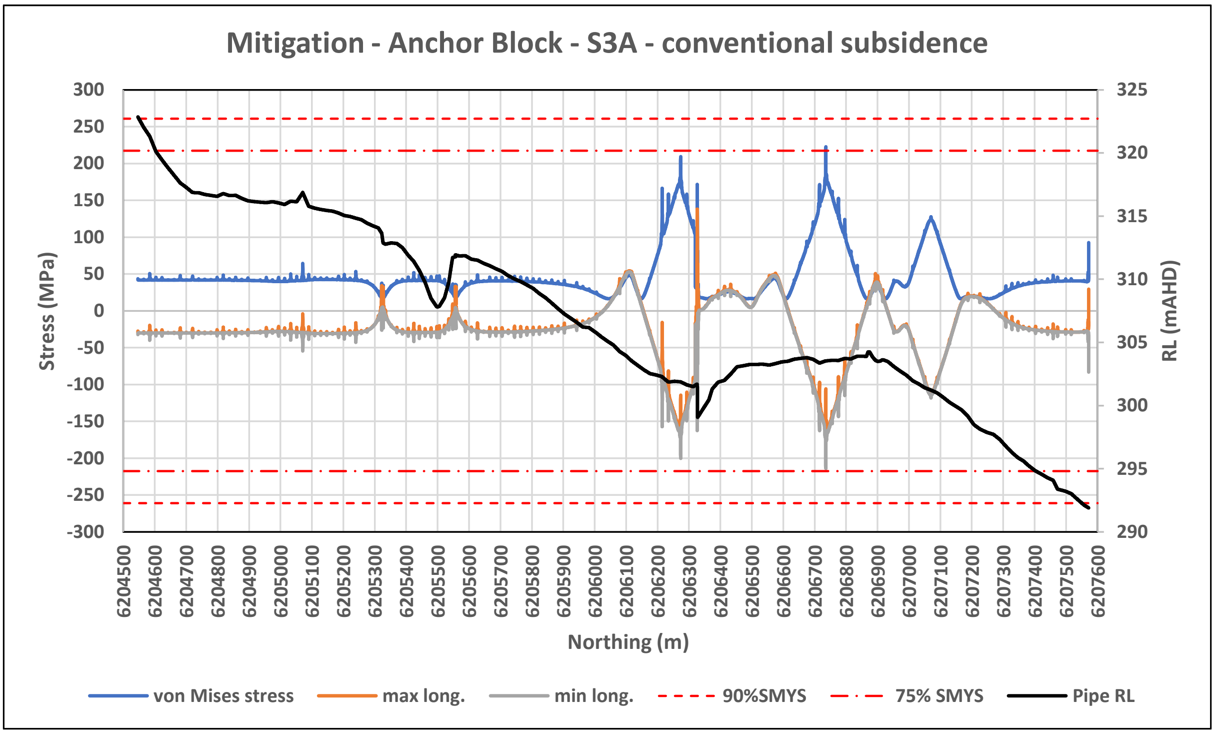


Figure 6-2: von Mises stress (left) and longitudinal stress (right) at the sharp bend – end of S3A conventional subsidence



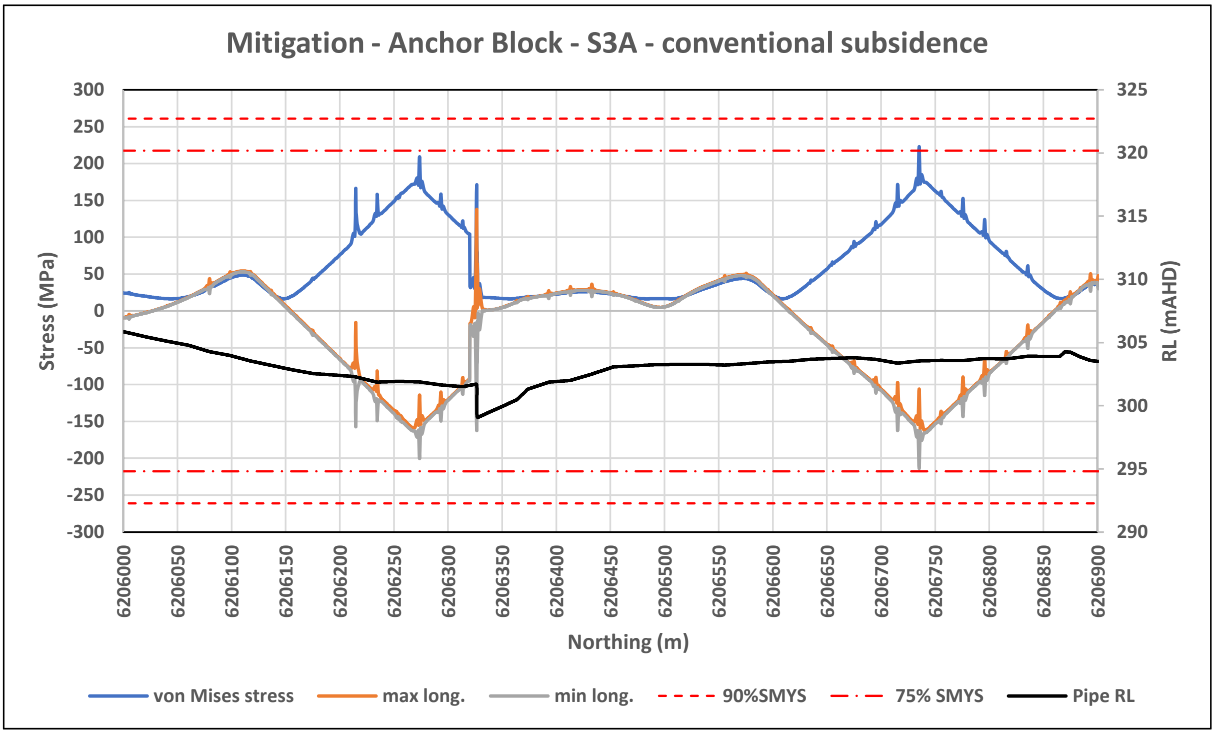


Figure 6-3: Pipeline stresses with anchor block – end of S3A conventional subsidence. Close-up view below.

6.2 Expose Pipe in Trench

Various trench lengths starting from 6.5 m south of the sharp bend were analysed for S3A conventional subsidence. The objective was to reduce the high stress in the bend located at the top of road embankment as it is subject to a significant differential lateral displacement mainly in the north-south direction. The pipe is allowed to deflect sideway inside the trench as it takes up the shortening effect due to the ground movement.

The von Mises stress and longitudinal stress for the various trench lengths are shown in Figure 6-4 and Figure 6-5 respectively. The sideway deflection is shown in Figure 6-6. For the 25m long trench the pipe stress exceeded the allowable limit. However, both von Mises and longitudinal stresses are within the limits for 50m and 75m long trench, and the sideway deflections are 1.3m and 1.4m respectively.

Further analysis was performed on the 50m long trench to determine if the sideway deflection can be reduced when a lateral restraint was applied. The results are shown in Figure 6-7. The maximum sideway deflection is now 1.2m due to the lateral support provided. The von Mises stress is within the allowable limit. However, the longitudinal stress exceeded the allowable limit by about 7 MPa. If a wide trench can be achieved along the road, then the exposed pipe should be allowed to freely deflect sideway.

This mitigation option is preferred than the anchor option because it is easier to implement. Furthermore, it can also alleviate the high pipe stress when closure occurs at the Teatree Hollow crossing which is just further south from this location. See Section 7.

The disadvantage of this option is that a wide trench is required to accommodate the sideway pipe deflection. Also the trench is close to the road pavement, and suitable offset and adequate protection in the form of crash barriers and covering plates over the trench should be considered as part of the solution.

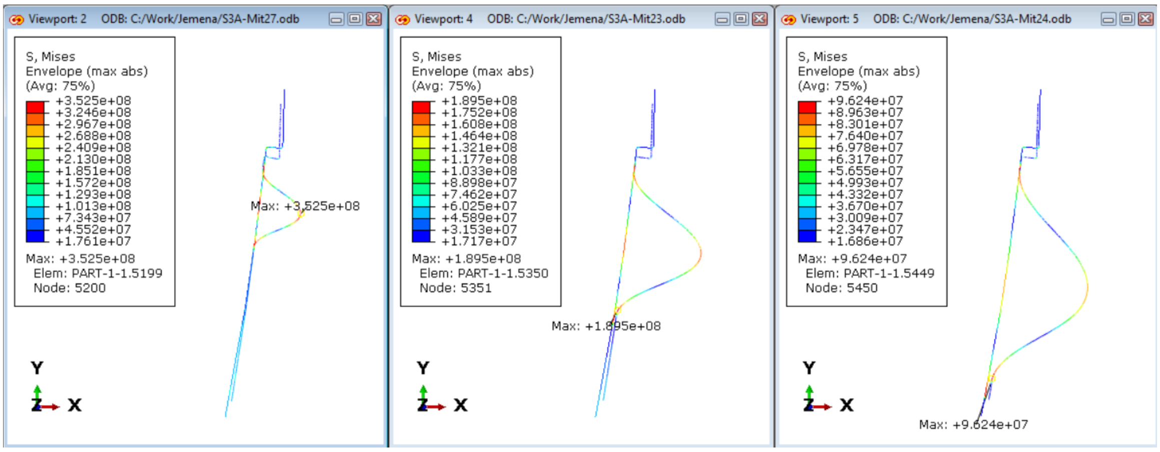


Figure 6-4: Plan view of von Mises stress contours for trench lengths 25m (left), 50m (middle) and 75m (right)

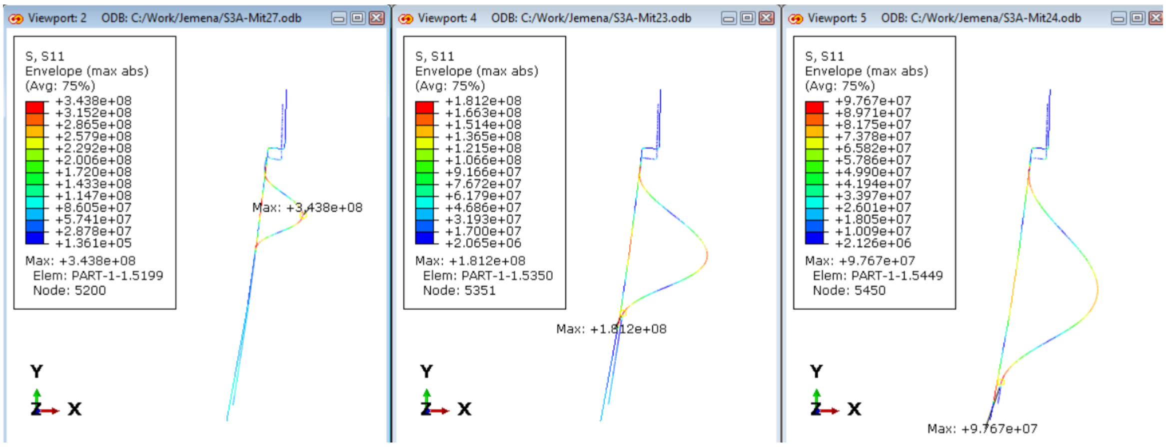


Figure 6-5: Plan view of longitudinal stress contours for trench lengths 25m (left), 50m (middle) and 75m (right)

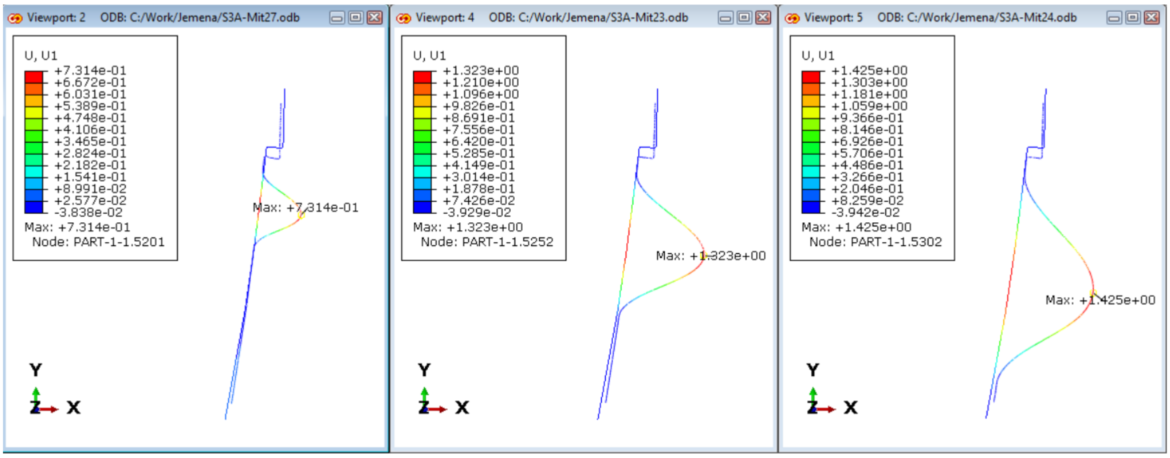


Figure 6-6: Plan view of pipeline sideway deflection for trench lengths 25m (left), 50m (middle) and 75m (right)

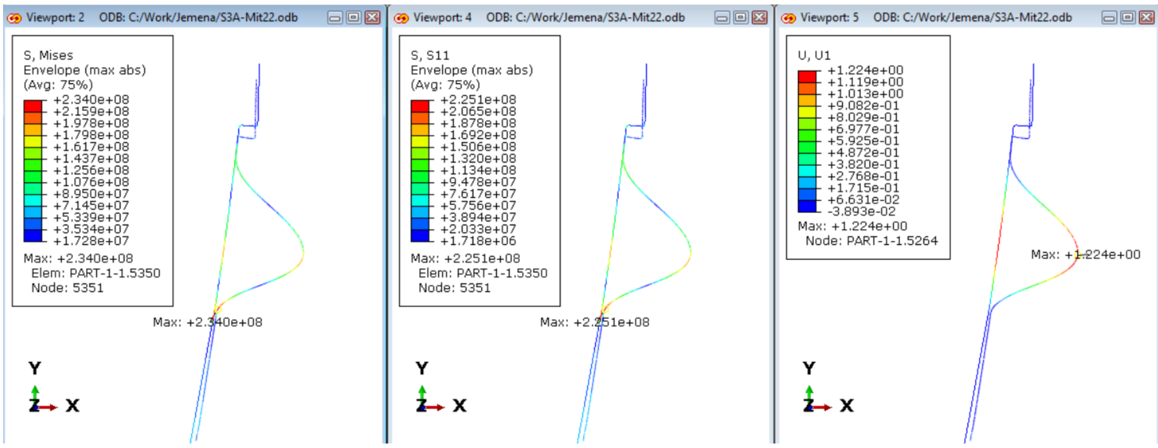


Figure 6-7: Trench length 50m with lateral restraint to exposed pipe: von Mises stress (left), longitudinal stress (middle) and sideway deflection (right)

7 Mitigation for Creek Closure

A 50m long trench positioned 25m either side of the centre of closure was analysed for the Teatree Hollow (0 degree bearing) closure case. The pipeline was allowed to deflect sideway within the trench.

The von Mises stress and longitudinal stress after 150mm total closure are shown in Figure 7-1 and Figure 7-2 respectively. The peak stress in the closure compression zone is below the allowable limit. Note that the high stresses at both ends of the model were caused by boundary effects that should be ignored.

The exposed pipe deflected sideway by about 1.5m as shown in Figure 7-3. Therefore, the trench needs to be sufficiently wide to accommodate the pipe deflection.

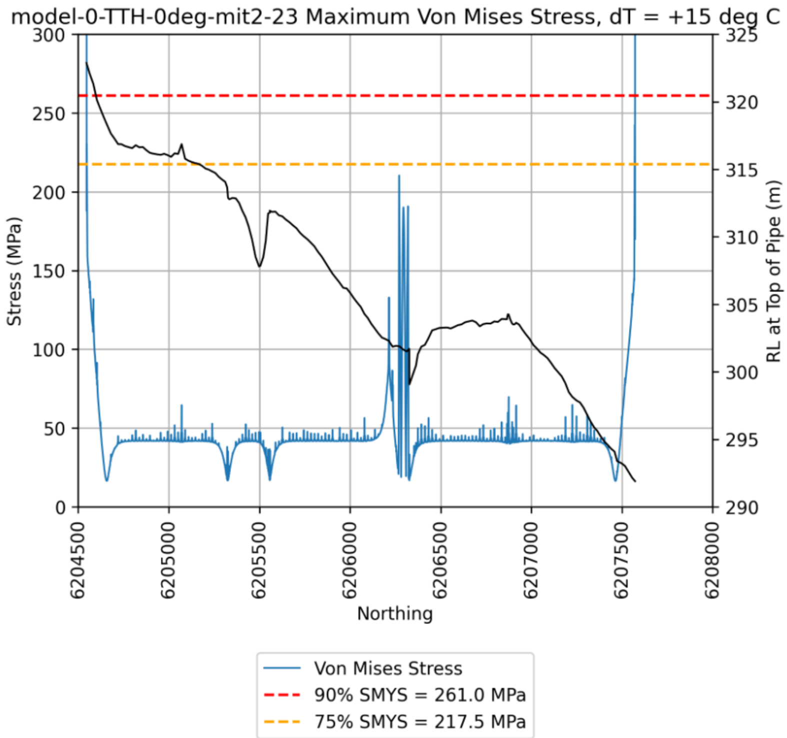


Figure 7-1: von Mises stress - 150mm total closure at Teatree Hollow

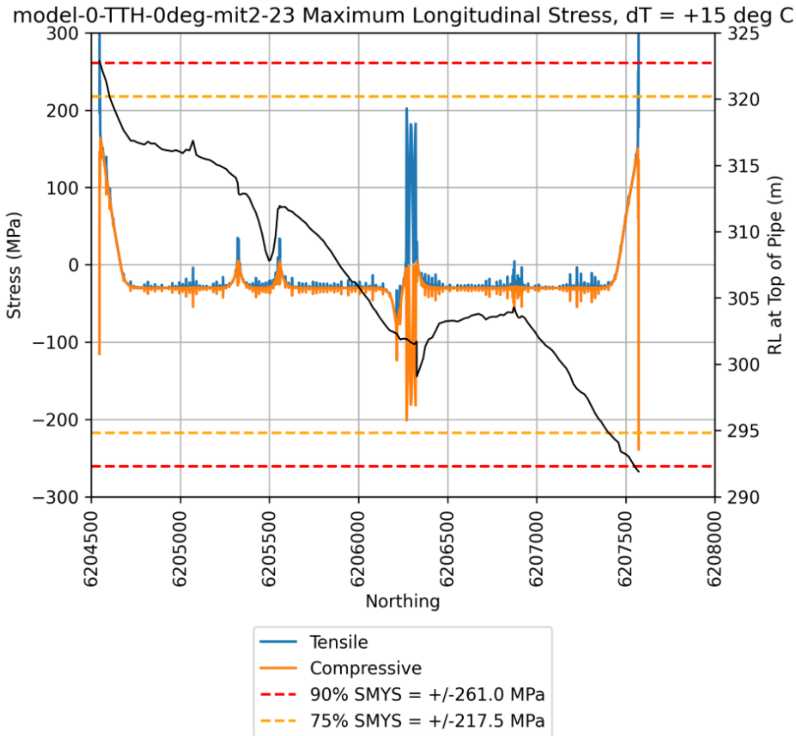


Figure 7-2: Longitudinal stress - 150mm total closure at Teatree Hollow

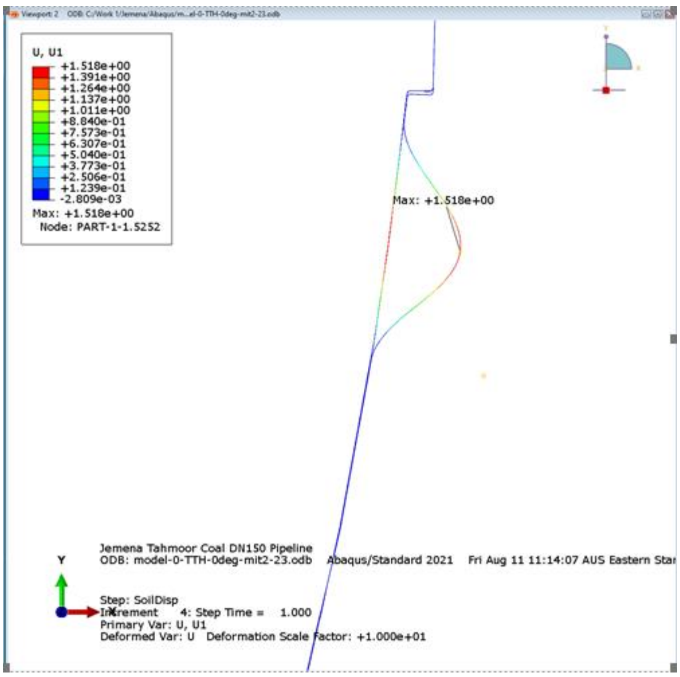


Figure 7-3: Exaggerated pipe deflection - 150mm total closure at Teatree Hollow

8 Risk Management and Mitigation Options

The analysis results indicate that the DN150 steel gas main will not be affected by the predicted conventional subsidence of LW S1A and LW S2A. Conventional subsidence due to LW S3A would cause the stress at the sharp bend (Location 1) at the top of road embankment to exceed the allowable limit. The analysis results show the subsequent conventional subsidence due to LW S4A to LW S6A would not result in the peak stress exceeding the allowable limit along the affected pipeline.

The high stress at the sharp bend (Location 1) can be mitigated by uncoupling a 50m length of pipe south of the bend in a trench. The trench design should consider the pipe sideway deflection (trench width), proximity to the road pavement, protection of the exposed pipe, managing surface water runoff and preventing flooding of the trench, ground condition in terms of trench support and ease of excavation, any nearby buried services, and other local council requirements and constraints.

To mitigate against creek closure, a length of the gas pipeline can be exposed in a trench as mentioned above. At Teatree Hollow, a trench can be used to mitigate the compression of the pipe caused by creek closure and to relieve the stress at the sharp bend caused by LW S3A conventional subsidence. Note that upsidence has not been included in the current study because of the uncertainty of the upsidence profile. Previous experience indicated the pipe can be exposed in a trench and with adjustable supports to overcome upsidence and closure. This mitigation was implemented successfully for 3 major high pressure gas transmission pipelines at Mallaty Creek during longwall coal mining at Westcliff colliery.

Survey of ground deformation along the pipe should be conducted as mining progresses. However, if the actual subsidence, in particular, the compressive ground strains, exceeds the prediction, then mitigation may be required. Note that reducing the operating pressure will not be an effective mitigation as it only reduces the hoop stress and not enough for the longitudinal stress.

In order to manage the risk to the gas main cause by mine subsidence, a trigger action response plan should be developed. Table 8-1 shows a suggested plan. The green trigger corresponds to the pipe stress below 70% SMYS. The amber trigger is for pipe stress between 70% and 80% SMYS. The red trigger is when the compressive ground strain causes the pipe stress to reach 80% to 90% SMYS and beyond.

For conventional subsidence the zones indicated in Figure 5-16 can be used to define the ground strain triggers for a range of radius of ground curvature. If the survey data is significantly different from the prediction, then the subsidence to be re-assessed and the ground strain triggers to be determined from a revised pipe stress analysis.

For non-conventional subsidence a blue trigger of 2 mm/m ground strain is suggested so that a more frequent monitoring and a finer survey resolution to be implemented to confirm the presence of step change or valley closure/upsidence at creek crossings.

Table 8-1: Suggested trigger action response plan for LW S1A and LW S2A

	Blue	Green	Amber	Red
Pipe stress		**Less than 70% SMYS**	**Between 70 & 80% SMYS**	**Above 80% SMYS**
Conventional Subsidence **Compressive ground strain trigger for LW S1A**	-	Less than 5.4 mm/m Use Figure 5-18 for radius of curvature is less than 16 km	5.4 to 10.8 mm/m Use Figure 5-18 for radius of curvature is less than 16 km	10.8 to 25.5 mm/m and above 25.5 mm/m Use Figure 5-18 for radius of curvature is less than 16 km
Conventional Subsidence **Compressive ground strain trigger for LW S2A to LW S6A**	-	Less than 4.1 mm/m Use Figure 5-18 for radius of curvature is less than 11 km	4.1 to 7.6 mm/m Use Figure 5-18 for radius of curvature is less than 11 km	7.6 to 12.4 mm/m and above 12.4 mm/m Use Figure 5-18 for radius of curvature is less than 11 km
Non-Conventional Subsidence: Vertical step change (fault) **Differential step movement**	Compressive ground strain approaching 2 mm/m	Less than 160 mm/m	160 to 196 mm/m	196 to 236 mm/m and above 236 mm/m
Non-Conventional Subsidence: Lateral step change (shear) **Differential step movement**	Compressive ground strain approaching 2 mm/m	Less than 240 mm/m	240 to 284 mm/m	284 to 328 mm/m and above 328 mm/m
Non-Conventional Subsidence: Creek closure **Compressive ground strain**	Compressive ground strain approaching 2 mm/m			
Teatree Hollow		Less than 45 mm/m	45 to 65 mm/m	Above 65 mm/m
Creek 1		Less than 125 mm/m	125 to 175 mm/m	Above 175 mm/m
Creek 2		Less than 110 mm/m	110 to 145 mm/m	Above 145 mm/m
Creek 3		Less than 100 mm/m	100 to 130 mm/m	Above 130 mm/m
Responses:	Review survey data to detect and confirm sustained irregularity in subsidence/ground deformation profile	Continue monitoring	Review survey data	Mining to stop
	If required, increase monitoring frequency in order to observe a trend and closing peg spacing to obtain a better movement resolution across the step change or irregularity	If required, increase monitoring frequency in order to observe a trend	Review and evaluate pipe performance	Review survey data and evaluate pipe performance
	Continue mining	Meeting with stakeholders to decide if further actions are required with respect to non-conventional subsidence	Meeting with stakeholders to decide if further actions are required	Meeting with stakeholders to decide if mitigation is required, and if so, select the appropriate mitigation option
		Continue mining	Continue mining as per outcome of the meeting	Implementation of the selected mitigation
				Continue mining after the mitigation has been implemented

In the unlikely event where the ground movement suddenly exceeds the red trigger or an unexpected large differential settlement, the affected pipe should be isolate by closing valves on either end. The condition of the pipe will then be assessed for damage to determine if repair is required.

Based on the Jemena Dial Before You Dig pipe network diagram Figure 8-1, there is a valve located at the beginning of the DN150 steel gas main along Hawthorne Road Figure 8-2 not far from the Moomba to Sydney Pipeline off-take. This valve will not affect the gas supply to Bargo. There is an above-ground valve at the off-take that can shut off the supply to the DN150 gas main as well as shown in Figure 8-3 and Figure 8-4. Further to the north of Bargo River, the DN150 steel gas main transitions to a DN160 PE line as shown in Figure 8-5 . This can be squeezed off and together with closing the valve upstream at Hawthorne Road, the affected steel gas main over the mine subsidence zone will be isolated and the affected pipe can be inspected and repaired.

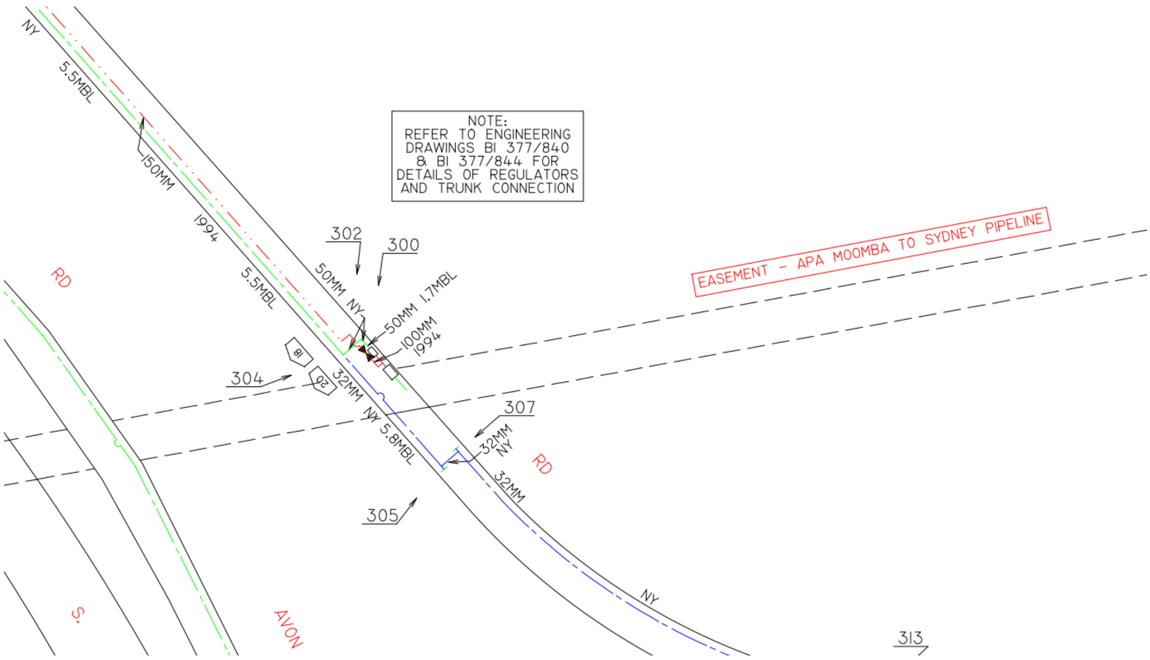


Figure 8-1: Pipe network close to the Moomba to Sydney Pipeline (Source: Jemena Dial Before You Dig).

Figure 8-2: Photo showing the below ground services at Hawthorne Road (Source: Google Street View).

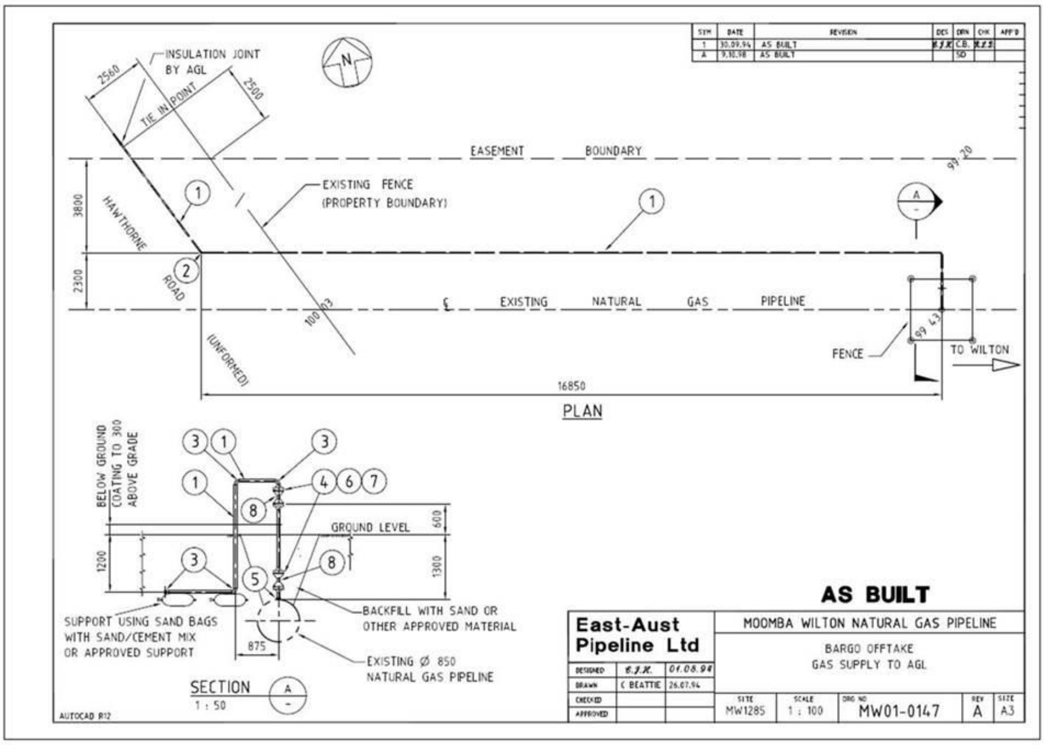


Figure 8-3: Diagram showing the Bargo offtake from the Moomba to Sydney Pipeline (Source: APA).

Figure 8-4: Photo of the Bargo offtake station at Hawthorne Road (Source: Google Street View).

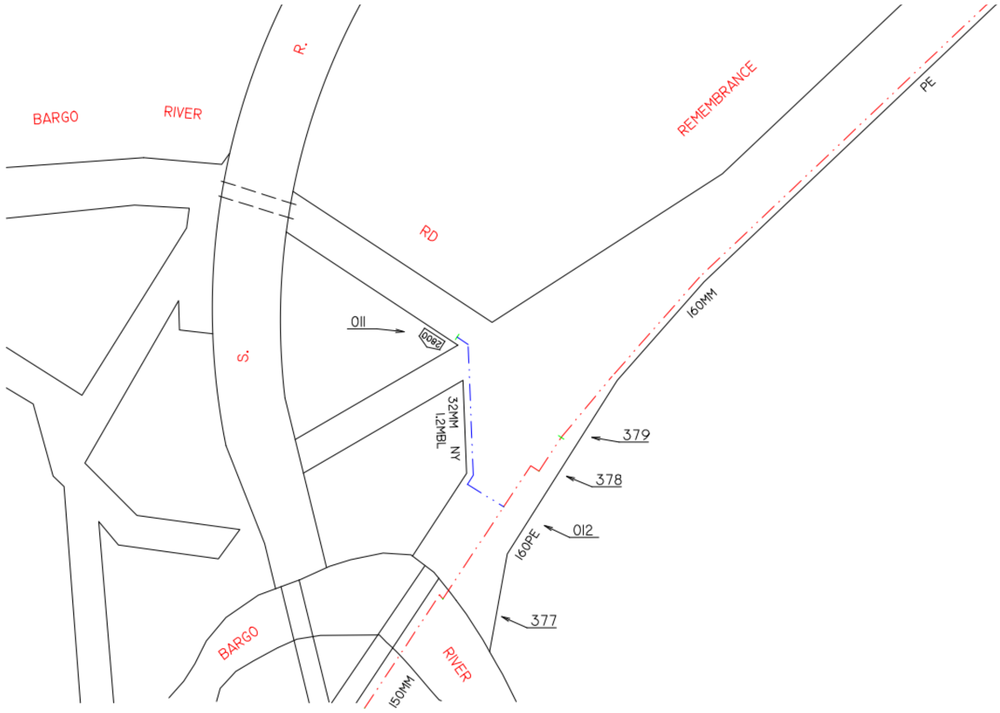


Figure 8-5: Pipe network north of Bargo River (Source: Jemena Dial Before You Dig).

9 Conclusions

Based on the findings of this study, the following conclusions are made:

1. The DN150 steel gas main when operates at the MAOP and a range of positive and negative temperature differentials, the pipe stress and strains are within their respective allowable limits when subject to the predicted ground deformation caused by LW S1A and LW S2A mining.

2. The sharp bend just north of Teatree Hollow would experience stress more than the allowable limit caused by LW S3A total conventional subsidence. This is caused by the north-south relative displacement at the bend location. Exposing the pipe in a trench of at least 50m long would be required just south of the bend to reduce the stress to below the allowable limit. It should be noted that the trench needs to be wide enough to accommodate a sideway pipe movement of 1.4m.

3. The pipeline was not overstressed when subjected to the predicted conventional subsidence caused by LW S4A to S6A. This assumed the high stress at the sharp bend north ot Teatree Hollow had been mitigated.

4. The pipe stress is dominated by the axial compressive stress caused by the thermal effects and ground movements. Assuming a reasonable temperature differential of +15^{o}C and -16^{o}C, the internal pressure has no significant influence on the combined (von Mises) stress of the pipe.

5. For non-conventional subsidence such as a step change in the ground, the pipe reached the allowable stress limit when the ground settled by 236 mm over 1 m or the ground sheared laterally by 328 mm over 1 m.

6. The pipe stress exceeded the allowable limit when subject to the predicted 150mm total creek closure at Teatree Hollow. Note that no conventional subsidence or upsidence was included in this case. This could be mitigated by exposing the pipe in a 50m long trench. However, the trench needs to be wide enough to accommodate 1.5m sideway pipe deflection.

7. The predicted total closure at Creeks 1, 2 and 3 did not cause the pipe stress to exceed the allowable limit. Note that no conventional subsidence or upsidence was included in these cases.

10 Recommendations

The following recommendations should be considered:

1. The valve at the upstream end of the DN150 steel gas main located along Hawthorne Road can be closed to isolate the pipe within the mine subsidence zone so that gas can be shut off immediately when an unexpected ground deformation occurs that may lead to damage or rupture to the pipe. The DN160 PE gas main north of Bargo River can be squeezed off in an emergency and thus isolate the affected gas main over the mine subsidence zone. The damaged pipe can then be repaired.
2. It will also be useful to check if the pipe is buried in a rock trench or not. It will have implications regarding the pipe responding to abrupt ground movement and trench excavation for mitigation purpose.
3. If there are faults/dykes that intersect the pipe alignment, relative movement across these discontinuities or weak zones may occur due to stress redistribution in the rock as coal extraction progresses. This would cause an abrupt ground deformation affecting the pipe stress. It is recommended that a geological mapping to be carried out along the pipe alignment to determine if the pipe intersects any of these geological features.
4. The present analysis assumed the pipe is defect free and no wall thickness loss. For assessment purpose, the weld material is assumed to be stronger than the line pipe material. It will be prudent to check with Jemena regarding the current condition of the gas main and the welding procedure/specification.
5. Determine nearby buried and overhead services along the gas main within the mine subsidence zone in the event that the pipe needs to be exposed in a trench to uncoupled from ground deformation. Overhead power lines will limit the headroom for excavator/crane boom, and nearby buried services may affect the extent of trench.
6. Further pipe stress analysis would be required to fine tune the trench mitigation arrangement once the upsidence profile can be determined based on survey data as LW S2A progresses. Conventional and non-conventional subsidence at similar creek location can be used to predict the likely ground movement at Teatree Hollow. Similarly, revised prediction should be done for Creeks 1 to 3, and stress analysis to confirm the pipe stress at those locations.
7. Alternative mitigation options should be considered if the trench width is limited by other constraints. For example, not sufficient width along the crest of the road embankment at Teatree Hollow.

11 References

11.1 Provided Information

1. *MSEC (23 June 2023) Excel spreadsheet of predicted conventional subsidence.*
2. *MSEC (email dated 26 July 2023) Closure prediction.*
3. *Locating Services Pty Ltd (2022) Potholing Report. 21 July 2022.*
4. *Jemena (2 Dec 2021) Route information.*
5. *Jemena (Emails 15 Nov 2021 and 10 Dec 2021) Pipe data.*
6. *Tahmoor Coal (Email 13 Oct 2022) Pothole Survey and Coordinates for Jemena Gas Main.*

11.2 Other References

7. *Advisian (2022) Mine Subsidence Impact Jemena DN150 Steel Gas Pipe. Report 311023-40903-AAG-REP-001, 31 March 2022.*
8. *American Lifelines Alliance (2001) Guidelines for the Design of Buried Steel Pipe.*
9. *AS/NZS 4645.2: 2018. Gas distribution networks Part 2: Steel pipe systems. Standards Australia.*
10. *AS 2885.1: 2018 – Pipelines – Gas and liquid petroleum Part 1: Design and construction. Standards Australia.*
11. *Gresnigt, A.M. (1986) Plastic Design of Buried Steel Pipelines in Settlement Areas. HERON, Vol. 31, No. 4, pp. 1-113.*

SIMEC Mining - Tahmoor Mine

Longwall LWS3A to LWS7A Subsidence Impacts to Jemena 150mm MP Gas Main

Risk Assessment Report

AR3793

Revision 2

27 October 2023

Assessment and report completed by;
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1. Revisions

Rev No	Date	Description
1	18 October 2023	Initial Release
2	27 October 2023	Minor corrections following internal review

TABLE OF CONTENTS

2. Participants

Name	Position	Relevant Years' Experience
Ross Barber	SIMEC Project Manager Subsidence	39 Years
Nafizul Akash	Wollongdilly Shire Council Team Leader - Asset Management	10 Years
David Talbert	SIMEC Project Manager Mine Site	30 Years
Graeme Robinson	Robinson Rail Project Manager Rail	53 Years
Glen Dominish	Advisian Worley Principal Consultant	43 Years
Bruno Martino	Jemena Networks Engineer	6 Years
Andrew Walker	Jemena Distribution Engineer	7 Years
Ryan Juhyun Son	Zinfra Project Manager	5 Years
Daryl Kay	MSEC Ming Subsidence Engineer	20 Years
David Ho	Advisian Worley Principal Consultant	20 Years

3. Introduction

This risk assessment was undertaken for Tahmoor Coking Coal Operations (Tahmoor), on potential subsidence impacts of Tahmoor's South Project longwalls LWS3A through to LWS7A on the Jemena 150mm medium pressure (MP) steel gas pipeline. The gas pipeline supplies gas to the townships of Tahmoor and Picton in the Macarthur Region of New South Wales.

Tahmoor has mined coal by longwall methods from the Southern Coalfields since 1987 and in that time has maintained a harmonious co-existence with the communities of; Tahmoor to the south-east, Thirlmere to the west and Picton to the north. Subsidence from longwall mining has impacted private dwellings, community and other infrastructure, including; the Main Southern Railway Line and associated bridges, culvert, embankments and cuttings; a Jemena 160mm Polyethylene (PE) gas pipeline running along Remembrance Drive and Bridge Street (above LW32) and the South Picton industrial area.

All subsidence is monitored commensurate with the criticality of impact and a range of mitigation measures has been devised to provide every means of ensuring that only tolerable and sustainable impacts occur. Mitigation measures include; rail expansion joints and relevelling on the Main Southern Railway Line and uncovering of the gas pipeline to uncouple it from the ground during subsidence.

This report is for the risk assessment of the impacts on the gas pipeline from LWS3A through to LWS7A only.

The overriding objective of this risk assessment was to engage with the asset owner (Jemena) and subject specialists (subsidence and pipelines) to identify and assess the risks and to develop mitigation strategies, where necessary, to prevent So Far As Is Reasonably Practicable (SFAIRP) unacceptable or unsustainable subsidence impacts to the pipeline and associated consequential outcomes, e.g., to public safety.

There were no non-consensus items identified during the risk assessment.

4. System Description

Tahmoor is located approximately 80 kilometres south-west of Sydney in the Southern Coalfields of New South Wales, within the Wollondilly Shire Council. Tahmoor has mined in this area employing longwall methods since 1987 and in that time has maintained a harmonious co-existence with the communities of; Tahmoor to the south-east, Thirlmere to the west and Picton to the north.

Tahmoor extracts up to 4Mtpa of Run of Mine (ROM), with up to 33Mt of ROM coal proposed over the remaining Life of the Project. This will produce approximately 2.5Mtpa of Hard Coking Coal for steel production.

The next years of production will focus on the Tahmoor South (Bargo) Area, which contains a further 4 longwall blocks, divided into the A-Series (northern blocks LWA3A – LWS6A) and the B-Series (southern blocks LW1B – LW6B). Tahmoor received Development Consent for both A and B Series blocks in early April 2022. Tahmoor Coal is also seeking approval for Longwall S7A that planned to be extracted after LW S6A.

Tahmoor South undermines private dwellings, businesses and private and government-owned infrastructure, e.g., roads, the Main Southern Railway Line, power, water, sewer, optical fibre communications cables and Jemena gas supply pipelines.

Jemena's 150mm diameter medium pressure (MP) steel gas pipeline passes directly above LWS1A to LWS7A. This risk assessment focuses on the interaction of the northern end of longwalls LWS3A through to LWS7A with the gas pipeline. The subsidence impacts from LWS1A and LWS2A were considered in a previous risk assessments.

The gas pipeline runs parallel to Remembrance Drive within the road easement on the norther side of the road and includes one creek crossing. Other improvements of note adjacent to the pipeline route (on Remembrance Drive) are high voltage overhead power lines and buried optic fibre cables which are managed by their own Subsidence Management Plans. Extraction of LWS1A was completed in July 2023. A anomalous high strain location was observed at markers 46/47 and mitigation on this compression hump is current underway.

Tahmoor has a proven track record for carrying out detailed monitoring, subsidence modelling and prediction and for assessing and mitigating impacts on all public utilities including gas mains. A 160mm polyethylene (PE) gas pipeline was undermined by LW32 on 2019 providing important subsidence and performance data for the impact on gas pipelines and the effectiveness of mitigation measures used to protect the pipeline's integrity.

Subsidence modelling and predictions have been carried out by Mine Subsidence Engineering Consultants (MSEC) and have been provided in a report. Detail engineering analysis and report of the proposed ground movements effects of the pipe insitu has been completed by Advisian. The contents of these reports were presented during the risk assessment and the reader should consult these reports to specific details.

5. Context Summary

5.1 Strategic Context

SIMEC Mining, Tahmoor Colliery, is committed to ensuring safety and environmental compliance within its operation. When new equipment or processes are implemented, SIMEC insist that risk assessment techniques are used to reduce the risks to people, equipment, environment and operations.

5.2 Corporate Context

As SIMEC is committed to safety and environmental compliance, when a change to systems or new equipment or systems are introduced into the operation, management insist that risk assessment techniques are used to identify and minimising exposure to its people and the operations. SIMEC is also committed to implementing risk assessment techniques to identify risk when required by external sources.

5.3 Risk Management Context

The primary objective of this risk assessment is to identify hazards and existing controls associated with the safety and serviceability of the Jemena 150mm steel Medium Pressure gas pipeline from the mining of Longwalls S3A through to S7A, and to make recommendations for further controls where appropriate.

The main consideration is for personal safety however equipment damage, operational loss and environmental issues will be considered where relevant.

6. Objectives and Scope

The objective of the risk assessment was to facilitate a structured process to enable critical and objective challenge of the subject area to assist Tahmoor fulfil its obligations, namely:

- Public safety by direct or consequential impacts from subsidence on the gas pipeline,

- Obligations imposed by NSW Work Health and Safety legislation, including;
    - Work Health & Safety Regulation 2017, with particular focus on:
        - Part 3.1 Managing risks to health and safety,
    - Work Health & Safety (Mines & Petroleum Sites) Regulation 2014, with particular focus on:
        - Clause 9 Management of risks to health and safety - risk assessment is conducted in accordance with this clause by a person who is competent to conduct the particular risk assessment having regard to the nature of the hazard.
        - Clause 23 Identification of principal hazards and conduct of risk assessments,
        - Clause 33 Notification of high risk activities,
        - Clause 67 Subsidence,
        - Clause 128 Duty to notify regulator of certain incidents, (5) High Potential Incidents (m) any indication from monitoring data of the development of subsidence which may result in damage to any plant or structure or a failure of ground
        - Schedule 1 Principal hazard management plans—additional matters to be considered, 3C Subsidence
        - Schedule 3 High risk activities, 16 Secondary extraction

- Risk assessment process in accordance with AS/NZ ISO 31000:2018 – Risk Management and MDG 1010 - Risk Management Handbook for the Mining Industry, with risk rating in accordance with the Tahmoor Risk Assessment Matrix

- Participation of the asset owner, subsidence and pipeline specialist engineers and Tahmoor,

- Compliance with Planning Approval - Key Performance Measures:
    - The project does not cause any exceedances of the performance measures to the satisfaction of the stakeholders,
    - The gas pipeline as key infrastructure serving the public is always safe and serviceable,
    - Damage that effects safety or serviceability must be fully repaired at the completion of the mining,
    - Arrangements are in place to maintain the serviceability of the asset.

- There were nil non-consensus matters raised during the risk assessment.

7. Assumptions and Constraints

The following assumptions were made during the risk assessment:

- Existing monitoring and control systems will be maintained throughout the project unless otherwise stated.
- Subsidence movements will normally occur gradually over a period of months.
- Stage 1 (Early Subsidence) refers to small movements and limited impacts as longwall extraction approaches the rail line.
- Stage 2 (Active Subsidence) refers to the period of significant movement and potential impacts as extraction occurs beneath the railway.
- Stage 3 (Post Active Subsidence) refers to the limited impacts and movements, reducing to zero over time, experienced as the longwall extraction continues to retreat away from the railway.
- Jemena has in place processes, procedures and contingency arrangements for dealing with gas leaks, potential fires, repairs and service reinstatement. Though these issues were discussed with the asset owner at length during the risk assessment the response to these events is reliant on a call-out of Jemena or prequalified contractors to deal with the incident.
- Jemena has in place maintenance and inspections schedules and procedures
- Odorised gas is used to facilitate leak detection
- Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes.

8. Risk Treatment

An audit system needs to be in place to ensure all recommendations from this assessment are implemented.

The group were introduced to the Risk Assessment Process at the commencement of the session by the facilitator. The various steps were explained and the group reviewed the Likelihood, Consequence and Risk Ranking matrix.

The risk ranking was done with consideration to existing controls being in place.

Controls were developed using the following forms.

1. Avoidance – avoid the risk by deciding not to proceed with the activity likely to generate the risk (where this is practicable).
2. Reduction – reduce the likelihood of the event.
3. Reduction – reduce the consequences of the event.
4. Accept – accept the risk within the organisation and establish an appropriate plan to manage the consequences of these risk if they are to occur.

The above risk control options were applied by reference to the following control methodologies in a hierarchical sequence.

1. Design – to the extent reasonable and practicable ensure that hazards are designed out when new materials, equipment or work systems are being planned for the workplace.
2. Remove the hazard or substitute less hazardous materials, equipment or substances.
3. Adopt a safer process – alter tool, equipment or work practices to make them safer.
4. Enclose or isolate the hazard – provide guards or remote operation and handling techniques.
5. Provide effective ventilation – install local or general exhaust ventilation systems.
6. Establish appropriate administrative procedures. Set up, document and implement new procedures that provide for:
   - Scheduling of the job so that fewer workers are exposed;
   - Routine maintenance and housekeeping procedures;
   - Training on hazards and correct work procedures.
7. Personal Protective Equipment – provide suitable and properly maintained personal protective equipment and training in its use.

9. Facilitator Qualifications and Experience

Shane Chiddy holds an Associate Diploma in Engineering (Electrical), is an Officer of the Institution of Engineers (Australia) and is a member of the Asset Management Council of Australia (AMC) and the Mining Electrical and Mining Mechanical Engineering Society (MEMMES). He has also completed Contract Law through Macquarie University, Carry out the Risk Management Process (G2) and Establish the Risk Management Systems (Mine 7033 - G3) through Queensland University and is certified as a Functional Safety Engineer by TÜV Rheinland for both Safety Instrumented Systems (#7652/13) and Machine Safety (#9315/14).

Prior to commencing his consulting career, Shane Chiddy qualified as an electrician and worked underground for 9 years. He then occupied a number of engineering roles within Rio Tinto, including such roles as electrical supervisor, Development Engineer and Senior Production Engineer. This latest role was responsible for the Longwall, underground diesel equipment and conveyors.

Additionally Shane Chiddy has been trained and accredited by John Moubray in the UK as a certified RCM II practitioner and has conducted a number of extensive Reliability-centred Maintenance II analyses including underground and surface equipment such as Longwalls, Continuous Miners and conveying systems. He has facilitated RCM II analysis and delivered training in the mining, defence, power distribution and telecommunications industries.

His consulting experience includes the application of Reliability-centred Maintenance II and extensive Risk Management and Project Management assignments.

10. Sub-Systems Considered in the Assessment

Sub-System		STEP IN PROCESS	
1	Subsidence from the mining of Longwalls S3A through to S7A in the area of Jemena 150mm Pipeline	A	Impact to pipe in plateau areas due to conventional and non-conventional subsidence
		B	Impact to pipe at Caloola Road (within the embankment) due to conventional and non-conventional subsidence from Longwall S3A
		C	Impact to pipe at Remembrance Drive cutting near longwall S3A due to conventional and non-conventional subsidence
		D	Impact to pipe at un-named creek crossing above longwall S5A (along base of embankment) due to conventional and non-conventional subsidence.
		E	Impact to pipe at Yarran Road creek crossing (within the embankment) due to conventional and non-conventional subsidence from Longwall S6A.
		F	Impact to pipe at Wellers Road creek crossing (within the embankment) due to conventional and non-conventional subsidence from Longwall S7A

11. Risk Assessment Methodology

11.1 Qualitative Risk Analysis

This Risk Assessment has been performed using Qualitative Risk Analysis techniques and has been performed to align with the principles of the Australian Standard AS31000 - Risk Management Principles and Guidelines and the Department of Mineral Resource Guideline MDG1010.

The Risk Assessment has followed the WRAC (Workplace Risk Assessment and Control) principles as outlined in the guideline.

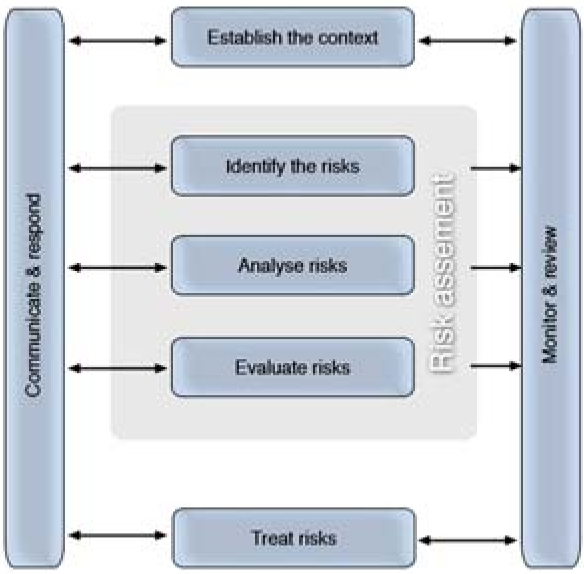
The qualitative approach succeeds by using local expert knowledge and relevant historical data.

This system of analysis uses a participative approach which is very powerful for identifying potential hazard scenarios.

The following steps outline the systematic identification of hazards, ranking of risks, and identification of new and/or improved controls that were used in the Risk Assessment session:

1. Introduce team to the Risk Assessment process and the context of the Risk Assessment. This includes the scope and method of the Risk Assessment.
2. Identify discrete components, or elements, of the Project.
3. Identify and add potential deviation steps.
4. Review each sub-system and identify loss scenarios - (Potential Incidents and Accidents).
5. For those hazards evaluate the risk using the risk rank method by determining the probability, consequence, and risk rank of each loss scenario.
6. Identify existing controls for each hazard.
7. Specify additional controls required to control the hazard(s).
8. Close the Risk Assessment.
9. Document and distribute to the team for proof reading.
10. Undertake verification of the assessment by a nominated person.

The available Standards on Risk Management (including MDG1010) define the Risk Management process as that shown below.



11.2 Establish the Context

This risk analysis has been performed using Qualitative Risk Analysis techniques and is performed in compliance with the Department of Mineral Resources (now the Resources Regulator) Guideline MDG1010.

11.3 Identify Hazards

This step involves identification of all the hazards to be managed. To correctly apply this step a well-structured systematic process must be used, because controls may not be able to be implemented to reduce or eliminate any hazards missed at this point in the analysis.

For each hazard, the team identifies:

1. What Can Happen; and
2. How and Why it Can Happen.

Checklists, Flowcharts and Brainstorming are used to identify hazards.

11.4 Analyse Risks

The main objectives of an analysis is to separate minor risks from major risks and to provide data to assist in the evaluation and treatment of hazards.

Risk Analysis involves considering the following:

1. Likelihood of the Hazard occurring (identified as 'L' within the worksheets).
2. Consequences if the Hazard does occur (identified as 'C' in the worksheets).
3. Determining any existing controls.

The combination of the Likelihood and the Consequence determines the level of the risk involved. The likelihood and consequence categories used are outlined in Section 13.

During the assessment the consequences are categorised as either hazards to personnel, the environment or to the site operations. Additional categories such as reputation and community may also be considered where deemed appropriate.

The consequence category is identified on the Analysis Worksheets in the Column labelled 'T' for Type.

11.5 Evaluate Risks

Evaluation involves comparing the level of risk found during the analysis with previously established risk criteria.

The output of this part of the process is a list of prioritised hazards for further action.

If the resulting hazards fall into the low or tolerable risk categories, they may be accepted with minimal further treatment. Although, low and tolerable hazards should be monitored and periodically reviewed to ensure that they remain tolerable.

If hazards do not fall into the low or tolerable risk category, then they should be treated using other options.

11.6 Treat Risks

Risk treatment involves identifying the range of options for treating risks, assessing the options and preparing risk treatment plans and implementing them.

Risk treatment may be in one of the following forms:

1. Risk Avoidance. Decide not to proceed with the activity.
2. Reduce Likelihood. Reduce the chance of the risk occurring.
3. Reduce the Risk Consequences. Reduce the consequence if the risk occurs.
4. Retain (or accept) the Risk. Plans should be put in place to mitigate the consequences of these risks in the event that they occur.

Risk treatment options should be assessed on the extent of any additional benefits or opportunities created. A number of options may be considered and applied either individually or in a combination.

Risk treatment plans should be developed to identify responsibilities, schedules, budgets and performance measures and the review process that is to be established. If no other actions are identified, as needing to be implemented, the group believed the risk was As Low As Reasonably Practicable (ALARP).

11.7 Monitor and Review

It is essential to monitor the effectiveness of the risk management system and the risk treatment implementation.

Risks and the effectiveness of control measures need to be monitored to ensure that the changing environments do not alter risk priorities. Few risks remain static.

Factors affecting Likelihood and/or Consequence change as do factors regarding suitability of controls.

11.8 Communications and Consultations

Communication and consultation are important during the entire risk management process. It is important to develop a communication plan for both internal and external stakeholders.

This should be a two-way consultation not a one-way flow of information.

Effectiveness of internal and external communications is important to ensure that those responsible for implementing risk management understand the basis on which all decisions have been made, and why particular actions are required.

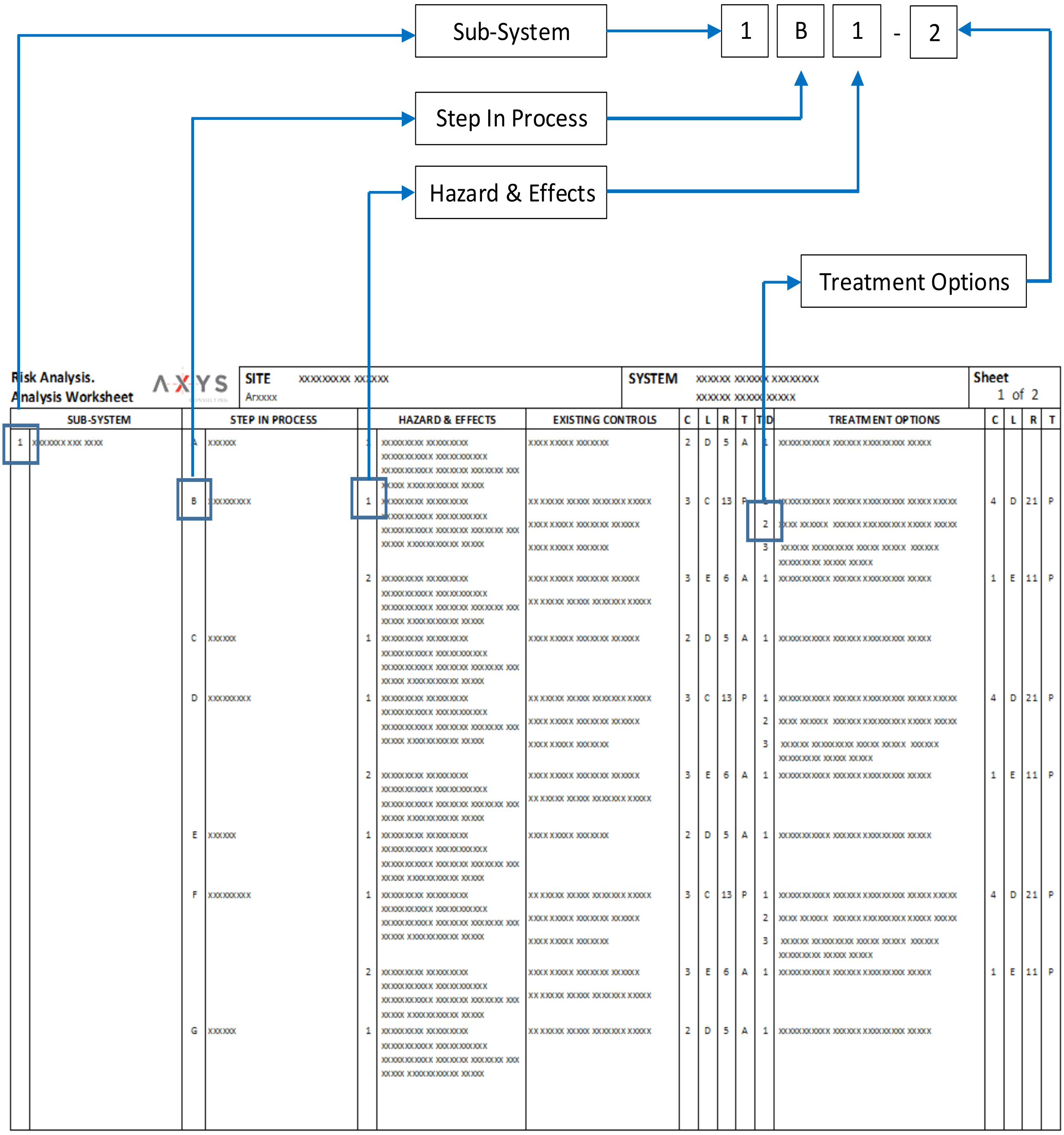
12. Risk Assessment Numbering

The assessment uses an alphanumeric numbering system to differentiate each component, the step in the process, the hazard and the treatment options.

The sub system number is found in the first column of the worksheets, the step is identified as a letter and is found in the third column, the hazard number in the fifth column and the treatment options in the TID (Treatment ID) column.

Using this method each hazard and treatment option throughout the analysis has a distinct identifier. This identifier then flows through all of the worksheets and can be referenced back to the Analysis Worksheets.

The example below shows the distinct identifier for the hazard is 1B1, the treatment option identified below would be identified as 1B1-2.



13. Risk Rank Method

For each event, the Likelihood (a letter A to E) and Consequence (a number 1 to 5) is selected. If an event effects more than one area of consequence (e.g. effects people and operations), the highest rank number is always selected.

Risk Matrix						
Likelihood		**Consequence**				
		Negligible	Minor	Moderate	Major	Catastrophic
A (Almost Certain)	May occur several times per year OR Expected to occur OR Has occurred several times within Glencore	**11 (M)**	**16 (H)**	**20 (H)**	**23 (H)**	**25 (H)**
B (Likely)	May occur about once per year OR More likely to occur than not occur OR Has occurred at least once within Glencore	**7 (M)**	**12 (M)**	**17 (H)**	**21 (H)**	**24 (H)**
C (Possible)	Could occur more than once during a lifetime OR As likely to occur as not to occur OR Has occurred at least once in the mining / commodities trading industries	**4 (L)**	**8 (M)**	**13 (M)**	**18 (H)**	**22 (E)**
D (Unlikely)	Could occur about once during a lifetime OR More likely NOT to occur than to occur OR Has occurred at least once in broader worldwide industry	**2 (L)**	**5 (L)**	**9 (M)**	**14(M)**	**19 (M)**
E (Rare)	Unlikely to occur during a lifetime OR Very unlikely to occur OR No known occurrences in broader worldwide industry	**1 (L)**	**3 (L)**	**6 (L)**	**10 (M)**	**15 (M)**

Area of Effect	**Estimated Level of Consequence**				
	1	2	3	4	5
(P) Health and Safety	First Aid Injury (FAI) illness (not considered disease or disorder)	Restricted Work Injury (RWI) / Disease (RWD) or Medical Treatment Injury (MTI) / Disease (MTD)	Lost Time Injury (LTI) / Disease (LTD) - Single incident resulting in multiple RWIs or MTIs	Fatalities (<5) due to a single incident or health cause Permanent disability or disease cases (<5) due to a single incident or health cause (mental or physical)	Multiple fatalities (5+) due to a single incident or health cause Multiple permanent disability or disease cases (5+) due to a single incident or health cause (mental or physical)
(E) Environment	Negligible, and reversible, environmental impact to ecosystems, habitat or species (<1 week to remediate)	Limited, but reversible, environmental impact to ecosystems, habitat or species (<3 months to remediate)	Limited, but reversible, environmental impact to ecosystems, habitat or species (<2 years to remediate)	Widespread, but reversible, environmental impact to ecosystems, habitat or species (2 to 10 years to remediate)	Widespread environmental impact to ecosystems, habitat or species (irreversible, or >10 years to remediate)
(F) Financial Impact	<$1M operating profit <$300k property damage <$1M asset devaluation	$1M to 5M operating profit $300k to $1M property damage $1M to $5M asset devaluation	$5M to $50M operating profit $1M to $5Mproperty damage $5M to $25M asset devaluation	$50M to $100M operating profit $5M to $50M property damage $25M to $250M asset devaluation	>$100M operating profit >$50M property damage >$250M asset devaluation

Area of Effect	Estimated Level of Consequence				
	1	2	3	4	5
(R) Image and Reputation	Negligible interest from media and no local, national or international pick-up Low-level social media pick-up, posts are neutral and isolated Negligible interest from local, regional or national government Negligible interest from NGOs and pressure groups Negligible interest from customers and/or suppliers Negligible interest from investors and/or analysts	Limited but negative media coverage at local / regional level that subsides after 24 hours Negative social media pick-up, but limited to local stakeholders that subsides after 24 hours Queries but no public statements from local, regional or national government Queries but no public statements from NGOs and pressure groups Queries from one or more customers and/or suppliers Queries from one or more investors and/or analysts	Negative media coverage at local / regional and national level for more than 24 hours, limited pick-up internationally Negative social media pick-up, from a mix of local and national stakeholders, limited pick-up internationally Public statements from local and/or regional but not national government Public statements from a limited number of NGOs and pressure groups Queries from multiple customers and/or suppliers Queries from multiple investors and/or analysts	Negative media coverage at local / regional, national and international levels over several days Negative social media internationally with a hostile tone Strongly negative public statements from local, regional and national government, and separately from multiple NGOs and pressure groups Threat of losing business from customers and/or suppliers Strong concerns from multiple investors and/or analysts	Sustained negative international media coverage lCondemnation from heads of state, governments, religious leaders and supranational bodies, e.g. the U.N. Negative social media campaigning reaches into mainstream public awareness Consistent and sustained negative public statements from high-profile NGOs and pressure groups Loss of customers and suppliers Investors consider divestment and analysts publish notes condemning the company and change their ratings
(L) Legal and Compliance	Civil investigation which might result in a non-penal remedy or with potential negligible financial consequences Any litigation or arbitration, license or permit non-compliance, or cancellation of a contract with potential negligible financial consequences	Civil investigation of any member of the Group with potential penalty of minor financial consequences Any litigation or arbitration, license or permit non-compliance, or cancellation of a contract with potential minor financial consequences	Civil investigation of any member of the Group with potential penalty of moderate financial consequences or short-term stop work order Any litigation or arbitration, loss of license or permit, or cancellation of a contract with potential moderate financial consequences	Criminal investigation of a Group company (but not for the Group) or directors or officers of a Group company Civil investigation at Group level or for any Group entity with potential penalty of major financial consequences or extended work stoppage Any litigation or arbitration, loss of license or permit, or cancellation of a contract with potential major financial consequences	Criminal investigation at Glencore Group level or in respect of the Board or senior management Any litigation or arbitration, loss of license or permit, or cancellation of a contract with potential catastrophic financial consequences Default under Group funding arrangements

PMC Category	Consequence Type	Ownership / Action
Cat 5	Catastrophic Hazard / Threat	**Ownership** - Department/Functional/Operational/Asset Leadership. **Action -** Detailed assessment is required to confirm achievement of ALARP ('As Low As Reasonably Practicable'). Critical Control Management is required.
Cat 4 (Health & Safety consequence)	Fatal Control	**Ownership** - Department/Functional/Operational/Asset Leadership **Action** - GCAA Fatal Hazard Protocol implementation is required.

Risk Rank	Risk Rating	Ownership / Action
23 – 25	Very High Risk	**Ownership** - Department/Functional/Operational/Asset Leadership **Escalation and Communication -** COO/CEO
17 – 22	High Risk	**Ownership** - Department/Functional/Operational/Asset Leadership. **Escalation and Communication -** Director/COO
7-16	Medium Risk	**Ownership** - Operation / Asset / Function /Department. **Escalation and Communication** - Operation / Asset / Function / Department
1 - 6	Low Risk	**Ownership** - Operation / Asset / Function /Department. **Escalation and Communication -** Operation / Asset / Function / Department

Attachment 1

Analysis Worksheets

SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS		EXISTING CONTROLS	RCE	PMC	C	L	R	T	TID	TREATMENT OPTIONS
1	Subsidence from the mining of Longwalls S3A through to S7A in the area of Jemena 150mm Pipeline	A	Impact to pipe in plateau areas due to conventional and non-conventional subsidence	1	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. E.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	Subsidence Monitoring Controls for other assets: includes 1. Ground surveys carried out weekly along with weekly review of data 2. Visual inspections, e.g., road pavement deformation as indication of non-conventional subsidence 3. Ground survey (Remembrance Drive and Main Southern Railway Early Warning Systems, continuously operating GNSS sensor) 4. Weekly meeting with asset owner Detailed location survey undertaken, including potholing investigation. As built drawings of pipeline installation held by Jemena Pipe design with corrosion coating, construction and installation standards at time of installation for pipeline with 50 year design life. Pipe installed in 1994. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength is well in excess of loads imposed by conventional and non-conventional subsidence effects in plateau areas. Subsidence assessment by MSEC predicts subsidence effects along pipeline	Improvement	2	2	D	5	F	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)

	SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS	EXISTING CONTROLS	RCE	PMC	C	L	R	T	TID	TREATMENT OPTIONS
1	Subsidence from the mining of Longwalls S3A through to S7A in the area of Jemena 150mm Pipeline	B	Impact to pipe at Caloola Road (within the embankment) due to conventional and non-conventional subsidence from Longwall S3A	1	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. e.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	Subsidence Monitoring Controls for other assets: includes 1. Ground surveys carried out weekly along with weekly review of data 2. Visual inspections, e.g., road pavement deformation as indication of non-conventional subsidence 3. Ground survey (Remembrance Drive and Main Southern Railway Early Warning Systems, continuously operating GNSS sensor) 4. Weekly meeting with asset owner Detailed location survey undertaken, including potholing investigation. As built drawings of pipeline installation held by Jemena Pipe design with corrosion coating, construction and installation standards at time of installation for pipeline with 50 year design life. Pipe installed in 1994. Engineering review of subsidence impacts on pipeline by Worley identifies pipeline alignment / bends and closure exceeds the allowable yield strength of the pipe Subsidence assessment by MSEC predicts subsidence effects along pipeline	Improvement	2	2	B	12	R	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)
													2	Subject to Jemena design approval implement either Option 1. Develop a mitigation plan that includes a Jemena approved design for a flexible pipe installation at the alignment bends at Caloola Road (within the embankment), including reduced depth of cover along the pipe embankment to 750mm depth. Or
													3	Option 2. Develop a mitigation plan that includes widening the embankment to support sideway movement of the pipeline due to closure. Decoupling of the pipe from existing embankment and manage pipe for the subsidence period. This option is to include review of existing roadway guardrail stability and mitigation controls.
													4	Review and implement most appropriate Caloola Road pipeline embankment monitoring programme. e.g. additional survey points and / or live monitoring

Risk Analysis. Analysis Worksheet	SITE SIMEC Mining - Tahmoor Mine AR3793	SYSTEM Longwall LWS3A to LWS7A Subsidence Impacts to Jemena 150mm MP Gas Main	Sheet Page 23

	SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS	EXISTING CONTROLS	RCE	PMC	C	L	R	T	TID	TREATMENT OPTIONS
1	Subsidence from the mining of Longwalls S3A through to S7A in the area of Jemena 150mm Pipeline	C	Impact to pipe at Remembrance Drive cutting near longwall S3A due to conventional and non-conventional subsidence	1	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. E.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	Geotechnical review of cutting batter slopes completed and did not identify any geological features of concern Subsidence Monitoring Controls for other assets: includes 1. Ground surveys carried out weekly along with weekly review of data 2. Visual inspections, e.g., road pavement deformation as indication of non-conventional subsidence 3. Ground survey (Remembrance Drive and Main Southern Railway Early Warning Systems, continuously operating GNSS sensor) 4. Weekly meeting with asset owner Detailed location survey undertaken, including potholing investigation. As built drawings of pipeline installation held by Jemena Pipe design with corrosion coating, construction and installation standards at time of installation for pipeline with 50 year design life. Pipe installed in 1994. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength is well in excess of loads imposed by conventional and non-conventional subsidence effects in the cutting area. Subsidence assessment by MSEC predicts subsidence effects along pipeline	Improvement	2	2	D	5	R	1 2	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP) Update the Uncoupling methodology to include exposure and re-instating of the pipeline during active subsidence to reduce period of temporary speed restriction at Remembrance Drive.

Risk Analysis. Analysis Worksheet	SITE SIMEC Mining - Tahmoor Mine AR3793	SYSTEM Longwall LWS3A to LWS7A Subsidence Impacts to Jemena 150mm MP Gas Main	Sheet Page 24

	SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS	EXISTING CONTROLS	RCE	PMC	C	L	R	T	TID	TREATMENT OPTIONS
1	Subsidence from the mining of Longwalls S3A through to S7A in the area of Jemena 150mm Pipeline	D	Impact to pipe at un-named creek crossing above longwall S5A (along base of embankment) due to conventional and non-conventional subsidence.	1	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. e.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	Subsidence Monitoring Controls for other assets: includes 1. Ground surveys carried out weekly along with weekly review of data 2. Visual inspections, e.g., road pavement deformation as indication of non-conventional subsidence 3. Ground survey (Remembrance Drive and Main Southern Railway Early Warning Systems, continuously operating GNSS sensor) 4. Weekly meeting with asset owner Detailed location survey undertaken, including potholing investigation. As built drawings of pipeline installation held by Jemena Pipe design with corrosion coating, construction and installation standards at time of installation for pipeline with 50 year design life. Pipe installed in 1994. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength is well in excess of loads imposed by conventional and non-conventional subsidence effects in the cutting area. Subsidence assessment by MSEC predicts subsidence effects along pipeline	Improvement	2	2	D	5	R	1 2	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP) Update the Uncoupling methodology to include maintaining the creek bed and reducing pipe exposure to water flow

Risk Analysis. Analysis Worksheet	**SITE** SIMEC Mining - Tahmoor Mine AR3793	**SYSTEM** Longwall LWS3A to LWS7A Subsidence Impacts to Jemena 150mm MP Gas Main	**Sheet** Page 25

	SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS	EXISTING CONTROLS	RCE	PMC	C	L	R	T	TID	TREATMENT OPTIONS
1	Subsidence from the mining of Longwalls S3A through to S7A in the area of Jemena 150mm Pipeline	E	Impact to pipe at Yarran Road creek crossing (within the embankment) due to conventional and non-conventional subsidence from Longwall S6A.	1	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. e.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	Subsidence Monitoring Controls for other assets: includes 1. Ground surveys carried out weekly along with weekly review of data 2. Visual inspections, e.g., road pavement deformation as indication of non-conventional subsidence 3. Ground survey (Remembrance Drive and Main Southern Railway Early Warning Systems, continuously operating GNSS sensor) 4. Weekly meeting with asset owner Detailed location survey undertaken, including potholing investigation. As built drawings of pipeline installation held by Jemena Pipe design with corrosion coating, construction and installation standards at time of installation for pipeline with 50 year design life. Pipe installed in 1994. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength is well in excess of loads imposed by conventional and non-conventional subsidence effects in the cutting area. Subsidence assessment by MSEC predicts subsidence effects along pipeline	Improvement	2	2	D	5	R	1 2	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP) Update the Uncoupling methodology to include exposure and re-instating of the pipeline during active subsidence to reduce period of temporary speed restriction at Remembrance Drive, near Yarran Road.

Risk Analysis. Analysis Worksheet	AXYS CONSULTING	SITE	SIMEC Mining - Tahmoor Mine AR3793	SYSTEM	Longwall LWS3A to LWS7A Subsidence Impacts to Jemena 150mm MP Gas Main	Sheet	Page 26

	SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS	EXISTING CONTROLS	RCE	PMC	C	L	R	T	TID	TREATMENT OPTIONS
1	Subsidence from the mining of Longwalls S3A through to S7A in the area of Jemena 150mm Pipeline	F	Impact to pipe at Wellers Road creek crossing (within the embankment) due to conventional and non-conventional subsidence from Longwall S7A	1	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. e.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	Subsidence Monitoring Controls for other assets: includes 1. Ground surveys carried out weekly along with weekly review of data 2. Visual inspections, e.g., road pavement deformation as indication of non-conventional subsidence 3. Ground survey (Remembrance Drive and Main Southern Railway Early Warning Systems, continuously operating GNSS sensor) 4. Weekly meeting with asset owner Detailed location survey undertaken, including potholing investigation. As built drawings of pipeline installation held by Jemena Pipe design with corrosion coating, construction and installation standards at time of installation for pipeline with 50 year design life. Pipe installed in 1994. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength is well in excess of loads imposed by conventional and non-conventional subsidence effects in plateau areas. Subsidence assessment by MSEC predicts subsidence effects along pipeline	Improvement	2	2	E	3	F	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)

Attachment 2

Assessment Worksheets
(Risk Rank Order)

REF	Risk	HAZARD	TID	TREATMENT OPTIONS
1B1	12	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. e.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)
			2	Subject to Jemena design approval implement either Option 1. Develop a mitigation plan that includes a Jemena approved design for a flexible pipe installation at the alignment bends at Caloola Road (within the embankment), including reduced depth of cover along the pipe embankment to 750mm depth. Or
			3	Option 2. Develop a mitigation plan that includes widening the embankment to support sideway movement of the pipeline due to closure. Decoupling of the pipe from existing embankment and manage pipe for the subsidence period. This option is to include review of existing roadway guardrail stability and mitigation controls.
			4	Review and implement most appropriate Caloola Road pipeline embankment monitoring programme. e.g. additional survey points and / or live monitoring
1A1	5	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. E.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)
1C1	5	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. E.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)
			2	Update the Uncoupling methodology to include exposure and re-instating of the pipeline during active subsidence to reduce period of temporary speed restriction at Remembrance Drive.
1D1	5	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. e.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)
			2	Update the Uncoupling methodology to include maintaining the creek bed and reducing pipe exposure to water flow
1E1	5	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. e.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)
			2	Update the Uncoupling methodology to include exposure and re-instating of the pipeline during active subsidence to reduce period of temporary speed restriction at Remembrance Drive, near Yarran Road.
1F1	3	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. e.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)

Attachment 3

Assessment Worksheets
(Consequence Order)

REF	Cons	HAZARD	TID	TREATMENT OPTIONS
1A1	2	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. E.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)
1B1	2	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. e.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)
			2	Subject to Jemena design approval implement either Option 1. Develop a mitigation plan that includes a Jemena approved design for a flexible pipe installation at the alignment bends at Caloola Road (within the embankment), including reduced depth of cover along the pipe embankment to 750mm depth. Or
			3	Option 2. Develop a mitigation plan that includes widening the embankment to support sideway movement of the pipeline due to closure. Decoupling of the pipe from existing embankment and manage pipe for the subsidence period. This option is to include review of existing roadway guardrail stability and mitigation controls.
			4	Review and implement most appropriate Caloola Road pipeline embankment monitoring programme. e.g. additional survey points and / or live monitoring
1C1	2	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. E.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)
			2	Update the Uncoupling methodology to include exposure and re-instating of the pipeline during active subsidence to reduce period of temporary speed restriction at Remembrance Drive.
1D1	2	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. e.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)
			2	Update the Uncoupling methodology to include maintaining the creek bed and reducing pipe exposure to water flow
1E1	2	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. e.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)
			2	Update the Uncoupling methodology to include exposure and re-instating of the pipeline during active subsidence to reduce period of temporary speed restriction at Remembrance Drive, near Yarran Road.
1F1	2	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. e.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)

Attachment 4

Risk Treatment Schedule Action Plan

Risk Analysis Treatment Schedule			SITE SIMEC Mining - Tahmoor Mine AR3793		SYSTEM Longwall LWS3A to LWS7A Subsidence Impacts to Jemena 150mm MP Gas Main		Sheet Page 32
ID	**HAZARD**	**TID**	**TREATMENT OPTIONS**	**RESPONSIBILITY**	**IMPLEMENTATION**	**COMMENTS**	**COMPLETED (Sign Off)**
1A1	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. E.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)	Subsidence Project Manager	Tuesday, 30 January 2024		
1B1	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. e.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)	Subsidence Project Manager	Tuesday, 30 January 2024		
		2	Subject to Jemena design approval implement either Option 1. Develop a mitigation plan that includes a Jemena approved design for a flexible pipe installation at the alignment bends at Caloola Road (within the embankment), including reduced depth of cover along the pipe embankment to 750mm depth. Or	Subsidence Project Manager	Friday, 3 May 2024		
		3	Option 2. Develop a mitigation plan that includes widening the embankment to support sideway movement of the pipeline due to closure. Decoupling of the pipe from existing embankment and manage pipe for the subsidence period. This option is to include review of existing roadway guardrail stability and mitigation controls.	Subsidence Project Manager	Friday, 3 May 2024		
		4	Review and implement most appropriate Caloola Road pipeline embankment monitoring programme. e.g. additional survey points and / or live monitoring	Subsidence Project Manager	Friday, 3 May 2024		

ID	HAZARD	TID	TREATMENT OPTIONS	RESPONSIBILITY	IMPLEMENTATION	COMMENTS	COMPLETED (Sign Off)
1C1	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. E.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)	Subsidence Project Manager	Tuesday, 30 January 2024		
		2	Update the Uncoupling methodology to include exposure and re-instating of the pipeline during active subsidence to reduce period of temporary speed restriction at Remembrance Drive.	Subsidence Project Manager	Friday, 3 May 2024		
1D1	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. e.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)	Subsidence Project Manager	Tuesday, 30 January 2024		
		2	Update the Uncoupling methodology to include maintaining the creek bed and reducing pipe exposure to water flow	Subsidence Project Manager	Friday, 3 May 2024		
1E1	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. e.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)	Subsidence Project Manager	Tuesday, 30 January 2024		
		2	Update the Uncoupling methodology to include exposure and re-instating of the pipeline during active subsidence to reduce period of temporary speed restriction at Remembrance Drive, near Yarran Road.	Subsidence Project Manager	Friday, 3 May 2024		

Risk Analysis Treatment Schedule		**SITE** SIMEC Mining - Tahmoor Mine AR3793		**SYSTEM** Longwall LWS3A to LWS7A Subsidence Impacts to Jemena 150mm MP Gas Main			**Sheet** Page 34
ID	**HAZARD**	**TID**	**TREATMENT OPTIONS**	**RESPONSIBILITY**	**IMPLEMENTATION**	**COMMENTS**	**COMPLETED (Sign Off)**
1F1	Ground strains and curvatures effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. e.g. - Development of a crack most likely at a weld - Cracking at deteriorated or corroded section of pipe - Full bore rupture Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture.	1	Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including - Monitoring Plan - Mitigation Plan - Response Plan (TARP)	Subsidence Project Manager	Tuesday, 30 January 2024		

SIMEC

Tahmoor Coking Coal Operations

Risk Assessment on the Tahmoor South Longwall LW1A & LW2A Subsidence Impacts on the Jemena 150mm High Pressure Steel Gas Pipeline

Draft Report
April 2022
HMS 1482

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SIMEC

Tahmoor Coking Coal Operations

Risk Assessment on the Tahmoor South Longwall LW1A & LW2A Subsidence Impacts on the Jemena 150mm High Pressure Steel Gas Pipeline

Draft Report

April 2022

HMS 1482

Client:

Mr Ross Barber, Project Manager, Tahmoor Coking Coal Operations.

Author:

Mr Chris Allanson, Senior Consultant, HMS Consultants Australia Pty Ltd

This Report was prepared on the basis of information recorded by HMS Consultants Australia Pty Ltd during a risk assessment held on 6th April 2022, being the group consensus opinion of the impacts of Tahmoor South Longwalls LW1A and LW2A on the Jemena 150mm High Pressure Steel Gas Pipeline.

File	Report	Prepared By	Client Review	Date
20220420 HMA1482 Tahmoor Sth LW1A & 2A Subsidence Impacts on Jemena Gas Pipeline	Draft	C. Allanson	R. Barber, D. Ho, D Swan	20 April 2022
	Final			

TABLE OF CONTENTS

1 EXECUTIVE SUMMARY

In April 2022, HMS Consultants Australia Pty Ltd (HMS) facilitated and recorded a risk assessment for Tahmoor Coking Coal Operations (Tahmoor), on potential subsidence impacts of Tahmoor's South Project longwalls LW1A and LW2A on the Jemena 150mm high pressure (HP) steel gas pipeline. The gas pipeline supplies gas to the townships of Tahmoor and Picton in the Macarthur Region of New South Wales.

The gas pipeline passes above LW1A and LW2A towards the northern end of the blocks, with only the north-western corner of LW1A being directly below the gas pipeline (See Figure 1). Extraction of LW1A is planned to commence from the southern (opposite) end of the block in September 2022. The gas pipeline also passes over subsequent longwall blocks LW3A – LW6A, however the focus of this risk assessment is for LW1A and LW2A only.

Tahmoor has mined coal by longwall methods from the Southern Coalfields since 1980 and in that time has maintained a harmonious co-existence with the communities of; Tahmoor to the south-east, Thirlmere to the west and Picton to the north. Subsidence from longwall mining has impacted private dwellings, community and other infrastructure, including; the Main Southern Railway Line and associated bridges, culvert, embankments and cuttings; a Jemena 160mm Polyethylene (PE) gas pipeline running along Remembrance Drive and Bridge Street (above LW32) and the South Picton industrial area.

All subsidence is monitored commensurate with the criticality of impact and a range of mitigation measures has been devised to provide very means of ensuring that only tolerable and sustainable impacts occur. Mitigation measures include; rail expansion joints and relevelling on the Main Southern Railway Line and uncovering of the gas pipeline to uncouple it from the ground during subsidence.

This report is for the risk assessment of the impacts on the gas pipeline from LW1A and LW2A only, facilitated on 6th April 2022 and it details the methods used and the recommendations resulting from that risk assessment. The reader should refer to Sections 3 and 5 of this report for details regarding the context and methodology of the risk assessment.

The overriding objective of this risk assessment was to engage with the asset owner (Jemena) and subject specialists (subsidence and pipelines) to identify and assess the risks and to develop mitigation strategies, where necessary, to prevent So Far As Is Reasonably Practicable (SFAIRP) unacceptable or unsustainable subsidence impacts to the pipeline and associated consequential outcomes, e.g., to public safety. There were nil non-consensus items identified in the risk assessment.

In total, thirteen (13) risks were identified by the participants. Of these risks, nil (0) were rated as HIGH risks and only two (2, 15%) were rated with a residual risk rating of MEDIUM. All risks were rated on Moderate or Minor consequence and all risks were rated as having Unlikely or Rare likelihood.

Though five (5, 38%) risks were assessed to have the potential to result in Public Safety impacts based on Maximum Foreseeable Consequence (MFC/ envisaged worst case), the residual risk ratings were determined to have Financial or Reputational impacts.

There are a number of actions arising from the risk assessment. These are listed in the Action Plan provided in Appendix B.

Appendices C to D provide the full risk tables in assessment and risk order respectively.

2 INTRODUCTION

HMS Consultants Australia Pty Ltd (HMS) facilitated and recorded a risk assessment for Tahmoor Coking Coal Operations (Tahmoor), on potential subsidence impacts of Tahmoor's South Project longwalls LW1A and LW2A on the Jemena 150mm high pressure (HP) steel gas pipeline. The gas pipeline supplies gas to the townships of Tahmoor and Picton in the Macarthur Region of New South Wales.

This report details the context, methods used and the recommendations resulting from the risk assessment which was facilitated at the Grace Hotel in Sydney on 6th April, 2022.

3 CONTEXT

3.1 Background

Tahmoor is located approximately 80 kilometres south-west of Sydney in the Southern Coalfields of New South Wales, within the Wollondilly Shire Council. Tahmoor has mined in this area employing longwall methods since 1980 and in that time has maintained a harmonious co-existence with the communities of; Tahmoor to the south-east, Thirlmere to the west and Picton to the north.

Tahmoor extracts up to 4Mtpa of Run of Mine (ROM), with up to 33Mt of ROM coal proposed over the remaining Life of the Project. This will produce approximately 2.5Mtpa of Hard Coking Coal for steel production.

The next ten (10) years of production will focus on the Tahmoor South (Bargo) Area, which contains twelve (12) separate longwall blocks, divided into the A-Series (northern blocks LW1A – LW6A) and the B-Series (southern blocks LW1B – LW6B). Tahmoor received Development Consent for both A and B Series blocks in early April 2022 and will need to lodge an extraction plan for the A-Series blocks by the end of April. Extraction of LW1A is planned to commence from the southern end of the block in September 2022.

Tahmoor South undermines private dwellings, businesses and private and government-owned infrastructure, e.g., roads, the Main Southern Railway Line, power, water, sewer, optical fibre communications cables and Jemena gas supply pipelines.

Jemena's 150mm diameter high pressure (HP) steel gas pipeline passes directly above LW1A to LW5A and LW6B (see Figure 1). This risk assessment focuses on the interaction of the northern end of longwalls LW1A and LW2A with the gas pipeline. The subsidence impacts of the remaining longwall blocks will be subject to separate future risk assessments.

Gas pipeline generally traverses a watershed along Remembrance Drive and there are no major creek crossings, though the headwaters of some historic creeks above LWS1A and S2A are hidden by Tahmoor Mine's coal handling facility. Other improvements of note adjacent to the pipeline route (on Remembrance Drive) above LW1A and LW2A include; the Wollondilly Anglican Church and College, a petrol station, high voltage overhead power lines and buried optic fibre cable.

Extraction of LW1A is planned to commence from the southern end in September 2022 and the gas pipeline will not experience material effects of subsidence until the longwall progresses closer to the pipeline over the ensuing months.

The Main Southern Railway Line will experience the effects of LW1A and LW2A before the gas pipeline. The subsidence monitoring carried out for the Main Southern Railway Line (and other features) will calibrate and inform predictions for the panels as a whole in advance of impacts on the gas pipeline.

Tahmoor has a proven track record for carrying out detailed monitoring, subsidence modelling and prediction and for assessing and mitigating impacts on both the Main Southern Railway Line and gas pipelines. A 160mm polyethylene (PE) gas pipeline was undermined by LW32 on 2019 providing important subsidence and performance data for the impact on gas pipelines and the effectiveness of mitigation measures used to protect the pipeline's integrity.

Subsidence modelling and predictions have been carried out by Mine Subsidence Engineering Consultants (MSEC)and have been provided in a report and the capability of the 150mm steel HP pipeline to safely accommodate the subsidence levels has been modelled by Advisian (part of the Worley Group). The contents of these reports were presented in the risk assessment and the reader should consult these reports to specific details.

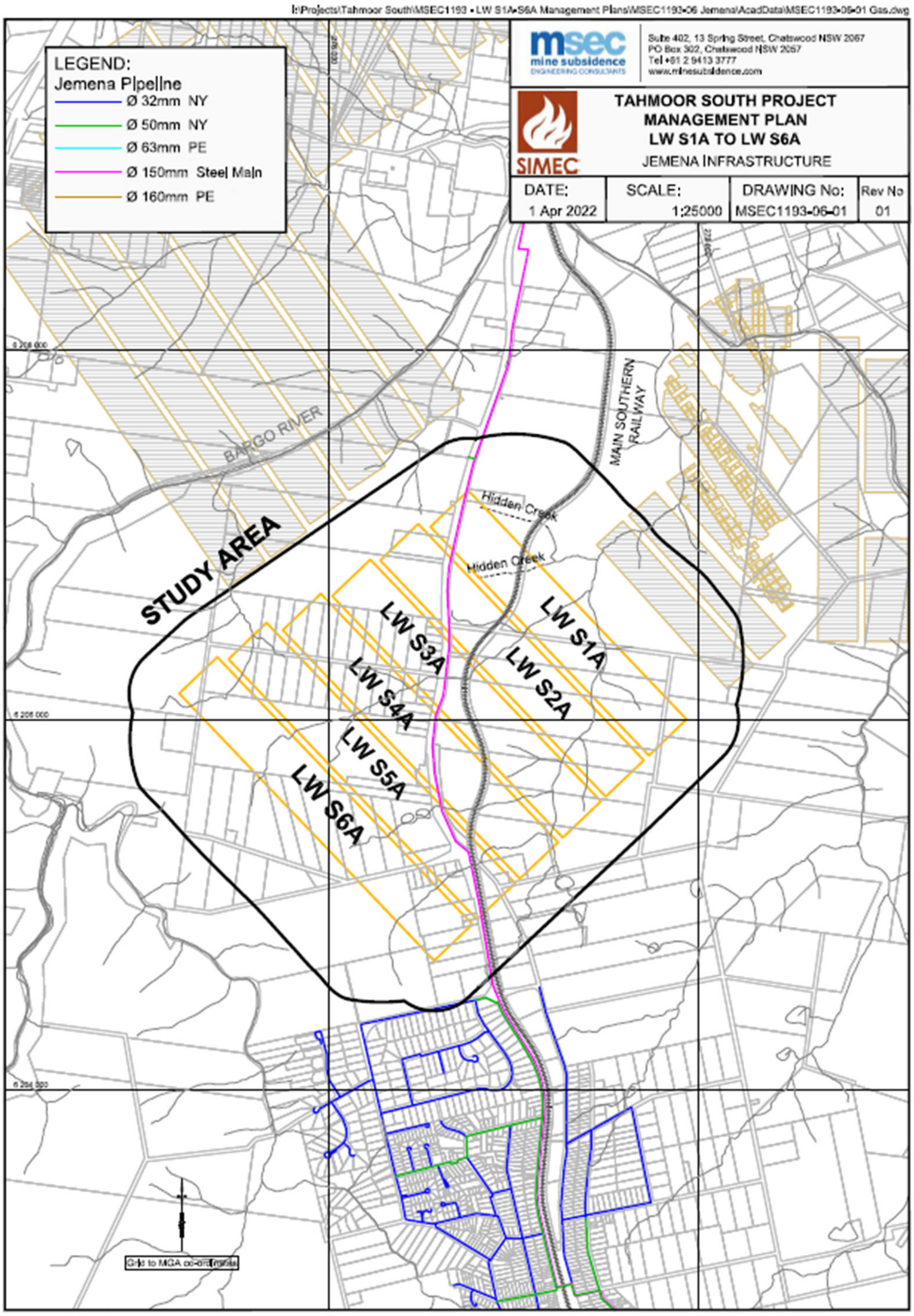


Figure 1 – Tahmoor South A Series Longwalls & Jemena 150mm HP Gas Pipeline

3.2 Purpose

The purpose of this risk assessment is to engage Tahmoor, the asset owner, subsidence and pipeline specialist engineers in a process to evaluate the risks and effectiveness of proposed controls for the safety and serviceability of the Jemena 150mm steel HP gas pipeline from the mining of LW1A and LW2A.

3.3 Scope

The scope of this risk assessment considered the impacts of LW1A and LW2A on the gas pipeline and potential consequential public safety and serviceability impacts from pipeline failure, deterioration and requirements to repair and or reinstate the gas supply.

The risk assessment was carried out to a pre-determined discussion list to provide for detailed and systematic assessment of all aspects of the hazard. The detained discussion list (scope) is provided in Section 5.5 Table 2.

Though safety and serviceability was the prime focus of this risk assessment other consequence types were recorded, e.g., reputational impacts.

3.4 Objectives

The objective of the risk assessment was to facilitate a structured process to enable critical and objective challenge of the subject area to assist Tahmoor fulfil its obligations, namely:

- Public safety by direct or consequential impacts from subsidence on the gas pipeline,
- Obligations imposed by NSW Work Health and Safety legislation, including;
    - Work Health & Safety Regulation 2017, with particular focus on:
        - Part 3.1 Managing risks to health and safety,
    - Work Health & Safety (Mines & Petroleum Sites) Regulation 2014, with particular focus on:
        - Clause 9 Management of risks to health and safety - *risk assessment is conducted in accordance with this clause by a person who is competent to conduct the particular risk assessment having regard to the nature of the hazard.*
        - Clause 23 Identification of principal hazards and conduct of risk assessments,
        - Clause 33 Notification of high risk activities,
        - Clause 67 Subsidence,
        - Clause 128 Duty to notify regulator of certain incidents, *(5) High Potential Incidents (m) any indication from monitoring data of the development of subsidence which may result in damage to any plant or structure or a failure of ground*
        - Schedule 1 Principal hazard management plans—additional matters to be considered, 3C Subsidence
        - Schedule 3 High risk activities, 16 Secondary extraction
- Risk assessment process in accordance with AS/NZ ISO 31000:2018 – Risk Management and MDG 1010 - Risk Management Handbook for the Mining Industry, with risk rating in accordance with the Tahmoor Risk Assessment Matrix
- Participation of the asset owner, subsidence and pipeline specialist engineers and Tahmoor,
- Compliance with Planning Approval - Key Performance Measures:
    - The project does not cause any exceedances of the performance measures to the satisfaction of the stakeholders,
    - The gas pipeline as key infrastructure serving the public is always safe and serviceable,
    - Damage that effects safety or serviceability must be fully repaired at the completion of the mining,
    - Arrangements are in place to maintain the serviceability of the asset.
- There were nil non-consensus matters raised durn the risk assessment.

- The finalised version of this report will have been reviewed and checked by the Client and represents a true and accurate record of the risk assessment.

3.5 Limitations

Limitations of the risk assessment include:

- Whereas the technical studies carried out to predict subsidence and to evaluate the tolerance of the gas pipeline to subsidence impacts, the risk assessment is qualitative and consequential impacts from subsidence are not quantitative, e.g., the impact on the Wollondilly Anglican Church and College or the petrol station from the outbreak of fire from a gas pipeline leak has not been subject to any quantitative assessment.

3.6 Assumptions

The following assumptions were made during the risk assessment:

- LW1A: September 2022 to March 2023 (6 months)
- LW2A: April 2023 to December 2023 (8 months)
- Existing monitoring and control systems will be maintained throughout the project unless otherwise stated.
- Subsidence movements will normally occur gradually over a period of months.
- Stage 1 (Early Subsidence) refers to small movements and limited impacts as longwall extraction approaches the rail line.
- Stage 2 (Active Subsidence) refers to the period of significant movement and potential impacts as extraction occurs beneath the railway.
- Stage 3 (Post Active Subsidence) refers to the limited impacts and movements, reducing to zero over time, experienced as the longwall extraction continues to retreat away from the railway.
- Jemena has in place processes, procedures and contingency arrangements for dealing with gas leaks, potential fires, repairs and service reinstatement. Though these issues were discussed with the asset owner at length during the risk assessment the response to these events is reliant on a call-out of Jemena or prequalified contractors to deal with the incident.

3.7 Exclusions

- Additional subsidence impacts from the extraction of subsequent longwall blocks was not considered.

4 DEFINITIONS

Risk

The chance of something happening or circumstances arising or changing that will have an impact upon public safety or Jemena or SIMEC objectives, measured in terms of likelihood and consequence. It encompasses both positive and negative impacts.

Cause

The factors that must be present for identified risk issue/ loss to occur – includes direct and indirect causes.

Impact

Impacts are specific adverse effects resulting from an incident and may be related to the organisation's strategic, business, operational or project objectives (including people, the environment, plant or property) or a combination of these.

Consequence

The outcome of an event expressed qualitatively or quantitatively, being a loss, injury, disadvantage or gain. There may be a range of possible outcomes associated with an event.

Likelihood

Used as a qualitative description of probability or frequency of a potential consequence.

Risk Rank

The rating applied to a risk determined from the Tahmoor Risk Assessment Matrix, by reading the junction of Likelihood line and Consequence column.

SAFERR Effects

What will be the Safety, Asset, Financial, Environmental, Regulatory and/or Reputational impacts of an option.

SFAIRP

So Far As Is Reasonably Practicable –The likelihood and consequences of a risk must be weighed against the availability, effectiveness and cost of measures to eliminate or reduce the risk. Further information on SFAIRP is provided in RSK- WI-002 Determining if Risk is Reduced So Far As Is Reasonably Practicable (SFAIRP).

5 WORKSHOP

The risk assessment was facilitated on the 6th April 2022 at the Grace Hotel in Sydney.

The risk assessment workshop involved representatives of the asset owner (Jemena), Tahmoor Coal, subsidence and pipeline specialist engineers who are involved with this project and the particular pipeline. The workshop was facilitated by a qualified mining engineer and experienced Underground Coal Mine Manager who also is familiar with Tahmoor and this type of risk assessment (thereby complying with Clause 9(2) of the Work Health & Safety (Mines & Petroleum Sites) Regulation 2014.

5.1 Participants

The workshop participants are listed in *Table 1 – Workshop Participants* following.

Name	Position	Company	Qualifications & Experience
Ross Barber	Project Manager Subsidence	SIMEC, Tahmoor	15 years subsidence experience – 40yrs rail, structural and management
Daryl Kay		MSEC	
David Ho	Principal Consultant AAG	Advisian	
Amanda Fitzgerald	Environment & Community Officer - Subsidence	SIMEC, Tahmoor	3 years Subsidence Experience
Andrew Walker	Gas Distribution Engineer	Jemena	Mechanical Engineer, 14 Years in gas, 6 years at Jemena
Muhammad Siddiqui	Gas Distribution Engineer	Jemena	Mechanical Engineer, 17 Years in oil and gas, 1 year at Jemena
Chris Allanson	Facilitator, Risk Consultant	HMS	BE Mining, MBA, Coal Mine Manager CoC, Dust Explosion Auditor Practising Certificate, 20yrs Mining Operations, 22yrs Risk Consulting
Andrew Whalan	Consultant	HMS	23 years Mining Industry, Operations Technology

Table 1 – Workshop Participants

5.2 Presentation of Information & Subsidence Data

At the commencement of the risk assessment presentations covering the planned mining, surface features, physical assets, subsidence data and potential impacts was delivered to the workshop.

A summary of the presenters and their speciality, follows:

- Ross Barber – PowerPoint presentation - Mining overview and timeline,
- Daryl Kay – PowerPoint presentation - Mine subsidence modelling predictions and features,
- David Ho – PowerPoint presentation - Modelling of pipeline response to subsidence impacts,
- Andrew Walker – Informal presentation - Overview of pipeline, condition, gas supply areas, associate infrastructure.

5.3 Method of Approach

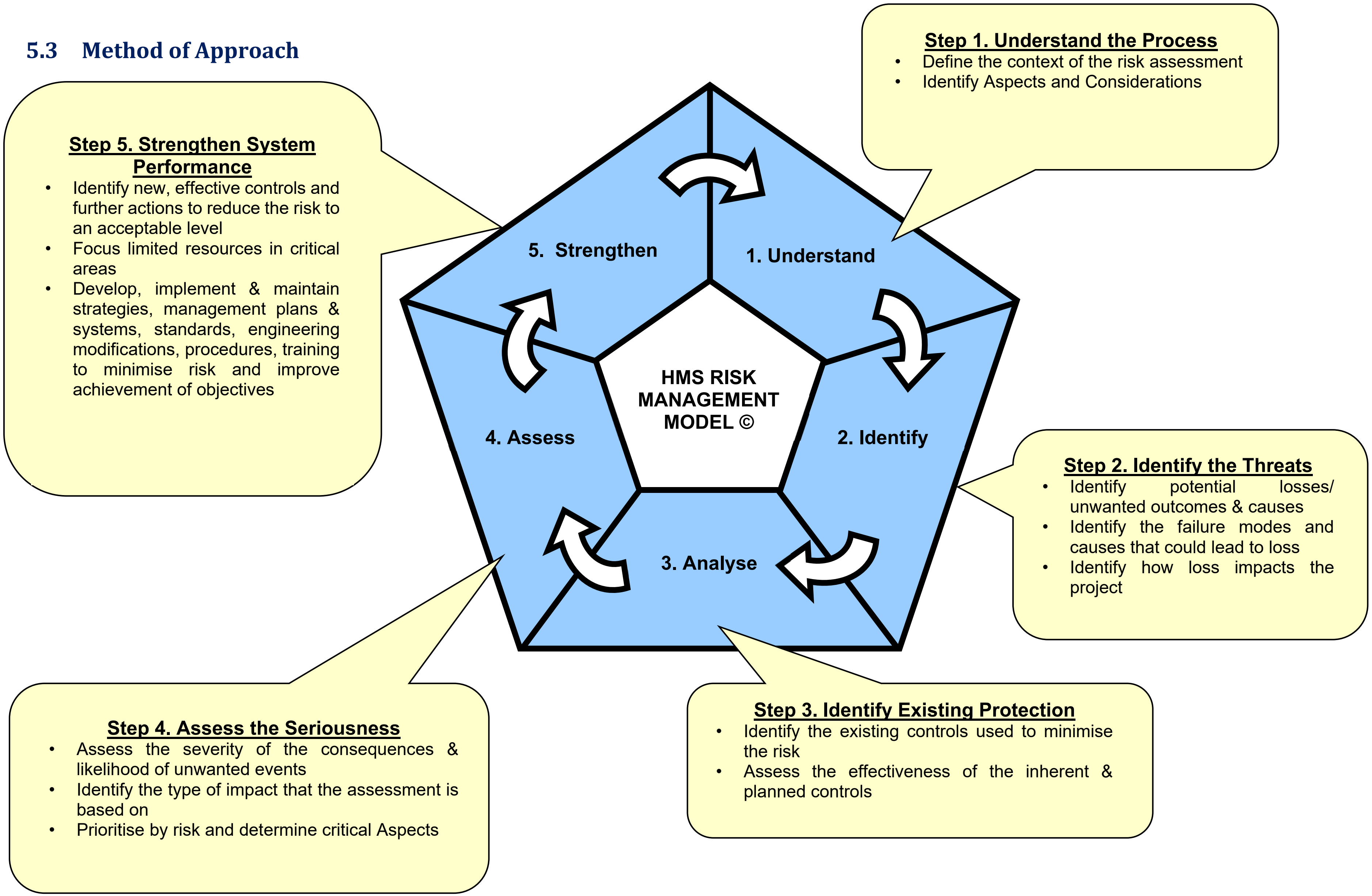


Figure 1 - HMS Risk Management Model

5.4 Preliminaries

Workshop preliminaries, follow:

- A workshop team of technical, operational and management people and an independent facilitator was assembled. The name, position title and experience of each team member were recorded.
- Presentations on Tahmoor's longwall mining impacts on the Jemena gas pipeline were made to the team (see Section 5.2).
- The objectives and scope, assumptions and limitations of the risk assessment were discussed, agreed and recorded.

5.5 Aspects and Considerations

The risk assessment team reviewed the draft Aspects and Considerations which was prepared in a scoping session between the Project Manager and the facilitator prior to the workshop and modified as required. The agreed Aspects and Considerations used in the workshop are shown in *Table 2 – Aspects and Considerations,* following.

Aspect	##	Consideration
1. Impact to pipe due to conventional subsidence	1.01	Pipeline design, installation, condition and serviceability
	1.02	Pipeline fault detectability
	1.03	Maintainability
2. Impact to pipe due to non-conventional subsidence	2.01	Pipeline and geology
	2.02	Pipeline and topography
	2.03	Pipeline & sub-surface features
3. Consequential impacts	3.01	Pipeline-Community
	3.02	Pipeline-Infrastructure
4. Control effectiveness	4.01	TARP triggers
	4.02	Gas detection inspections
	4.03	Uncovering pipeline
	4.04	Monitoring pipeline
	4.05	Pipeline isolation & repair
	4.06	Emergency management

Table 2 – Aspects and Considerations

5.6 Risk Identification & Analysis

5.6.1 Identification of Loss Scenarios/ Risk Issues

The risk assessment workshop team systematically considered each Aspect and Consideration identified in Table 2. Risks pertaining to these areas that could have a material impact on the gas pipeline and consequential impacts were considered. Additional assumptions and limitations as applicable were also recorded. Each Aspect was considered in relation to the following, and recorded in a risk table:

- Loss Scenario/ Risk
- Failure Mode and Causes
- Potential consequences of each risk, including the worst credible consequence where applicable

- Existing controls for each potential consequence

5.7 Risk Evaluation

5.7.1 Residual Risk Basis

Risks were evaluated on a residual risk basis; i.e., in consideration of the effectiveness and efficiency of current and planned controls at the time of assessment. The scales of Consequence and Likelihood were used to determine the "Risk Level" in accordance with Appendix E – Tahmoor Risk Assessment Matrix.

5.7.2 Risk Materiality & Consequence Level

The potential consequence for any risk can be defined as a statistical distribution of outcomes, each with a related probability of occurrence. The consequence level selected for the particular risks identified in this risk assessment relied on the expert judgement of the participants as to the level of consequence on railway operations. Unless, in the opinion of the participants the catastrophic consequence was the most appropriate level to select, consequence was rated as the point at which the impact becomes material.

5.7.3 Likelihood

The likelihood selected was the likelihood of the selected risk consequence occurring, based on the expert judgement of the participants, drawing on their knowledge and experience of the effectiveness and efficiency of the existing and planned controls.

5.7.4 Determination of Risk Level

The risk level was determined using the Tahmoor Risk Assessment Matrix (Appendix E) by reading the co-incidence of the Likelihood line and Consequence column.

5.8 Risk Reduction Strategy

The risk assessment team considered the risk issues in terms of the existing standard controls, that is, residual risk ranking was used to determine risk levels on the assumption that the specified existing and proposed controls will be in place during the operation processes.

The team then identified further risk controls that must be implemented to reduce each risk "So Far as is Reasonably Practicable" (SFAIRP), in line with the Risk Management Procedure.

In the final stage of the risk reduction strategy, the participants are required to formally accept these further risk controls and assign people, resources and time frames for the effective implementation. Before LW1A – LW2A commences to impact on the gas pipeline an audit or review of the existing, planned and additional controls identified should be completed to ensure they have been effectively implemented to control the identified risk to SFAIRP levels.

6 RESULTS

6.1 Risks

In total, the risk assessment team identified Thirteen (13) risk issues, of which all were considered credible risks and were subsequently assessed by the workshop team.

6.2 Risk Distribution

The following *Table 3 – Risk Distribution by Risk Ranking* summarises the risk distribution of all risks by risk rank.

RISK RANKING	No.	%
High	Nil	0%
Medium	2	15%
Low	11	85%
TOTAL	**13**	**100**

Table 3 – Risk Distribution by Risk Rank

6.3 Consequence Distribution

The following *Table 4 – Risk Distribution by Consequence* summarises the risk distribution of all risks by consequence.

CONSEQUENCE	No.	%
Extreme	Nil	0%
Major	Nil	0%
Moderate	7	54%
Minor	6	46%
Negligible	Nil	0%
TOTAL	**13**	**100**

Table 4 – Risk Distribution by Consequence

6.4 Maximum Foreseeable Consequence

The following risk issues were identified to have the potential to result in a public safety threat in the worst case:

- Ground strains and curvatures exceed pipeline allowable or actual yield strength resulting in a gas leak, (ref. 1.01.01),
- Inadequate or delayed response due to less than adequate (LTA) detection of leaks, (ref. 1.02.01),
- LTA access to carry out timely maintenance or repair of the pipeline, (ref. 1.03.01),
- Non-conventional subsidence effects over faults, dykes results in potential adverse impacts on pipeline, (ref. 2.01.01),

- Non-conventional subsidence effects over creeks (exposed or hidden) results in potential adverse impacts on pipeline, (ref. 2.02.01).

6.5 Risk Type

The following *Table 5 – Risk Distribution by Risk Type* summarises the risk distribution of all risks by risk type.

RISK TYPE	No.	%
Health & Safety	Nil	0%
Environment	Nil	0%
Reputation	5	38.5%
Financial	8	61.5%
Legal & Compliance	Nil	0%
TOTAL	**13**	**100**

Table 5 – Risk Distribution by Type

6.6 Action Plan

An Action Plan has been prepared (see Appendix B), listing potential additional controls / further actions from the risk assessment.

A full list of all results is shown in Appendices C to D, being the risk registers in assessment and consequence order respectively.

7 MINERAL RESOURCES MDG1014 CHECKLIST

To ensure this risk assessment complies with the Minerals Resources MDG 1010 Risk Management Handbook, the following checklist/ sign-off (MDG 1014) has been included.

Sub-sections 7.1, 7.2 and 7.3 are to be completed by the Client.

7.1 Report Checklist

1.	Is there a description of the operation or equipment being assessed?	Yes / ~~No~~
2.	Is there a summary of the strategic, corporate and risk management context?	Yes / ~~No~~
3.	Is there a list of the people involved in the risk identification step, together with their organisational roles and experience relevant to the risk assessment topic?	Yes / ~~No~~
4.	Is there an adequately detailed outline of the approach used to identify the risks?	Yes / ~~No~~
5.	Is there an outline of the method used for assessing the likelihood and consequences of the risks?	Yes / ~~No~~
6.	Are there two lists of identified risks, ranked by: a) risk magnitude, and b) consequence magnitude	Yes / ~~No~~
7.	Is there discussion of the basis for defining either the safety standard to be achieved, or the level of risk management expenditure?	Yes / ~~No~~
8.	Is there a list of the main actions to be taken to reduce risks and to manage risks?	Yes / ~~No~~
9.	Have responsibilities for implementing additional controls / further actions been allocated?	Yes / ~~No~~
10.	Is there a timetable for implementing main actions?	Yes / ~~No~~
11.	Does the report specify a requirement for a working audit required after completion of all implementation stages?	Yes / ~~No~~

7.2 Risk Assessment Process Evaluation

How do you rate the following?			*Poor*				*Good*
			(Please Highlight)				
1.	The range of expertise of team which did the study	✓	1	2	3	4	5
2.	The appropriateness of the degree of detail of the study	✓	1	2	3	4	5
3.	The comprehensiveness of the systematic approach	✓	1	2	3	4	5
4.	The identification of the key risk scenarios to be addressed	✓	1	2	3	4	5
5.	The bases for deciding the required safety level or effort	✓	1	2	3	4	5
6.	The method for assessing likelihood and consequences	✓	1	2	3	4	5
7.	The thoroughness of consideration of planned risk reduction actions	✓	1	2	3	4	5
8.	The thoroughness of consideration of existing or planned risk controls	✓	1	2	3	4	5
9.	The objectivity and balance of the study (i.e., not unduly optimistic or pessimistic	✓	1	2	3	4	5

7.3 Risk Assessment Process Signoff

Name: Mr Ross Barber

Position: Project Manager Subsidence

Signature: [signature] **Date:** May 22

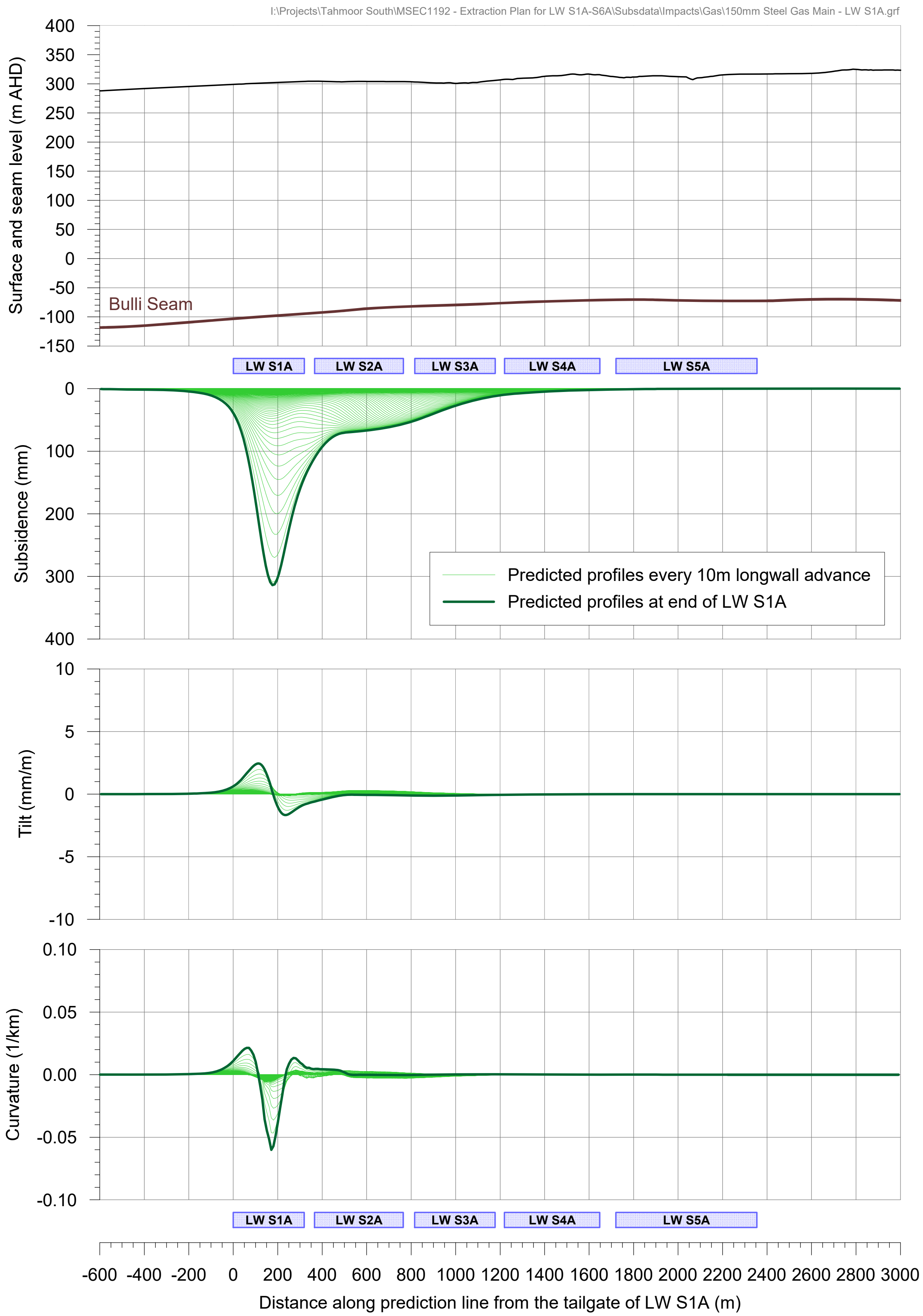
Appendix A

SIMEC Pty Ltd

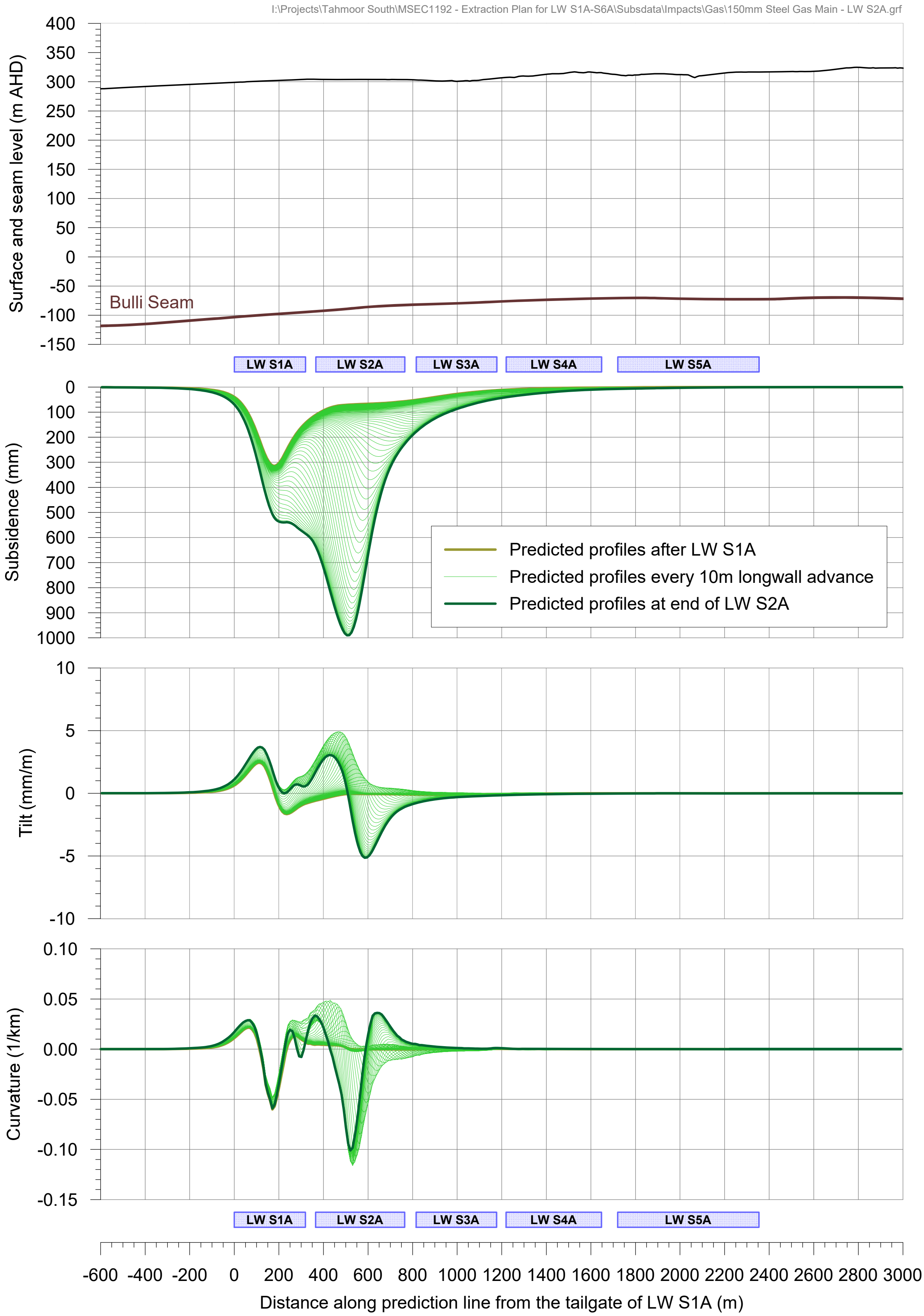
Tahmoor Mine

Tahmoor South & Jemena 150mm High Pressure Steel Gas Pipeline

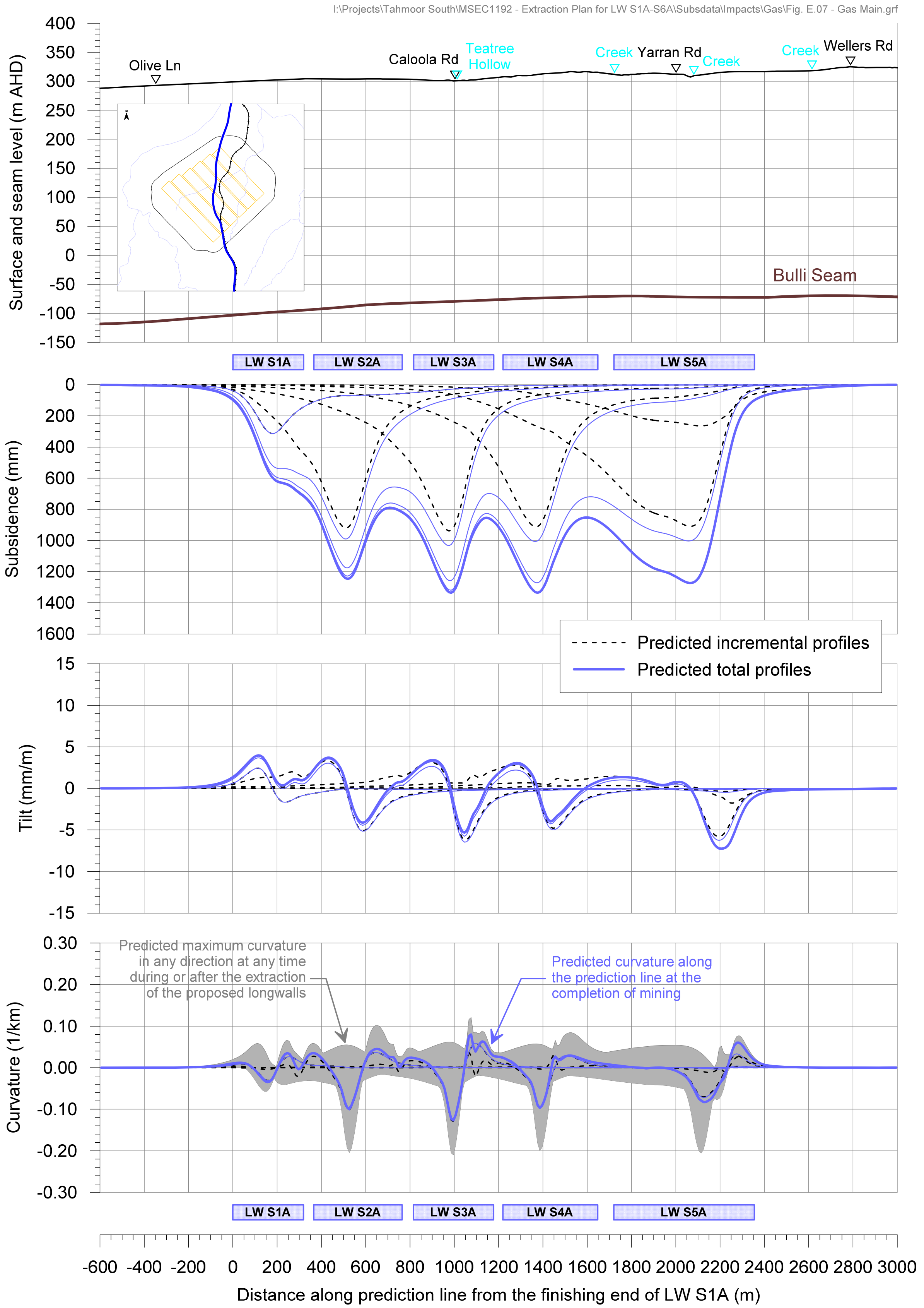
Progressive Subsidence Profiles



Subsidence Profiles for LW1A



Cumulative Subsidence Profiles for LW1A and LW2A



Combined Subsidence for A Series Blocks

Appendix B

SIMEC Pty Ltd

Tahmoor Mine

LW1A & LW2A Subsidence Impacts on Jemena 150mm High Pressure Steel Gas Pipeline

Action Plan

April 2022

	Actions	**By Who**	**By When**	**Status**		R#, Aspect - Consideration **Risk Issue, Level, Type, due to:**
1.1.	Carry out a pipe detection survey to determine exact location and depth of cover of the gas pipeline and other adjacent buried services as applicable.	Ross Barber	Prior to subsidence effect			1.03.01, Impact to pipe due to conventional subsidence - Maintainability **LTA access to carry out timely maintenance or repair of the pipeline** MEDIUM Financial risk, due to: **Failure Mode:** Untimely preventative maintenance allows for exceedance of pipeline strength and development of cracks and potential full bore rupture. Severe deformation of pipe Potential for service disruption **Causes:** 1. Other infrastructure or constraints along the alignment 2. Failure to have appropriate access agreements in place, associated with other asset owners 3. Environmental constraints, e.g., cannot remove problem trees 4. Council restrictions 5. Work permit requirements e.g., partial road closure 6. LTA ready access 7. LTA availability of equipment to uncover and isolate pipe 8. LTA means to isolate 9. Hawthorn Rd valve doesn't work 10. PE pipeline squeeze method not suitable 11. Deteriorated condition of pipe not readily repairable without replacing long run of pipe
1.2.	Provide the Excavate & Expose Methodology and include in the Gas Pipeline Subsidence Management Plan and gain Jemena pre-approval for this methodology	Ross Barber	Prior to subsidence effect			
1.3.	Identify and develop all Access Agreements for carrying out pipeline maintenance	Ross Barber	Prior to subsidence effect			
1.4.	Jemena to clarify all notification and access requirements to carry out excavate/ expose/ repair pipe	Ross Barber	Prior to subsidence effect			
2.1.	Carry out pipe detection survey to determine exact location and depth of cover of the pipeline (repeat action)	Ross Barber	Prior to subsidence effect			4.03.01, Control effectiveness - Uncovering pipeline **Exposing pipeline to relieve stress is not appropriate for particular scenarios** MEDIUM Financial risk, due to: **Failure Mode:** Pipe failure due to temperature effects Pipeline damaged intentionally or unintentionally Pipe buckles due to inadequate support and/or depth of cover beyond the trench **Causes:** 1. Tampering with exposed pipeline 2. Radiant heat 3. Trench filling with water 4. Impact by vehicle 5. LTA physical protection of exposed pipeline
2.2.	Provide the Excavate & Expose Methodology and include in the Gas Pipeline Subsidence Management Plan and gain Jemena pre-approval for this methodology (repeat action)	Ross Barber	Prior to subsidence effect			
2.3.	Identify and develop all Access Agreements for carrying out pipeline maintenance (repeat action)	Ross Barber	Prior to subsidence effect			
2.4.	Jemena to clarify all notification and access requirements to carry out excavate/ expose/ repair pipe. (repeat action)	Ross Barber	Prior to subsidence effect			
2.5.	Engage with Jemena to determine emergency repair arrangements required for the timely response to leaking or ruptured pipelines	Ross Barber	Prior to subsidence effect			
2.6.	Carry out engineering review for each pipeline uncovering/ destressing to determine extent of uncovering and potential for damage/ deformation in excavated state	Ross Barber	Prior to subsidence effect			

	Actions	By Who	By When	Status		R#, Aspect - Consideration **Risk Issue, Level, Type, due to:**
3.1.	Engage with Jemena to determine emergency repair arrangements required for the timely response to leaking or ruptured pipelines (repeat action)	Ross Barber	Prior to subsidence effect			3.01.01, Consequential impacts - Pipeline-Community **Disruption of gas supply resulting in unacceptable public impacts** LOW Financial risk, due to: **Failure Mode:** Large/ open pipe leak Severe restriction or squeezing of pipe **Causes:** 1. Subsidence impacts to pipeline 2. LTA means to isolate and provide alternative supply 3. Extended time to restore gas supply to customers - Relighting Process to purge air from gas lines
3.2.	Confirm Petrol station emergency response procedures and pump shutoff switch is in place (maybe should go on the other column	Ross Barber	Prior to subsidence effect			
4.1.	Engage with Jemena to determine emergency repair arrangements required for the timely response to leaking or ruptured pipelines (repeat action)	Ross Barber	prior to subsidence effect			3.01.02, Consequential impacts - Pipeline-Community **Unacceptable reputational impacts from gas leak affecting road, resulting in road closure until repairs can be made** LOW Reputational risk, due to: **Failure Mode:** High volume leak with potential to ignite - road cordoned off for repairs **Causes:** 1. Large gas leak 2. Need to control potential ignition sources 3. Need to provide unhindered access for repair
5.1.	Determine actual separation distances between pipeline alignment and nearest Wollondilly Anglican Church outside area (children's playground) locations	Ross Barber				3.01.03, Consequential impacts - Pipeline-Community **Gas leak outside Wollondilly Anglican Community Church and College resulting in evacuation and significant media attention** LOW Reputational risk, due to: **Failure Mode:** High volume leak **Causes:** 1. Proximity of Wollondilly Anglican Church and associated children's playground (approx.15m from centreline of Remembrance Drive) to pipeline alignment (estimated +25m) 2. Prevailing wind conditions could direct leaking gas in direction of school
5.2.	Carry out consultation with the Wollondilly Anglican Church to determine actual site activities and any potential need for additional risk mitigation.	Ross Barber				

	Actions	By Who	By When	Status		R#, Aspect - Consideration **Risk Issue, Level, Type, due to:**
6.1.	Engage with Jemena to determine emergency repair arrangements required for the timely response to leaking or ruptured pipelines (repeat action)	Ross Barber	Prior to subsidence effect			4.01.01, Control effectiveness - TARP triggers **Monitoring controls are not adequate (surveys, gas detection, visual inspections) to trigger timely action** LOW Financial risk, due to: **Failure Mode:** Critical parameter not adequately monitored **Causes:** 1. LTA manual monitoring frequency 2. Survey station damaged 3. Infrastructure not monitored 4. Data errors
7.1.	Obtain from Jemena a summary of the pipeline monitoring and condition reports and highlight any relevant issues raised and review engineering assessment as applicable	Ross Barber	Prior to subsidence effect			1.01.01, Impact to pipe due to conventional subsidence - Pipeline design & installation **Ground strains and curvatures exceed pipeline allowable or actual yield strength resulting in a gas leak** LOW Financial risk, due to: Failure Mode: Development of a crack most likely at a weld. Cracking at deteriorated or corroded section of pipe. Full bore rupture Causes: 1. Pipeline not installed to design 2. Pipeline deterioration (note: Worley Pipeline assessment/ modelling assumes pipeline is in good condition). 2.1. Corrosion 2.2. Deformation or stress imposed by tree roots 2.3. Substandard as-installed condition, e.g., coating, weld quality, manufactured pipe 3. Pipeline tee-connections are anchored in place and provide for possible pipe stress concentration point
7.2.	Engage with Jemena to determine emergency repair arrangements required for the timely response to leaking or ruptured pipelines (repeat action)	Ross Barber	Prior to subsidence effect			
7.3.	Ensure that survey monitoring lines include coverage of pipeline tee-connections within the subsidence affected zones.	Ross Barber	Prior to subsidence effect			
7.4.	Review pipeline engineering assessment in relation to the existence of any fixed tee-connections within the subsidence affected zones.	Ross Barber	Prior to subsidence effect			

	Actions	By Who	By When	Status		R#, Aspect - Consideration **Risk Issue, Level, Type, due to:**
8.1.	Engage a structural geologist to perform an assessment of surface expressions of geological structures in vicinity of the pipeline	Ross Barber	Prior to subsidence effect			2.01.01, Impact to pipe due to non-conventional subsidence - Pipeline and geology **Non-conventional subsidence effects over faults, dykes results in potential adverse impacts on pipeline** LOW Financial risk, due to: **Failure Mode:** Crack develops at stress concentration point - step or shear **Causes:** 1. Non-conventional subsidence 2. Failure to identify geological features that could cause areas of non-conventional subsidence
9.1.	Carry out a pipe detection survey to determine exact location and depth of cover of the gas pipeline and other adjacent buried services as applicable. (repeat action)	Ross Barber	Prior to subsidence effect			2.02.01, Impact to pipe due to non-conventional subsidence - Pipeline and topography **Non-conventional subsidence effects over creeks (exposed or hidden) results in potential adverse impacts on pipeline** LOW Financial risk, due to: **Failure Mode:** Deformation or kinking of pipe Development of cracks in pipe **Causes:** 1. Valley closure at creek or historic creek bed crossing 2. Upsidence 2.1. Geological structure 3. LTA surveys
9.2.	Provide the Excavate & Expose Methodology and include in the Gas Pipeline Subsidence Management Plan and gain Jemena pre-approval for this methodology (repeat action)	Ross Barber	Prior to subsidence effect			
9.3.	Identify and develop all Access Agreements for carrying out pipeline maintenance (repeat action)	Ross Barber	Prior to subsidence effect			
9.4.	Jemena to clarify all notification and access requirements to carry out excavate/ expose/ repair pipe. (repeat action)	Ross Barber	Prior to subsidence effect			
10.1.	Determine actual separation distances between pipeline alignment and nearest potential ignition points at petrol station	Ross Barber	Prior to subsidence effect			3.01.04, Consequential impacts - Pipeline-Community **Gas leak outside petrol station and threat of fire that could propagate to petrol station** LOW Reputational risk, due to: **Failure Mode:** High volume gas leak in vicinity of petrol station **Causes:** 1. Proximity of petrol station bowsers (approx. 18m from centreline of Remembrance Drive) to pipeline alignment (estimated +25m) 2. Prevailing wind conditions could direct leaking gas in direction of petrol station

	Actions	By Who	By When	Status		R#, Aspect - Consideration **Risk Issue, Level, Type, due to:**
11.1.	Carry out a survey to determine proximity of individual premises to pipeline alignment to determine if there are any close receivers	Ross Barber	Prior to subsidence effect			3.01.05, Consequential impacts - Pipeline-Community **Gas leak outside residences and businesses resulting in need to evacuate premises** LOW Reputational risk, due to: **Failure Mode:** High volume gas leak in vicinity of residences or businesses **Causes:** 1. Proximity of residences or businesses to pipeline and potential leak points 2. Prevailing wind conditions could direct leaking gas in direction of residences or businesses
12.1	Carry out pipe detection survey to determine exact location and depth of cover of the pipeline (repeat action)	Ross Barber	Prior to subsidence effect			3.02.01, Consequential impacts - Pipeline-Infrastructure **Gas leak adjacent to other services (power line, Sydney Water potable main, Sewer main, Optic fibre cable) with potential to ignite gas or cause unacceptable consequential impacts** LOW Reputational risk, due to: **Failure Mode:** High volume gas leak in vicinity of other infrastructure where there may be ignition sources **Causes:** 1. Proximity of infrastructure to pipeline and potential leak points 2. Prevailing conditions could allow leaking gas to accumulate and come in contact with potential ignition sources
12.2	Provide the Excavate & Expose Methodology and include in the Gas Pipeline Subsidence Management Plan and gain Jemena pre-approval for this methodology (repeat action)	Ross Barber	Prior to subsidence effect			
12.3	Identify and develop all Access Agreements for carrying out pipeline maintenance (repeat action)	Ross Barber	Prior to subsidence effect			
12.4	Jemena to clarify all notification and access requirements to carry out excavate/ expose/ repair pipe. (repeat action)	Ross Barber	Prior to subsidence effect			
12.5	Engage with Jemena to determine emergency repair arrangements required for the timely response to leaking or ruptured pipelines (repeat action)	Ross Barber	Prior to subsidence effect			

Appendix C

SIMEC Pty Ltd

Tahmoor Mine

LW1A & LW2A Subsidence Impacts on Jemena 150mm High Pressure Steel Gas Pipeline

Risk Register – Assessment Order

April 2022

Risk Identification & Analysis					Residual Risk Evaluation						Risk Reduction Strategy				
R#, Aspect - Consideration	**Risk Issue**	**Failure Mode & Causes**	**Potential Impacts**	**Existing Controls**	**Loss Type**	**Consequence**	**Likelihood**	**Risk Rank**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**By Who**	**By When**	**Historical Knowledge/ SFAIRP Comments**	**SFAIRP achieved (Yes/ No)**
1.01.01, Impact to pipe due to conventional subsidence - Pipeline design & installation	Ground strains and curvatures exceed pipeline allowable or actual yield strength resulting in a gas leak	Failure Mode: Development of a crack most likely at a weld. Cracking at deteriorated or corroded section of pipe. Full bore rupture Causes: 1. Pipeline not installed to design 2. Pipeline deterioration (note: Worley Pipeline assessment/ modelling assumes pipeline is in good condition). 2.1. Corrosion 2.2. Deformation or stress imposed by tree roots 2.3. Substandard as-installed condition, e.g., coating, weld quality, manufactured pipe 3. Pipeline tee-connections are anchored in place and provide for possible pipe stress concentration point	Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture **Worst Credible:** Full bore rupture resulting in initial uncontrolled gas release. This could result in a gas fire potentially in the vicinity of the petrol station or school. MFC = Negative media attention, 3rd party damage, Partial Road Closure, Public Safety impacts associated with the ignition of gas	**Information & analysis:** 1.1. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.2. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Pipe design, construction and installation standards at time of installation for pipeline with 50 year design life. Pipe installed in 1994. 2.2. As built drawings of pipeline installation held by Jemena 2.3. Protective coating on pipeline 2.4. Range of gas pipeline live repair equipment & methodologies available **Mitigating Controls:** 3.1. Odorised gas to facilitate leak detection 3.2. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. Subsidence Monitoring Controls: 4.1. Ground surveys carried out weekly along with weekly review of data 4.2. Visual inspections, e.g., road pavement deformation as indication of non-conventional subsidence 4.3. Ground survey (Remembrance Drive and Main Southern Railway Early Warning Systems, additional subsidence early warning line for REA boundary survey line, continuously operating GNSS sensor) 4.4. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment 6.3. End of line pressure monitoring 6.4. 5 yearly Jemena Leakage Survey (Last done 2019)	F	2	D	5	L	1. Obtain from Jemena a summary of the pipeline monitoring and condition reports and highlight any relevant issues raised and review engineering assessment as applicable. 2. Engage with Jemena to determine emergency repair arrangements required for the timely response to leaking or ruptured pipelines 3. Ensure that survey monitoring lines include coverage of pipeline tee-connections within the subsidence affected zones. 4. Review pipeline engineering assessment in relation to the existence of any fixed tee-connections within the subsidence affected zones.	Ross Barber	Prior to subsidence effect		Yes

R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
1.02.01, Impact to pipe due to conventional subsidence - Pipeline fault detectability	Inadequate or delayed response due to less than adequate (LTA) detection of leaks	**Failure Mode:** Development of a crack or leak with potential to progresses to full bore rupture if not acted upon. **Causes:** 1. LTA monitoring arrangements in place to provide adequate timely response to mitigate leak 2. Failure to trigger response at appropriate levels	Gas leak liberating to surface. Supply disruption. **Worst Credible:** Full bore rupture resulting in initial uncontrolled gas release. This could result in a gas fire potentially in the vicinity of the petrol station or school. MFC = Negative media attention, 3rd party damage, Partial Road Closure, Public Safety impacts associated with the ignition of gas	**Information & analysis:** 1.1. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.2. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Odorised gas facilitates leak detectability 2.2. Range of gas pipeline live repair equipment & methodologies available **Mitigating Controls:** 3.1. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. Subsidence Monitoring Controls: 4.1. Weekly ground surveys and review of data, visual inspections and other subsidence data (e.g., Remembrance Drive, Main Southern Railway Early Warning Systems, early warning line for REA, continuously operating GNSS sensor) trigger responses well in advance of gas leak, including use of gas detection equipment. 4.2. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment 6.3. End of line pressure monitoring 6.4. 5 yearly Jemena Leakage Survey (Last done 2019)	F	3	E	6	L	Nil Additional Controls Identified	NA	NA		Yes

R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
1.03.01, Impact to pipe due to conventional subsidence - Maintainability	LTA access to carry out timely maintenance or repair of the pipeline	**Failure Mode:** Untimely preventative maintenance allows for exceedance of pipeline strength and development of cracks and potential full bore rupture. Severe deformation of pipe Potential for service disruption **Causes:** 1. Other infrastructure or constraints along the alignment 2. Failure to have appropriate access agreements in place, associated with other asset owners 3. Environmental constraints, e.g., cannot remove problem trees 4. Council restrictions 5. Work permit requirements e.g., partial road closure 6. LTA ready access 7. LTA availability of equipment to uncover and isolate pipe 8. LTA means to isolate 9. Hawthorn Rd valve doesn't work 10. PE pipeline squeeze method not suitable 11. Deteriorated condition of pipe not readily repairable without replacing long run of pipe	Gas leak liberating to surface. Supply disruption. **Worst Credible:** Full bore rupture resulting in initial uncontrolled gas release. This could result in a gas fire potentially in the vicinity of the petrol station or school. MFC = Negative media attention, 3rd party damage, Partial Road Closure, Public Safety impacts associated with the ignition of gas	**Information & analysis:** 1.1. Location of pipeline and other infrastructure is known **Engineered Controls:** 2.1. Pipe design, construction and installation standards at time of installation for pipeline with 50 year design life. Pipe installed in 1994. 2.2. As built drawings of pipeline installation held by Jemena 2.3. Range of gas pipeline live repair equipment & methodologies available **Mitigating Controls:** 3.1. Pipeline corridor and associated access agreement/ easements in place 3.2. Alignment is beside roads with ready access 3.2. All excavation within 3m of pipeline require Jemena supervision 3.3. Tahmoor/ Jemena will engage prequalified contractors to carry out maintenance (excavate/ relieve) and repair work 3.4. Access agreements to carry out preventative maintenance (excavate/ relieve) will be included within the Gas Pipeline Subsidence Management Plan, which will be agreed with Jemena 3.5. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. Subsidence Monitoring Controls: 4.1. Weekly ground surveys and review of data, visual inspections and other subsidence data (e.g., Remembrance Drive, Main Southern Railway Early Warning Systems, early warning line for REA, continuously operating GNSS sensor) trigger responses well in advance of need to carry out preventative maintenance work. 4.2. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment	F	3	D	9	M	1. Carry out a pipe detection survey to determine exact location and depth of cover of the gas pipeline and other adjacent buried services as applicable 2. Provide the Excavate & Expose Methodology and include in the Gas Pipeline Subsidence Management Plan and gain Jemena pre-approval for this methodology 3. Identify and develop all Access Agreements for carrying out pipeline maintenance 4. Jemena to clarify all notification and access requirements to carry out excavate/ expose/ repair pipe.				Yes

2.01.01, Impact to pipe due to non-conventional subsidence - Pipeline and geology	Non-conventional subsidence effects over faults, dykes results in potential adverse impacts on pipeline	**Failure Mode:** Crack develops at stress concentration point - step or shear **Causes:** 1. Non-conventional subsidence 2. Failure to identify geological features that could cause areas of non-conventional subsidence	Gas leak liberating to surface Supply disruption **Worst Credible:** Full bore rupture resulting in initial uncontrolled gas release. This could result in a gas fire potentially in the vicinity of the petrol station or school. MFC = Negative media attention, 3rd party damage, Partial Road Closure, Public Safety impacts	**Information & analysis:** 1.1. Rail cuttings provide information regarding geological structures at surface 1.2. UG geological mapping identifies major structures 1.3. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.4. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Pipe design, construction and installation standards at time of installation for pipeline with 50 year design life. Pipe installed in 1994. 2.2. As built drawings of pipeline installation held by Jemena 2.3. Range of gas pipeline live repair equipment & methodologies available **Mitigating Controls:** 3.1. Odorised gas to facilitate leak detection 3.2. Access agreements to carry out preventative maintenance (excavate/ relieve) will be included within the Gas Pipeline Subsidence Management Plan, which will be agreed with Jemena 3.3. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. Subsidence Monitoring Controls: 4.1. Ground surveys carried out weekly along with weekly review of data 4.2. Visual inspections, e.g., road pavement deformation as indication of non-conventional subsidence 4.3. Ground survey (Remembrance Drive and Main Southern Railway Early Warning Systems, additional subsidence early warning line for REA boundary survey line, continuously operating GNSS sensor) 4.4. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment	F	2	D	5	L	1. Engage a structural geologist to perform an assessment of surface expressions of geological structures in vicinity of the pipeline	Ross Barber	Prior to subsidence effect		Yes
2.02.01, Impact to pipe due to non-conventional subsidence -	Non-conventional subsidence effects over creeks (exposed or hidden) results in	**Failure Mode:** Deformation or kinking of pipe Development of cracks in pipe	Gas leak liberating to surface Supply disruption **Worst Credible:**	**Information & analysis:** 1.1. Current topographic information 1.2. Historic aerial photos identifying hidden creek beds (stockpile area)	F	2	E	3	L	1. Carry out a pipe detection survey to determine exact location and depth of cover of the gas pipeline and other			No deeply incised creeks above LWs S1a and s2a	Yes

R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
Pipeline and topography	potential adverse impacts on pipeline	**Causes:** 1. Valley closure at creek or historic creek bed crossing 2. Upsidence 2.1. Geological structure 3. LTA surveys	Full bore rupture resulting in initial uncontrolled gas release. This could result in a gas fire MFC = Negative media attention, 3rd party damage, Partial Road Closure, Public Safety impacts	1.3. Visual inspection has been carried out along pipeline alignment 1.4. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.5. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Pipe design, construction and installation standards at time of installation for pipeline with 50 year design life. Pipe installed in 1994. 2.2. As built drawings of pipeline installation held by Jemena 2.3. Existing isolation valves 2.4. Range of gas pipeline live repair equipment & methodologies available **Mitigating Controls:** 3.1. Odorised gas to facilitate leak detection 3.2. Access agreements to carry out preventative maintenance (excavate/ relieve) will be included within the Gas Pipeline Subsidence Management Plan, which will be agreed with Jemena 3.3. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. Subsidence Monitoring Controls: 4.1. Ground surveys carried out weekly along with weekly review of data 4.2. Visual inspections, e.g., road pavement deformation as indication of non-conventional subsidence 4.3. Ground survey (Remembrance Drive and Main Southern Railway Early Warning Systems, additional subsidence early warning line for REA boundary survey line, Continuously operating GNSS sensor) 4.4. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment						adjacent buried services as applicable 2. Provide the Excavate & Expose Methodology and include in the Gas Pipeline Subsidence Management Plan and gain Jemena pre-approval for this methodology 3. Identify and develop all Access Agreements for carrying out pipeline maintenance 4. Jemena to clarify all notification and access requirements to carry out excavate/ expose/ repair pipe.			along pipeline	

R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
2.03.01, Impact to pipe due to non-conventional subsidence - Pipeline & sub-surface features	No additional risks identified associated with subsurface features - see Items 2.01.01 and 2.02.01	NA	NA	NA						NA	NA	NA	NA	NA
3.01.01, Consequential impacts - Pipeline-Community	Disruption of gas supply resulting in unacceptable public impacts	**Failure Mode:** Large/ open pipe leak Severe restriction or squeezing of pipe **Causes:** 1. Subsidence impacts to pipeline 2. LTA means to isolate and provide alternative supply 3. Extended time to restore gas supply to customers - Relighting Process to purge air from gas lines	Community without adequate gas supply to operate necessary infrastructure **Worst Credible:** Loss of gas supply impacts public health or safety MFC = loss of gas supply to critical equipment (e.g., heating, cooling), leading to unacceptable consequential impacts	**Information & analysis:** 1.1. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.2. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Odorised gas facilitates detectability 2.2. Range of gas pipeline live repair equipment & methodologies available **Mitigating Controls:** 3.1. Jemena gas restoration procedures, e.g., Relighting Procedure 3.2. Jemena Gas Tanker Trucks for temporary supply while mains supply disrupted 3.3. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. Subsidence Monitoring Controls: 4.1. Weekly ground surveys and review of data, visual inspections and other subsidence data (e.g., Remembrance Drive, Main Southern Railway Early Warning Systems, early warning line for REA, continuously operating GNSS sensor) trigger responses well in advance of need to carry out preventative maintenance work. 4.2. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment	F	3	E	6	L	1. Engage with Jemena to determine emergency repair arrangements required for the timely response to leaking or ruptured pipelines 2. Confirm Petrol station emergency response procedures and pump shutoff switch is in place (maybe should go on the other column	Ross Barber	Prior to subsidence effect		Yes

R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
3.01.02, Consequential impacts - Pipeline- Community	Unacceptable reputational impacts from gas leak affecting road, resulting in road closure until repairs can be made	**Failure Mode:** High volume leak with potential to ignite - road cordoned off for repairs **Causes:** 1. Large gas leak 2. Need to control potential ignition sources 3. Need to provide unhindered access for repair	Diversion of traffic. Increased traffic on alternative streets **Worst Credible:** Motor vehicle accident as result of detours MFC = Third party damage, moderate injuries	**Information & analysis:** 1.1. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.2. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Odorised gas facilitates detectability 2.2. Existing isolation valves 2.3. Range of gas pipeline live repair equipment & methodologies available **Mitigating Controls:** 3.1. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. Subsidence Monitoring Controls: 4.1. Weekly ground surveys and review of data, visual inspections and other subsidence data (e.g., Remembrance Drive, Main Southern Railway Early Warning Systems, early warning line for REA, continuously operating GNSS sensor) trigger responses well in advance of need to carry out preventative maintenance work. 4.2. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment	R	3	E	6	L	1. Engage with Jemena to determine emergency repair arrangements required for the timely response to leaking or ruptured pipelines	Ross Barber	prior to subsidence effect		Yes

R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
3.01.03, Consequential impacts - Pipeline-Community	Gas leak outside Wollondilly Anglican Community Church and College resulting in evacuation and significant media attention	**Failure Mode:** High volume leak **Causes:** 1. Proximity of Wollondilly Anglican Church and associated children's playground (approx.15m from centreline of Remembrance Drive) to pipeline alignment (estimated +25m) 2. Prevailing wind conditions could direct leaking gas in direction of school	Children affected / upset by gas smell. Need to evacuate children to safe distance from gas leak **Worst Credible:** Ambulances called to attend school children Negative media attention	**Information & analysis:** 1.1. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.2. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Odorised gas facilitates detectability 2.2. Existing isolation valves 2.3. Range of gas pipeline live repair equipment & methodologies available **Mitigating Controls:** 3.1. Separation distance of Wollondilly Anglican Church and associated children's playground from pipeline alignment Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. Subsidence Monitoring Controls: 4.1. Weekly ground surveys and review of data, visual inspections and other subsidence data (e.g., Remembrance Drive, Main Southern Railway Early Warning Systems, early warning line for REA, continuously operating GNSS sensor) trigger responses well in advance of need to carry out preventative maintenance work. 4.2. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment	R	3	E	6	L	1. Determine actual separation distances between pipeline alignment and nearest Wollondilly Anglican Church outside area (children's playground) locations 2. Carry out consultation with the Wollondilly Anglican Church to determine actual site activities and any potential need for additional risk mitigation.	Ross Barber			Yes

R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
3.01.04, Consequential impacts - Pipeline-Community	Gas leak outside petrol station and threat of fire that could propagate to petrol station	**Failure Mode:** High volume gas leak in vicinity of petrol station **Causes:** 1. Proximity of petrol station bowsers (approx. 18m from centreline of Remembrance Drive) to pipeline alignment (estimated +25m) 2. Prevailing wind conditions could direct leaking gas in direction of petrol station	Area cordoned off and disruption of petrol station operation **Worst Credible:** Local Fire Brigade attend Negative media attention	**Information & analysis:** 1.1. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.2. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Odorised gas facilitates detectability 2.2. Petrol station compliance **Mitigating Controls:** 3.1. Separation distance of petrol station from pipeline alignment 3.2. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. Subsidence Monitoring Controls: 4.1. Weekly ground surveys and review of data, visual inspections and other subsidence data (e.g., Remembrance Drive, Main Southern Railway Early Warning Systems, early warning line for REA, continuously operating GNSS sensor) trigger responses well in advance of need to carry out preventative maintenance work. 4.2. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment	R	2	E	3	L	1. Determine actual separation distances between pipeline alignment and nearest potential ignition points at petrol station	Ross Barber	Prior to subsidence effect		Yes

R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
3.01.05, Consequential impacts - Pipeline-Community	Gas leak outside residences and businesses resulting in need to evacuate premises	**Failure Mode:** High volume gas leak in vicinity of residences or businesses **Causes:** 1. Proximity of residences or businesses to pipeline and potential leak points 2. Prevailing wind conditions could direct leaking gas in direction of residences or businesses	Members of public/ residences affected / upset by gas smell **Worst Credible:** Ambulances called to attend Negative media attention	**Information & analysis:** 1.1. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.2. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Odorised gas facilitates detectability **Mitigating Controls:** 3.1. Separation distance of petrol station from pipeline alignment 3.2. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. Subsidence Monitoring Controls: 4.1. Weekly ground surveys and review of data, visual inspections and other subsidence data (e.g., Remembrance Drive, Main Southern Railway Early Warning Systems, early warning line for REA, continuously operating GNSS sensor) trigger responses well in advance of need to carry out preventative maintenance work. 4.2. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment	R	2	E	3	L	1. Carry out a survey to determine proximity of individual premises to pipeline alignment to determine if there are any close receivers	Ross Barber	Prior to subsidence effect		Yes

R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
3.02.01, Consequential impacts - Pipeline-Infrastructure	Gas leak adjacent to other services (power line, Sydney Water potable main, Sewer main, Optic fibre cable) with potential to ignite gas or cause unacceptable consequential impacts	**Failure Mode:** High volume gas leak in vicinity of other infrastructure where there may be ignition sources **Causes:** 1. Proximity of infrastructure to pipeline and potential leak points 2. Prevailing conditions could allow leaking gas to accumulate and come in contact with potential ignition sources	Adjacent other service disruption to remove ignition sources until repaired **Worst Credible:** Power loss to essential community infrastructure leading to financial impacts Negative media attention	**Information & analysis:** 1.1. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.2. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Individual easements for other services **Mitigating Controls:** 3.1. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. Subsidence Monitoring Controls: 4.1. Weekly ground surveys and review of data, visual inspections and other subsidence data (e.g., Remembrance Drive, Main Southern Railway Early Warning Systems, early warning line for REA, continuously operating GNSS sensor) trigger responses well in advance of need to carry out preventative maintenance work. 4.2. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment	R	2	E	3	L	1. Carry out pipe detection survey to determine exact location and depth of cover of the pipeline 2. Provide the Excavate & Expose Methodology and include in the Gas Pipeline Subsidence Management Plan and gain Jemena pre-approval for this methodology 3. Identify and develop all Access Agreements for carrying out pipeline maintenance 4. Jemena to clarify all notification and access requirements to carry out excavate/ expose/ repair pipe. 5. Engage with Jemena to determine emergency repair arrangements required for the timely response to leaking or ruptured pipelines	Ross Barber	Prior to subsidence effect		Yes

R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
4.01.01, Control effectiveness - TARP triggers	Monitoring controls are not adequate (surveys, gas detection, visual inspections) to trigger timely action	**Failure Mode:** Critical parameter not adequately monitored **Causes:** 1. LTA manual monitoring frequency 2. Survey station damaged 3. Infrastructure not monitored 4. Data errors	**Worst Credible:** delayed detection, resulting in greater severity impact	**Information & analysis:** 1.1. Subsidence assessment by MSEC predicts subsidence effects along pipeline **Engineered Controls:** 2.1. **Mitigating Controls:** 3.1. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. **Subsidence Monitoring Controls:** 4.1. Redundancy in Subsidence Monitoring 4.1.1. Ground surveys carried out weekly along with weekly review of data 4.1.2. Visual inspections, e.g., road pavement deformation as indication of non-conventional subsidence 4.1.3. Ground survey (Remembrance Drive and Main Southern Railway Early Warning Systems, additional subsidence early warning line for REA boundary survey line, continuously operating GNSS sensor) 4.1.4. OTDR monitoring of optic fibre cable 4.3. Weekly reporting/ review of subsidence data 4.4. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks	F	3	E	6	L	Engage with Jemena to determine emergency repair arrangements required for the timely response to leaking or ruptured pipelines	Ross Barber	Prior to subsidence effect		Yes
4.02.01, Control effectiveness - Gas detection inspections	See 1.02.01	NA	NA	NA						NA	NA	NA	NA	NA

R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
4.03.01, Control effectiveness - Uncovering pipeline	Exposing pipeline to relieve stress is not appropriate for particular scenarios	**Failure Mode:** Pipe failure due to temperature effects Pipeline damaged intentionally or unintentionally Pipe buckles due to inadequate support and/or depth of cover beyond the trench **Causes:** 1. Tampering with exposed pipeline 2. Radiant heat 3. Trench filling with water 4. Impact by vehicle 5. LTA physical protection of exposed pipeline	Uncovered pipeline leaks or ruptures **Worst Credible:** Motor vehicle accident collision with pipeline and gas release ignited. MFC = Fatality of vehicle occupants	**Information & analysis:** 1.1. Natural gas is lighter than air and therefore will not tend to accumulate in an open trench **Engineered Controls:** 2.1. Trench covers will be used to provide protection of the pipeline from the elements and impact 2.2. Concrete jersey barriers to prevent motor vehicles entering pipeline trench **Mitigating Controls:** 3.1. **Monitoring Controls:** 4.1. Security arrangements will be implemented to prevent unauthorised access to uncovered pipeline 4.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment **Triggered Responses:** 5.1.	F	3	D	9	M	1. Carry out pipe detection survey to determine exact location and depth of cover of the pipeline 2. Provide the Excavate & Expose Methodology and include in the Gas Pipeline Subsidence Management Plan and gain Jemena pre-approval for this methodology 3. Identify and develop all Access Agreements for carrying out pipeline maintenance 4. Jemena to clarify all notification and access requirements to carry out excavate/ expose/ repair pipe. 5. Engage with Jemena to determine emergency repair arrangements required for the timely response to leaking or ruptured pipelines 6. Carry out engineering review for each pipeline uncovering/ destressing to determine extent of uncovering and potential for damage/ deformation in excavated state	Ross Barber	Prior to subsidence effect		Yes
4.04.01, Control effectiveness - Monitoring pipeline	See 1.01.01, 1.02.01, 1.03.01, 2.01.01, 2.02.01	NA	NA	NA						NA	NA	NA	NA	NA
4.05.01, Control effectiveness - Pipeline isolation & repair	Isolation and repair method does not provide suitable timely response See 1.03.01	**Failure Mode:** LTA repairability of the pipe **Causes:** 1. LTA ready access 2. LTA availability of equipment to uncover and isolate pipe 3. LTA means to isolate 4. Hawthorn Rd valve doesn't work 5. PE pipeline squeeze method not suitable 6. Deteriorated condition of pipe not readily repairable without replacing long run of pipe	NA	NA						NA	NA	NA	NA	NA

R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
4.05.02, Control effectiveness - Pipeline isolation & repair	Injury during repair See 1.03.01	**Failure Mode:** Gas ignition **Causes:** 1. Uncontrolled ignition sources 2. Larger leak triggered during repair 3. Unauthorised tampering	NA	NA						NA	NA	NA	NA	NA
4.06.01, Control effectiveness - Emergency management	See 1.03.01	NA	NA	NA						NA	NA	NA	NA	NA

Appendix D

SIMEC Pty Ltd

Tahmoor Mine

LW1A & LW2A Subsidence Impacts on Jemena 150mm High Pressure Steel Gas Pipeline

Risk Register – Risk Order

April 2022

Risk Identification & Analysis				Residual Risk Evaluation						Risk Reduction Strategy				
R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
1.03.01, Impact to pipe due to conventional subsidence - Maintainability	LTA access to carry out timely maintenance or repair of the pipeline	**Failure Mode:** Untimely preventative maintenance allows for exceedance of pipeline strength and development of cracks and potential full bore rupture. Severe deformation of pipe Potential for service disruption **Causes:** 1. Other infrastructure or constraints along the alignment 2. Failure to have appropriate access agreements in place, associated with other asset owners 3. Environmental constraints, e.g., cannot remove problem trees 4. Council restrictions 5. Work permit requirements e.g., partial road closure 6. LTA ready access 7. LTA availability of equipment to uncover and isolate pipe 8. LTA means to isolate 9. Hawthorn Rd valve doesn't work 10. PE pipeline squeeze method not suitable 11. Deteriorated condition of pipe not readily repairable without replacing long run of pipe	Gas leak liberating to surface. Supply disruption. **Worst Credible:** Full bore rupture resulting in initial uncontrolled gas release. This could result in a gas fire potentially in the vicinity of the petrol station or school. MFC = Negative media attention, 3rd party damage, Partial Road Closure, Public Safety impacts associated with the ignition of gas	**Information & analysis:** 1.1. Location of pipeline and other infrastructure is known **Engineered Controls:** 2.1. Pipe design, construction and installation standards at time of installation for pipeline with 50 year design life. Pipe installed in 1994. 2.2. As built drawings of pipeline installation held by Jemena 2.3. Range of gas pipeline live repair equipment & methodologies available **Mitigating Controls:** 3.1. Pipeline corridor and associated access agreement/ easements in place 3.2. Alignment is beside roads with ready access 3.2. All excavation within 3m of pipeline require Jemena supervision 3.3. Tahmoor/ Jemena will engage prequalified contractors to carry out maintenance (excavate/ relieve) and repair work 3.4. Access agreements to carry out preventative maintenance (excavate/ relieve) will be included within the Gas Pipeline Subsidence Management Plan, which will be agreed with Jemena 3.5. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. **Subsidence Monitoring Controls:** 4.1. Weekly ground surveys and review of data, visual inspections and other subsidence data (e.g., Remembrance Drive, Main Southern Railway Early Warning Systems, early warning line for REA, continuously operating GNSS sensor) trigger responses well in advance of need to carry out preventative maintenance work. 4.2. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment	F	3	D	9	M	1. Carry out a pipe detection survey to determine exact location and depth of cover of the gas pipeline and other adjacent buried services as applicable 2. Provide the Excavate & Expose Methodology and include in the Gas Pipeline Subsidence Management Plan and gain Jemena pre-approval for this methodology 3. Identify and develop all Access Agreements for carrying out pipeline maintenance 4. Jemena to clarify all notification and access requirements to carry out excavate/ expose/ repair pipe.				Yes

Risk Identification & Analysis				Residual Risk Evaluation						Risk Reduction Strategy				
R#, Aspect - Consideration	**Risk Issue**	**Failure Mode & Causes**	**Potential Impacts**	**Existing Controls**	**Loss Type**	**Consequence**	**Likelihood**	**Risk Rank**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**By Who**	**By When**	**Historical Knowledge/ SFAIRP Comments**	**SFAIRP achieved (Yes/ No)**
4.03.01, Control effectiveness - Uncovering pipeline	Exposing pipeline to relieve stress is not appropriate for particular scenarios	**Failure Mode:** Pipe failure due to temperature effects Pipeline damaged intentionally or unintentionally Pipe buckles due to inadequate support and/or depth of cover beyond the trench **Causes:** 1. Tampering with exposed pipeline 2. Radiant heat 3. Trench filling with water 4. Impact by vehicle 5. LTA physical protection of exposed pipeline	Uncovered pipeline leaks or ruptures **Worst Credible:** Motor vehicle accident collision with pipeline and gas release ignited. MFC = Fatality of vehicle occupants	**Information & analysis:** 1.1. Natural gas is lighter than air and therefore will not tend to accumulate in an open trench **Engineered Controls:** 2.1. Trench covers will be used to provide protection of the pipeline from the elements and impact 2.2. Concrete jersey barriers to prevent motor vehicles entering pipeline trench **Mitigating Controls:** 3.1. **Monitoring Controls:** 4.1. Security arrangements will be implemented to prevent unauthorised access to uncovered pipeline 4.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment **Triggered Responses:** 5.1.	F	3	D	9	M	1. Carry out pipe detection survey to determine exact location and depth of cover of the pipeline 2. Provide the Excavate & Expose Methodology and include in the Gas Pipeline Subsidence Management Plan and gain Jemena pre-approval for this methodology 3. Identify and develop all Access Agreements for carrying out pipeline maintenance 4. Jemena to clarify all notification and access requirements to carry out excavate/ expose/ repair pipe. 5. Engage with Jemena to determine emergency repair arrangements required for the timely response to leaking or ruptured pipelines 6. Carry out engineering review for each pipeline uncovering/ destressing to determine extent of uncovering and potential for damage/ deformation in excavated state	Ross Barber	Prior to subsidence effect		Yes

Risk Identification & Analysis				Residual Risk Evaluation						Risk Reduction Strategy				
R#, Aspect - Consideration	**Risk Issue**	**Failure Mode & Causes**	**Potential Impacts**	**Existing Controls**	**Loss Type**	**Consequence**	**Likelihood**	**Risk Rank**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**By Who**	**By When**	**Historical Knowledge/ SFAIRP Comments**	**SFAIRP achieved (Yes/ No)**
1.02.01, Impact to pipe due to conventional subsidence - Pipeline fault detectability	Inadequate or delayed response due to less than adequate (LTA) detection of leaks	**Failure Mode:** Development of a crack or leak with potential to progresses to full bore rupture if not acted upon. **Causes:** 1. LTA monitoring arrangements in place to provide adequate timely response to mitigate leak 2. Failure to trigger response at appropriate levels	Gas leak liberating to surface. Supply disruption. **Worst Credible:** Full bore rupture resulting in initial uncontrolled gas release. This could result in a gas fire potentially in the vicinity of the petrol station or school. MFC = Negative media attention, 3rd party damage, Partial Road Closure, Public Safety impacts associated with the ignition of gas	**Information & analysis:** 1.1. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.2. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Odorised gas facilitates leak detectability 2.2. Range of gas pipeline live repair equipment & methodologies available **Mitigating Controls:** 3.1. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. **Subsidence Monitoring Controls:** 4.1. Weekly ground surveys and review of data, visual inspections and other subsidence data (e.g., Remembrance Drive, Main Southern Railway Early Warning Systems, early warning line for REA, continuously operating GNSS sensor) trigger responses well in advance of gas leak, including use of gas detection equipment. 4.2. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment 6.3. End of line pressure monitoring 6.4. 5 yearly Jemena Leakage Survey (Last done 2019)	F	3	E	6	L	Nil Additional Controls Identified	NA	NA		Yes

Risk Identification & Analysis				Residual Risk Evaluation						Risk Reduction Strategy				
R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
3.01.01, Consequential impacts - Pipeline- Community	Disruption of gas supply resulting in unacceptable public impacts	**Failure Mode:** Large/ open pipe leak Severe restriction or squeezing of pipe **Causes:** 1. Subsidence impacts to pipeline 2. LTA means to isolate and provide alternative supply 3. Extended time to restore gas supply to customers - Relighting Process to purge air from gas lines	Community without adequate gas supply to operate necessary infrastructure **Worst Credible:** Loss of gas supply impacts public health or safety MFC = loss of gas supply to critical equipment (e.g., heating, cooling), leading to unacceptable consequential impacts	**Information & analysis:** 1.1. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.2. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Odorised gas facilitates detectability 2.2. Range of gas pipeline live repair equipment & methodologies available **Mitigating Controls:** 3.1. Jemena gas restoration procedures, e.g., Relighting Procedure 3.2. Jemena Gas Tanker Trucks for temporary supply while mains supply disrupted 3.3. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. **Subsidence Monitoring Controls:** 4.1. Weekly ground surveys and review of data, visual inspections and other subsidence data (e.g., Remembrance Drive, Main Southern Railway Early Warning Systems, early warning line for REA, continuously operating GNSS sensor) trigger responses well in advance of need to carry out preventative maintenance work. 4.2. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment	F	3	E	6	L	1. Engage with Jemena to determine emergency repair arrangements required for the timely response to leaking or ruptured pipelines 2. Confirm Petrol station emergency response procedures and pump shutoff switch is in place (maybe should go on the other column	Ross Barber	Prior to subsidence effect		Yes

Risk Identification & Analysis				Residual Risk Evaluation						Risk Reduction Strategy				
R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
3.01.02, Consequential impacts - Pipeline-Community	Unacceptable reputational impacts from gas leak affecting road, resulting in road closure until repairs can be made	**Failure Mode:** High volume leak with potential to ignite - road cordoned off for repairs **Causes:** 1. Large gas leak 2. Need to control potential ignition sources 3. Need to provide unhindered access for repair	Diversion of traffic. Increased traffic on alternative streets **Worst Credible:** Motor vehicle accident as result of detours MFC = Third party damage, moderate injuries	**Information & analysis:** 1.1. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.2. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Odorised gas facilitates detectability 2.2. Existing isolation valves 2.3. Range of gas pipeline live repair equipment & methodologies available **Mitigating Controls:** 3.1. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. **Subsidence Monitoring Controls:** 4.1. Weekly ground surveys and review of data, visual inspections and other subsidence data (e.g., Remembrance Drive, Main Southern Railway Early Warning Systems, early warning line for REA, continuously operating GNSS sensor) trigger responses well in advance of need to carry out preventative maintenance work. 4.2. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment	R	3	E	6	L	1. Engage with Jemena to determine emergency repair arrangements required for the timely response to leaking or ruptured pipelines	Ross Barber	prior to subsidence effect		Yes

Risk Identification & Analysis				Residual Risk Evaluation						Risk Reduction Strategy				
R#, Aspect - Consideration	**Risk Issue**	**Failure Mode & Causes**	**Potential Impacts**	**Existing Controls**	**Loss Type**	**Consequence**	**Likelihood**	**Risk Rank**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**By Who**	**By When**	**Historical Knowledge/ SFAIRP Comments**	**SFAIRP achieved (Yes/ No)**
3.01.03, Consequential impacts - Pipeline- Community	Gas leak outside Wollondilly Anglican Community Church and College resulting in evacuation and significant media attention	**Failure Mode:** High volume leak **Causes:** 1. Proximity of Wollondilly Anglican Church and associated children's playground (approx.15m from centreline of Remembrance Drive) to pipeline alignment (estimated +25m) 2. Prevailing wind conditions could direct leaking gas in direction of school	Children affected / upset by gas smell. Need to evacuate children to safe distance from gas leak **Worst Credible:** Ambulances called to attend school children Negative media attention	**Information & analysis:** 1.1. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.2. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Odorised gas facilitates detectability 2.2. Existing isolation valves 2.3. Range of gas pipeline live repair equipment & methodologies available **Mitigating Controls:** 3.1. Separation distance of Wollondilly Anglican Church and associated children's playground from pipeline alignment Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. **Subsidence Monitoring Controls:** 4.1. Weekly ground surveys and review of data, visual inspections and other subsidence data (e.g., Remembrance Drive, Main Southern Railway Early Warning Systems, early warning line for REA, continuously operating GNSS sensor) trigger responses well in advance of need to carry out preventative maintenance work. 4.2. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment	R	3	E	6	L	1. Determine actual separation distances between pipeline alignment and nearest Wollondilly Anglican Church outside area (children's playground) locations 2. Carry out consultation with the Wollondilly Anglican Church to determine actual site activities and any potential need for additional risk mitigation.	Ross Barber			Yes

Risk Identification & Analysis				Residual Risk Evaluation						Risk Reduction Strategy				
R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
4.01.01, Control effectiveness - TARP triggers	Monitoring controls are not adequate (surveys, gas detection, visual inspections) to trigger timely action	**Failure Mode:** Critical parameter not adequately monitored **Causes:** 1. LTA manual monitoring frequency 2. Survey station damaged 3. Infrastructure not monitored 4. Data errors	**Worst Credible:** delayed detection, resulting in greater severity impact	**Information & analysis:** 1.1. Subsidence assessment by MSEC predicts subsidence effects along pipeline **Engineered Controls:** 2.1. **Mitigating Controls:** 3.1. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. **Subsidence Monitoring Controls:** 4.1. Redundancy in Subsidence Monitoring 4.1.1. Ground surveys carried out weekly along with weekly review of data 4.1.2. Visual inspections, e.g., road pavement deformation as indication of non-conventional subsidence 4.1.3. Ground survey (Remembrance Drive and Main Southern Railway Early Warning Systems, additional subsidence early warning line for REA boundary survey line, continuously operating GNSS sensor) 4.1.4. OTDR monitoring of optic fibre cable 4.3. Weekly reporting/ review of subsidence data 4.4. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks	F	3	E	6	L	Engage with Jemena to determine emergency repair arrangements required for the timely response to leaking or ruptured pipelines	Ross Barber	Prior to subsidence effect		Yes

Risk Identification & Analysis				Residual Risk Evaluation						Risk Reduction Strategy				
R#, Aspect - Consideration	**Risk Issue**	**Failure Mode & Causes**	**Potential Impacts**	**Existing Controls**	**Loss Type**	**Consequence**	**Likelihood**	**Risk Rank**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**By Who**	**By When**	**Historical Knowledge/ SFAIRP Comments**	**SFAIRP achieved (Yes/ No)**
1.01.01, Impact to pipe due to conventional subsidence - Pipeline design & installation	Ground strains and curvatures exceed pipeline allowable or actual yield strength resulting in a gas leak	Failure Mode: Development of a crack most likely at a weld. Cracking at deteriorated or corroded section of pipe. Full bore rupture Causes: 1. Pipeline not installed to design 2. Pipeline deterioration (note: Worley Pipeline assessment/ modelling assumes pipeline is in good condition). 2.1. Corrosion 2.2. Deformation or stress imposed by tree roots 2.3. Substandard as-installed condition, e.g., coating, weld quality, manufactured pipe 3. Pipeline tee-connections are anchored in place and provide for possible pipe stress concentration point	Gas leak liberating to surface. Potential fire source. Supply disruption in event of full bore rupture **Worst Credible:** Full bore rupture resulting in initial uncontrolled gas release. This could result in a gas fire potentially in the vicinity of the petrol station or school. MFC = Negative media attention, 3rd party damage, Partial Road Closure, Public Safety impacts associated with the ignition of gas	**Information & analysis:** 1.1. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.2. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Pipe design, construction and installation standards at time of installation for pipeline with 50 year design life. Pipe installed in 1994. 2.2. As built drawings of pipeline installation held by Jemena 2.3. Protective coating on pipeline 2.4. Range of gas pipeline live repair equipment & methodologies available **Mitigating Controls:** 3.1. Odorised gas to facilitate leak detection 3.2. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. **Subsidence Monitoring Controls:** 4.1. Ground surveys carried out weekly along with weekly review of data 4.2. Visual inspections, e.g., road pavement deformation as indication of non-conventional subsidence 4.3. Ground survey (Remembrance Drive and Main Southern Railway Early Warning Systems, additional subsidence early warning line for REA boundary survey line, continuously operating GNSS sensor) 4.4. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment 6.3. End of line pressure monitoring 6.4. 5 yearly Jemena Leakage Survey (Last done 2019)	F	2	D	5	L	1. Obtain from Jemena a summary of the pipeline monitoring and condition reports and highlight any relevant issues raised and review engineering assessment as applicable. 2. Engage with Jemena to determine emergency repair arrangements required for the timely response to leaking or ruptured pipelines 3. Ensure that survey monitoring lines include coverage of pipeline tee-connections within the subsidence affected zones. 4. Review pipeline engineering assessment in relation to the existence of any fixed tee-connections within the subsidence affected zones.	Ross Barber	Prior to subsidence effect		Yes

2.01.01, Impact to pipe due to non-conventional subsidence - Pipeline and geology	Non-conventional subsidence effects over faults, dykes results in potential adverse impacts on pipeline	**Failure Mode:** Crack develops at stress concentration point - step or shear **Causes:** 1. Non-conventional subsidence 2. Failure to identify geological features that could cause areas of non-conventional subsidence	Gas leak liberating to surface Supply disruption **Worst Credible:** Full bore rupture resulting in initial uncontrolled gas release. This could result in a gas fire potentially in the vicinity of the petrol station or school. MFC = Negative media attention, 3rd party damage, Partial Road Closure, Public Safety impacts	**Information & analysis:** 1.1. Rail cuttings provide information regarding geological structures at surface 1.2. UG geological mapping identifies major structures 1.3. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.4. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Pipe design, construction and installation standards at time of installation for pipeline with 50 year design life. Pipe installed in 1994. 2.2. As built drawings of pipeline installation held by Jemena 2.3. Range of gas pipeline live repair equipment & methodologies available **Mitigating Controls:** 3.1. Odorised gas to facilitate leak detection 3.2. Access agreements to carry out preventative maintenance (excavate/ relieve) will be included within the Gas Pipeline Subsidence Management Plan, which will be agreed with Jemena 3.3. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. **Subsidence Monitoring Controls:** 4.1. Ground surveys carried out weekly along with weekly review of data 4.2. Visual inspections, e.g., road pavement deformation as indication of non-conventional subsidence 4.3. Ground survey (Remembrance Drive and Main Southern Railway Early Warning Systems, additional subsidence early warning line for REA boundary survey line, continuously operating GNSS sensor) 4.4. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment	F	2	D	5	L	1. Engage a structural geologist to perform an assessment of surface expressions of geological structures in vicinity of the pipeline	Ross Barber	Prior to subsidence effect		Yes
2.02.01, Impact to pipe due to non-conventional subsidence -	Non-conventional subsidence effects over creeks (exposed or hidden) results in potential adverse impacts on pipeline	**Failure Mode:** Deformation or kinking of pipe Development of cracks in pipe **Causes:**	Gas leak liberating to surface Supply disruption **Worst Credible:**	**Information & analysis:** 1.1. Current topographic information 1.2. Historic aerial photos identifying hidden creek beds (stockpile area) 1.3. Visual inspection has been carried out along pipeline alignment	F	2	E	3	L	1. Carry out a pipe detection survey to determine exact location and depth of cover of the gas pipeline and other adjacent buried services as applicable			No deeply incised creeks above LWs S1a and s2a	Yes

Risk Identification & Analysis				Residual Risk Evaluation						Risk Reduction Strategy				
R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
Pipeline and topography		1. Valley closure at creek or historic creek bed crossing 2. Upsidence 2.1. Geological structure 3. LTA surveys	Full bore rupture resulting in initial uncontrolled gas release. This could result in a gas fire MFC = Negative media attention, 3rd party damage, Partial Road Closure, Public Safety impacts	1.4. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.5. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Pipe design, construction and installation standards at time of installation for pipeline with 50 year design life. Pipe installed in 1994. 2.2. As built drawings of pipeline installation held by Jemena 2.3. Existing isolation valves 2.4. Range of gas pipeline live repair equipment & methodologies available **Mitigating Controls:** 3.1. Odorised gas to facilitate leak detection 3.2. Access agreements to carry out preventative maintenance (excavate/ relieve) will be included within the Gas Pipeline Subsidence Management Plan, which will be agreed with Jemena 3.3. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. **Subsidence Monitoring Controls:** 4.1. Ground surveys carried out weekly along with weekly review of data 4.2. Visual inspections, e.g., road pavement deformation as indication of non-conventional subsidence 4.3. Ground survey (Remembrance Drive and Main Southern Railway Early Warning Systems, additional subsidence early warning line for REA boundary survey line, Continuously operating GNSS sensor) 4.4. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment						2. Provide the Excavate & Expose Methodology and include in the Gas Pipeline Subsidence Management Plan and gain Jemena pre-approval for this methodology 3. Identify and develop all Access Agreements for carrying out pipeline maintenance 4. Jemena to clarify all notification and access requirements to carry out excavate/ expose/ repair pipe.			along pipeline	

Risk Identification & Analysis				Residual Risk Evaluation						Risk Reduction Strategy				
R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
3.01.04, Consequential impacts - Pipeline-Community	Gas leak outside petrol station and threat of fire that could propagate to petrol station	**Failure Mode:** High volume gas leak in vicinity of petrol station **Causes:** 1. Proximity of petrol station bowsers (approx. 18m from centreline of Remembrance Drive) to pipeline alignment (estimated +25m) 2. Prevailing wind conditions could direct leaking gas in direction of petrol station	Area cordoned off and disruption of petrol station operation **Worst Credible:** Local Fire Brigade attend Negative media attention	**Information & analysis:** 1.1. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.2. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Odorised gas facilitates detectability 2.2. Petrol station compliance **Mitigating Controls:** 3.1. Separation distance of petrol station from pipeline alignment 3.2. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. **Subsidence Monitoring Controls:** 4.1. Weekly ground surveys and review of data, visual inspections and other subsidence data (e.g., Remembrance Drive, Main Southern Railway Early Warning Systems, early warning line for REA, continuously operating GNSS sensor) trigger responses well in advance of need to carry out preventative maintenance work. 4.2. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment	R	2	E	3	L	1. Determine actual separation distances between pipeline alignment and nearest potential ignition points at petrol station	Ross Barber	Prior to subsidence effect		Yes

Risk Identification & Analysis				Residual Risk Evaluation						Risk Reduction Strategy				
R#, Aspect - Consideration	**Risk Issue**	**Failure Mode & Causes**	**Potential Impacts**	**Existing Controls**	**Loss Type**	**Consequence**	**Likelihood**	**Risk Rank**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**By Who**	**By When**	**Historical Knowledge/ SFAIRP Comments**	**SFAIRP achieved (Yes/ No)**
3.01.05, Consequential impacts - Pipeline-Community	Gas leak outside residences and businesses resulting in need to evacuate premises	**Failure Mode:** High volume gas leak in vicinity of residences or businesses **Causes:** 1. Proximity of residences or businesses to pipeline and potential leak points 2. Prevailing wind conditions could direct leaking gas in direction of residences or businesses	Members of public/ residences affected / upset by gas smell **Worst Credible:** Ambulances called to attend Negative media attention	**Information & analysis:** 1.1. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.2. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Odorised gas facilitates detectability **Mitigating Controls:** 3.1. Separation distance of petrol station from pipeline alignment 3.2. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. **Subsidence Monitoring Controls:** 4.1. Weekly ground surveys and review of data, visual inspections and other subsidence data (e.g., Remembrance Drive, Main Southern Railway Early Warning Systems, early warning line for REA, continuously operating GNSS sensor) trigger responses well in advance of need to carry out preventative maintenance work. 4.2. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment	R	2	E	3	L	1. Carry out a survey to determine proximity of individual premises to pipeline alignment to determine if there are any close receivers	Ross Barber	Prior to subsidence effect		Yes

Risk Identification & Analysis				Residual Risk Evaluation						Risk Reduction Strategy				
R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
3.02.01, Consequential impacts - Pipeline-Infrastructure	Gas leak adjacent to other services (power line, Sydney Water potable main, Sewer main, Optic fibre cable) with potential to ignite gas or cause unacceptable consequential impacts	**Failure Mode:** High volume gas leak in vicinity of other infrastructure where there may be ignition sources **Causes:** 1. Proximity of infrastructure to pipeline and potential leak points 2. Prevailing conditions could allow leaking gas to accumulate and come in contact with potential ignition sources	Adjacent other service disruption to remove ignition sources until repaired **Worst Credible:** Power loss to essential community infrastructure leading to financial impacts Negative media attention	**Information & analysis:** 1.1. Subsidence assessment by MSEC predicts subsidence effects along pipeline 1.2. Engineering review of subsidence impacts on pipeline by Worley identifies pipe strength well in excess of loads imposed by conventional subsidence effects **Engineered Controls:** 2.1. Individual easements for other services **Mitigating Controls:** 3.1. Jemena's Emergency Management Plan provided for leaking and broken pipes, including emergency repairs involving insitu live or bypassed repair processes. **Subsidence Monitoring Controls:** 4.1. Weekly ground surveys and review of data, visual inspections and other subsidence data (e.g., Remembrance Drive, Main Southern Railway Early Warning Systems, early warning line for REA, continuously operating GNSS sensor) trigger responses well in advance of need to carry out preventative maintenance work. 4.2. Weekly meeting with asset owner **Triggered Responses:** 5.1. Gas detection surveys along pipeline pre-mining, post-mining and triggered by Subsidence TARP 5.2. Excavate & relieve stress on the pipeline over affected areas triggered by subsidence data reviews and TARP 5.3. Isolate and repair in relation to identified gas leaks Asset Monitoring Controls: 6.1. Pipe condition monitored by Jemena (Corrosion/ Cathodic Protection) 6.2. Jemena pipeline patrol (at least monthly), including use of gas detection equipment	R	2	E	3	L	1. Carry out pipe detection survey to determine exact location and depth of cover of the pipeline 2. Provide the Excavate & Expose Methodology and include in the Gas Pipeline Subsidence Management Plan and gain Jemena pre-approval for this methodology 3. Identify and develop all Access Agreements for carrying out pipeline maintenance 4. Jemena to clarify all notification and access requirements to carry out excavate/ expose/ repair pipe. 5. Engage with Jemena to determine emergency repair arrangements required for the timely response to leaking or ruptured pipelines	Ross Barber	Prior to subsidence effect		Yes
2.03.01, Impact to pipe due to non-conventional subsidence - Pipeline & sub-surface features	No additional risks identified associated with subsurface features - see Items 2.01.01 and 2.02.01	NA	NA	NA						NA	NA	NA	NA	NA
4.02.01, Control effectiveness - Gas detection inspections	See 1.02.01	NA	NA	NA						NA	NA	NA	NA	NA

Risk Identification & Analysis				Residual Risk Evaluation						Risk Reduction Strategy				
R#, Aspect - Consideration	Risk Issue	Failure Mode & Causes	Potential Impacts	Existing Controls	Loss Type	Consequence	Likelihood	Risk Rank	Risk Level	Additional Controls/ Further Actions (SAFERR)	By Who	By When	Historical Knowledge/ SFAIRP Comments	SFAIRP achieved (Yes/ No)
4.04.01, Control effectiveness - Monitoring pipeline	See 1.01.01, 1.02.01, 1.03.01, 2.01.01, 2.02.01	NA	NA	NA						NA	NA	NA	NA	NA
4.05.01, Control effectiveness - Pipeline isolation & repair	Isolation and repair method does not provide suitable timely response See 1.03.01	**Failure Mode:** LTA repairability of the pipe **Causes:** 1. LTA ready access 2. LTA availability of equipment to uncover and isolate pipe 3. LTA means to isolate 4. Hawthorn Rd valve doesn't work 5. PE pipeline squeeze method not suitable 6. Deteriorated condition of pipe not readily repairable without replacing long run of pipe	NA	NA						NA	NA	NA	NA	NA
4.05.02, Control effectiveness - Pipeline isolation & repair	Injury during repair See 1.03.01	**Failure Mode:** Gas ignition **Causes:** 1. Uncontrolled ignition sources 2. Larger leak triggered during repair 3. Unauthorised tampering	NA	NA						NA	NA	NA	NA	NA
4.06.01, Control effectiveness - Emergency management	See 1.03.01	NA	NA	NA						NA	NA	NA	NA	NA

Appendix E

Tahmoor Coking Coal Operations Risk Assessment Matrix

CONSEQUENCE [potential foreseeable outcome of the event]

	Health & Safety	Environment	Financial Impact	Image & Reputation / Community	Legal & Compliance
5 Catastrophic	• Multiple fatalities (5 or more fatalities in a single incident) • Multiple cases (5 or more) of Permanent Damage Injuries or Diseases that result in permanent disabilities in a single incident	• Unconfined and widespread • Environmental damage or effect (permanent; >10 years) • Requires major remediation	• >$600M investment return • >$100M operating profit • >$20M property damage	• Loss of multiple major customers or large proportion of sales contracts • Sustained campaign by one or more international NGOs resulting in physical impact on the assets or loss of ability to operate • Security incident resulting in multiple fatalities or major equipment damage • Formal expression of significant dissatisfaction by government • Grievance from internal or external stakeholder alleging human rights violation resulting in multiple fatalities	• Major litigation / prosecution at corporate level • Nationalisation / loss of licence to operate
4 Major	• Single incident resulting in: Less than 5 Fatalities • Permanent Damage Injury or Disease that results in a permanent disability-less than 5 cases in a single incident	• Long-term (2 to 10 years) impact • Requires significant remediation	• $60-600M investment return • $20-100M operating profit • $2-20M property damage	• Security/ stakeholder incident resulting in single loss of life or equipment damage • Grievance from internal or external stakeholder alleging human rights violation resulting in single fatality or serious injuries • Topic of broad societal concern and criticism • Negative media coverage at international level resulting in a Corporate statement within 24 hours • Investigation from government and/ or international (or high-profile) NGOs • Complaints from multiple "final" customers • Loss of major customer • Negative impact on share price	• Major litigation / prosecution at Department level
3 Moderate	• Lost Time Injury (LTI) • Lost Time Disease (LTD) • Permanent Disabling Injury (PDI) • Permanent Disabling Disease (PDD) • Single incident that results in multiple medical treatments	• Medium-term (<2 years) impact (typically within a year) • Requires moderate remediation	• $6-60M investment return • $2-20M operating profit • $200K-2M property damage	• Negative media coverage at national level over more than one day • Complaint from a "final" customer • Off-spec product • Local Stakeholder action resulting in national societal scrutiny	• Major litigation / prosecution at Operation level
2 Minor	• Medical Treatment Injury (MTI) • Medical Treatment Disease (MTD) • Restricted Work Injury (RWI) • Restricted Work Disease (RWD)	• Near source • Short-term impact (typically <week) • Requires minor remediation	• $600K-6M investment return • $200K-2M operating profit • $10-200K property damage	• Negative local/ regional media coverage • Complaint received from an internal or external stakeholder	• Regulation breaches resulting in fine or litigation
1 Negligible	• First Aid Injury (FAI) or Illness (not considered disease or disorder)	• Near source and confined • No lasting environmental damage or effect (typically <day) • Requires minor or no remediation	• <$600K investment return • <$200K operating profit • <$10K property damage	• Negligible media interest	• Regulation breaches without fine or litigation

LIKELIHOOD [of the event occurring with that consequence]

Basis of Rating	E - Rare	D - Unlikely	C - Possible	B - Likely	A – Almost Certain
LIFETIME OR PROJECT OR TRIAL OR FIXED TIME PERIOD OR NEW PROCESS / PLANT / R&D	Unlikely to occur during a lifetime OR Very unlikely to occur OR No known occurrences in broader worldwide industry	Could occur about once during a lifetime OR More likely NOT to occur than to occur OR Has occurred at least once in broader worldwide industry	Could occur more than once during a lifetime OR As likely to occur as not to occur OR Has occurred at least once in the mining / commodities trading industries	May occur about once per year OR More likely to occur than not occur OR Has occurred at least once within the business	May occur several times per year OR Expected to occur OR Has occurred several times within the business
5 Catastrophic	15 (M)	19 (H)	22 (H)	24 (H)	25 (H)
4 Major	10 (M)	14 (M)	18 (H)	21 (H)	23 (H)
3 Moderate	6 (L)	9 (M)	13 (M)	17 (H)	20 (H)
2 Minor	3 (L)	5 (L)	8 (M)	12 (M)	16 (M)
1 Negligible	1 (L)	2 (L)	4 (L)	7 (M)	11 (M)

Consequence Category	Consequence Type	Ownership	Action
Cat. 5	Catastrophic Hazard	Department / Functional / Operational / Asset Leadership	• Quantitative or semi-quantitative risk assessment required. • Capital expenditure will be justified to achieve ALARP ('As Low As Reasonably Practicable'). • Catastrophic Hazard Management Plans (CHMP) must be implemented where practical, Crisis Management Plans (CMP) tested and Catastrophic Event Recovery Plans (CERP) developed.
Cat. 4 (Health & Safety consequence)	Fatal Hazard	Department / Functional / Operational / Asset Leadership	• Fatal Hazard Protocols or appropriate management plans must be applied. • Capital expenditure will be justified to achieve ALARP.
Risk Rank	**Risk Rating**	**Ownership**	**Action**
17 to 25	High Risk	Department / Functional / Operational / Asset Leadership	• Install additional HARD and SOFT controls to achieve ALARP. • Capital expenditure will be justified to achieve ALARP.
7 to 16	Medium Risk	Operational / Asset Leadership	• Install additional HARD and SOFT controls if necessary to achieve ALARP. • Capital expenditure may be justified.
1 to 6	Low Risk	Operational / Asset Leadership	• Install additional controls if necessary to achieve ALARP. • Capital expenditure is not usually justified.

Contingency Plan to uncouple the 150mm Jemena Gas pipeline along Remembrance Drive, Bargo, from the ground in the event of a triggered response from longwall mining

Document Review Process

Name	Task	Signed	Dated
Graeme Robinson	Develop Contingency Plan	**G. Robinson**	**20 Mar 24**
Ross Barber	Review Contingency Plan	Ross Barber	**20 Mar 24**

Document Version Control

Version	Brief oversight of changes	Date
Draft	Initial Draft Report to RB for review	13 July 2022
Revision 1	Added Readiness and Contingency Plan	4 August 2022
Revision 2	Added amendments to suit comments	5 August
Revision 3	Added TMP Details	20 December 2022
Revision 4	Added amendments to suit comments	31 December 2022
Revision 5	Update "No dig zone" zone as requested by Jemena	9 August 2023
Revision 6	Update PM and Jemena Pipe Check requirement	17 August 2023
Revision 7	Update following Risk Assessment	1 November 2023
Revision 8	Added sketches to Section 4.3, Option 2.	20 March 2024

Table of contents

References

Mine Subsidence Impact, Jemena DN150 Steel Gas Pipe, Advisian (Worley Group), 18 August 2023.

Tahmoor Coal – LWs S1A-S6A Management Plan for Potential Impacts to Jemena Gas Infrastructure, Report No. MSEC1193 06, Rev B, 2024.

Risk Assessment on the Tahmoor South Longwall LW1A & LW2A Subsidence Impacts on the Jemena 150mm High Pressure Steel Gas Pipeline, HMSC, April 2022.

SIMEC Mining - Tahmoor Mine Longwall LWS3A to LWS7A, Subsidence Impacts to Jemena 150mm MP Gas Main, Revision 2, Risk Assessment Report, 27 October 2023.

1 BACKGROUND

Tahmoor Colliery is located approximately 80 kilometres southwest of Sydney in the township of Tahmoor NSW and is managed and operated by SIMEC. The mine produces Hard Coking Coal for export and domestic use in steel production.

Tahmoor Coal has previously mined 32 longwalls to the south and west of the mine's current location and at the time of this report has completed the mining of all longwalls in the Northern and Western Domain that affected the Main Southern Railway (MSR).

Tahmoor Coal have mining development approval to extract coal south of the mine site towards Bargo. Tahmoor South A and B Series will ensure coal mining potential for the next 10 years.

There are 6 short longwalls in the A series block with 4-year extraction program as shown in Figure 1.

At the time of updating this uncoupling Plan, LW S1A had completed extraction on 4 July 2023 and Longwall S2A had commenced extraction operations on 2 August 2023.

The current schedule for Longwall sequencing is all A series first with program dates as follows:

- LW S1A – October 2022 to July 2023 (9 months) - Finished
- LW S2A – August 2023 to April 2024 (8 months) - Commenced
- LW S3A – May 2024 to September 2024 (7 months)
- LW S4A – October 2024 to June 2025 (8 months)
- LW S5A – July 2025 to February 2026 (7 months)
- LW S6A – March 2026 to November 2026 (8 months)
- LW S7A – TBC

2 SUBSIDENCE

2.1 DEPTH OF COVER

Tahmoor Coal mine the Bulli Seam that is generally shallower in Tahmoor South compared to Tahmoor North. The depth of cover is initially 400m above LW1A, then reduces to 375m above LW5A. The depth of cover above LW32 was approx. 480m.

2.2 EXTRACTION HEIGHT

The extraction height is 2.1m to 2.2m in Tahmoor South, similar to Tahmoor North at approx. 2.1m.

2.3 PREDICTED SUBSIDENCE

Predicted subsidence, tilt, curvature and strain is therefore slightly higher compared to Tahmoor North similar levels to Appin Area 7.

Predicted total subsidence can be seen in Table 1.

Longwall	Maximum predicted subsidence (mm)	Maximum predicted tilt along alignment (mm/m)	Maximum predicted tilt across alignment (mm/m)	Maximum predicted hogging curvature in any direction (km^{-1})	Maximum predicted sagging curvature in any direction (km^{-1})
LW S1A	325	2.5	5.0	0.06	0.06
LW S2A	1000	5.0	5.5	0.08	0.20
LW S3A	1200	6.5	5.5	0.10	0.21
LW S4A	1300	6.0	6.0	0.12	0.21
LW S5A	1350	6.5	5.5	0.12	0.21
LW S6A	1375	7.5	5.5	0.12	0.21
LW S7A	1400	7.5	5.5	0.12	0.21

Table 1 – Predicted Total Conventional Subsidence (courtesy MSEC)

3 Gas Pipeline Structural Analysis

Tahmoor Coal requested Advisian (Worley Group) to carry out an investigation of the mine subsidence impact on the Jemena's DN150 steel HP gas main at Bargo, NSW, which will be undermined by LW S1A to S6A as shown in Figure 1 using the subsidence forecasts provided by MSEC as mentioned in Section 1.4 of this submission. The ground movement associated with the mined longwalls can potentially affect the structural integrity of the pipe.

The main objectives of the Advisian investigation were to:

- Perform stress analysis of the buried steel gas main under the design operating condition and subjected to the predicted subsidence ground movement;
- Assess the pipe stress against the code (AS/NZS 4652.2: 2018) requirements;
- Provide potential mitigation solutions if the pipe stress exceeds the code requirement;
- Provide input such as trigger levels in the Mine Plan which is being prepared by MSEC; and
- Provide technical advice to the Gas Team for risk assessment purposes.

The Advisian Report presented, details the methodology, inputs, assumptions, results, discussion, conclusions and recommendations that were included in the Risk Assessment (RA) workshop and report and in the Action List in Appendix A of the RA.

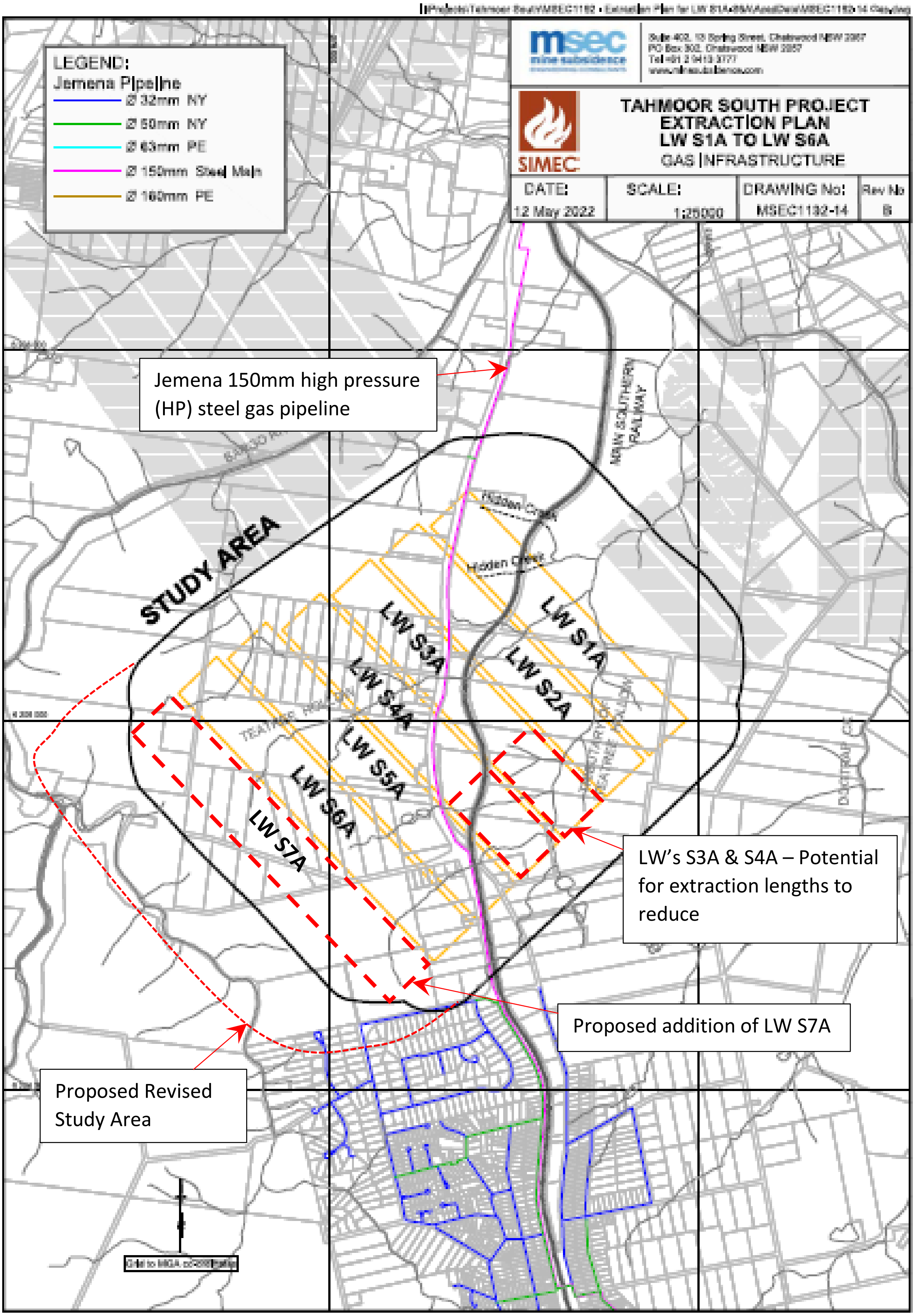


Figure 1 – Gas Pipeline Location

4 Risk Assessment

4.1 Longwalls S1A and S2A

In April 2022, Tahmoor Coal conducted a risk assessment to review potential subsidence impacts of Tahmoor's South Project (TSP) longwalls LW S1A and LW S2A on the Jemena 150mm high pressure (HP) steel gas pipeline. The gas pipeline supplies gas to the over 1000 customers in the townships of Tahmoor and Picton in the Macarthur Region of New South Wales.

The gas pipeline is located in the Remembrance Drive, road reserve. The easement passes above LW S1A and LW S2A towards the northern end of the blocks, with only the north-western corner of LW S1A being directly below the gas pipeline (See Figure 1). Extraction of LW S1A commenced from the southern (opposite) end of the block in October 2022. The gas pipeline also passes over subsequent longwall blocks LW S3A – LW S6A, however the focus of this risk assessment and Management Plan will only cover LW S1A and LW S2A.

Tahmoor has mined coal by longwall methods from the Southern Coalfields since 1980 and in that time has maintained a harmonious co-existence with the communities of Tahmoor to the south-east, Thirlmere to the west and Picton to the north. Subsidence from longwall mining has impacted private dwellings, community and other infrastructure, including the Main Southern Railway Line and associated bridges, culvert, embankments and cuttings.

A Jemena 160mm Polyethylene (PE) gas pipeline running along Remembrance Drive and Bridge Street (above LW32) and the South Picton industrial area.

All subsidence is monitored commensurate with the criticality of impact and a range of mitigation measures has been devised to provide every means of ensuring that only tolerable and sustainable impacts occur. Mitigation measures may include uncovering the gas pipeline to uncouple it from the subsidence induced ground stresses.

The overriding objective of the risk assessment was to engage with the asset owner (Jemena) and subject specialists (subsidence and pipelines) to identify and assess the risks and to develop mitigation strategies, where necessary, to prevent So Far As Is Reasonably Practicable (SFAIRP) unacceptable or unsustainable subsidence impacts to the pipeline and associated consequential outcomes, e.g., to public safety.

The outcome of the risk assessment was as follows:

- In total, thirteen (13) risks were identified by the participants. Of these risks:
    - Nil (0) were rated as HIGH risks
    - Two (2, 15%) were rated with a residual risk rating of MEDIUM.
    - Eleven (11, 85%) were rated as LOW risks by the group

All risks were rated on Moderate or Minor consequence and all risks were rated as having Unlikely or Rare likelihood.

Five (5, 38%) risks were assessed to have the potential to result in Public Safety impacts based on Maximum Foreseeable Consequence (MFC/ envisaged worst case), the residual risk ratings were determined to have Financial or Reputational impacts.

There were a number of actions arising from the risk assessment that were listed in the Action Plan provided in Appendix B of the Risk Assessment Report.

4.2 Longwalls S3A to S7A

On 18 October 2023, a second risk assessment was undertaken for Tahmoor Coking Coal Operations (Tahmoor), on potential subsidence impacts of Tahmoor's South Project longwalls LWS3A through to LWS7A on the Jemena 150mm medium pressure (MP) steel gas pipeline.

The location of local gas infrastructure within and adjacent to the Study Area are shown in Fig. 1. There is a 150 mm diameter steel gas main, which runs along Remembrance Drive and distributes gas to the townships north of Bargo, including Tahmoor, Thirlmere and Picton and services over 1000 customers.

The total length of gas pipelines within the Study Area is approximately 3.2 km.

The source take-off point for the 150 mm steel gas main is from the Moomba-Sydney Gas Pipeline is located on Hawthorne Road outside the Study Area. The local Jemena gas infrastructure servicing the Bargo township has a take-off point at the same location and at Wellers Road.

This 150mm steel gas pipe passes through the Bargo township, mainly along Remembrance Drive. The steel pipe was constructed in 1994, it was designed and constructed in accordance with the requirements of SA NSW.

This Sub-Systems Considered in the Risk Assessment Plan included the following comprehensive scenarios that have been included in this Plan:

1. Impact to pipe in plateau areas due to conventional and non-conventional subsidence;
2. Impact to pipe at Caloola Road (within the embankment) due to conventional and non-conventional subsidence from Longwall S3A;
3. Impact to pipe at Remembrance Drive cutting near longwall S3A due to conventional and non-conventional subsidence;
4. Impact to pipe at un-named creek crossing above longwall S5A (along base of embankment) due to conventional and non-conventional subsidence;
5. Impact to pipe at Yarran Road creek crossing (within the embankment) due to conventional and non-conventional subsidence from Longwall S6A;
6. Impact to pipe at Wellers Road creek crossing (within the embankment) due to conventional and non-conventional subsidence from Longwall S7A.

Uncoupling options for managing impact on pipe stresses are included in *Section 7.4 Gas Main Excavation/Uncoupling Options*.

A number of recommendations were made that were included in the Assessment Worksheets (Risk Rank Order) in response to the hazards relating to ground strains and curvatures that effect pipe stresses that exceed pipeline allowable or actual yield strength resulting in a gas leak. The risks in order of severity included:

Develop a Jemena Pipeline Management Plan for Longwalls S3A to S7A, including:

- Monitoring Plan
- Mitigation Plan
- Response Plan (TARP)

Actions proposed, subject to engineering advice and Jemena design approval, were to implement and develop a mitigation plan that includes:

4.2.1 Realignment of Tight Bends at Caloola Road

Option 1.

Develop a mitigation plan that includes a Jemena approved design for a flexible (Polyethylene Pipe – EP) installation at the alignment bends at Caloola Road (within the embankment) for a length of approx. 50 m that will replace the existing steel pipe that is affected by tight radius curves that will impose a restriction on the flexibility of the existing pipe to respond favourably to the influence that will be imposed by mining related ground strain. The revised design will need to include reduced depth of cover along the pipe embankment to 750mm depth as shown in Figures 2, 3 and 4.

The design will include the ability for a 'live' cut-over from the existing steel pipe to the PE pipe in a very short timeframe that will minimise customer disruptions. The two junctions will incorporate 3-way valves that will be boxed in ploughable material as mechanical protection until the effects of mining have ceased.

The Jemena/Zinfra design will incorporate this arrangement to model and run the S3A conventional mine subsidence and Teatree Hollow closure to check the stresses in both the steel pipe and PE100 pipe are acceptable and fine tune the alignment, in particular at the 3-way tees, and the rest of the design.

The design will be delivered by Jemena for installation by Zinfra as their nominated construction contractor.

The PE pipe will need to follow AS4645.3 Section 3.3 to determine the design factor and the SDR.

Tahmoor Coal will arrange survey and 3rd modelling of the existing Pipe and the Embankment to facilitate the flexible pipe route connection.

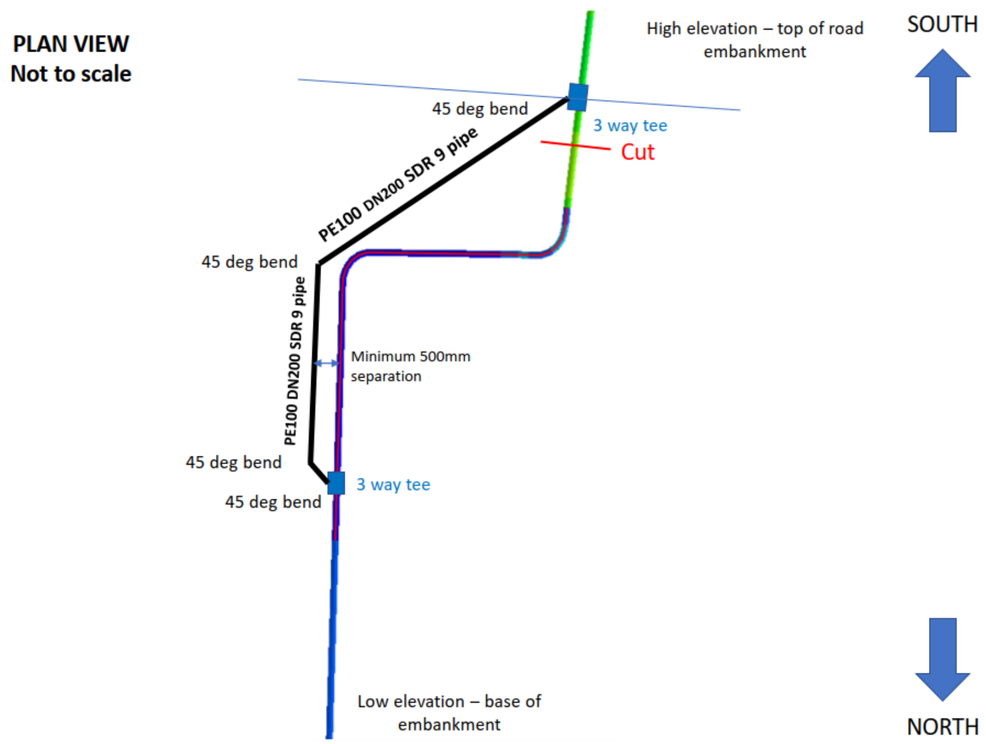


Figure 2 – Proposed PE Pipe Bypass Alignment

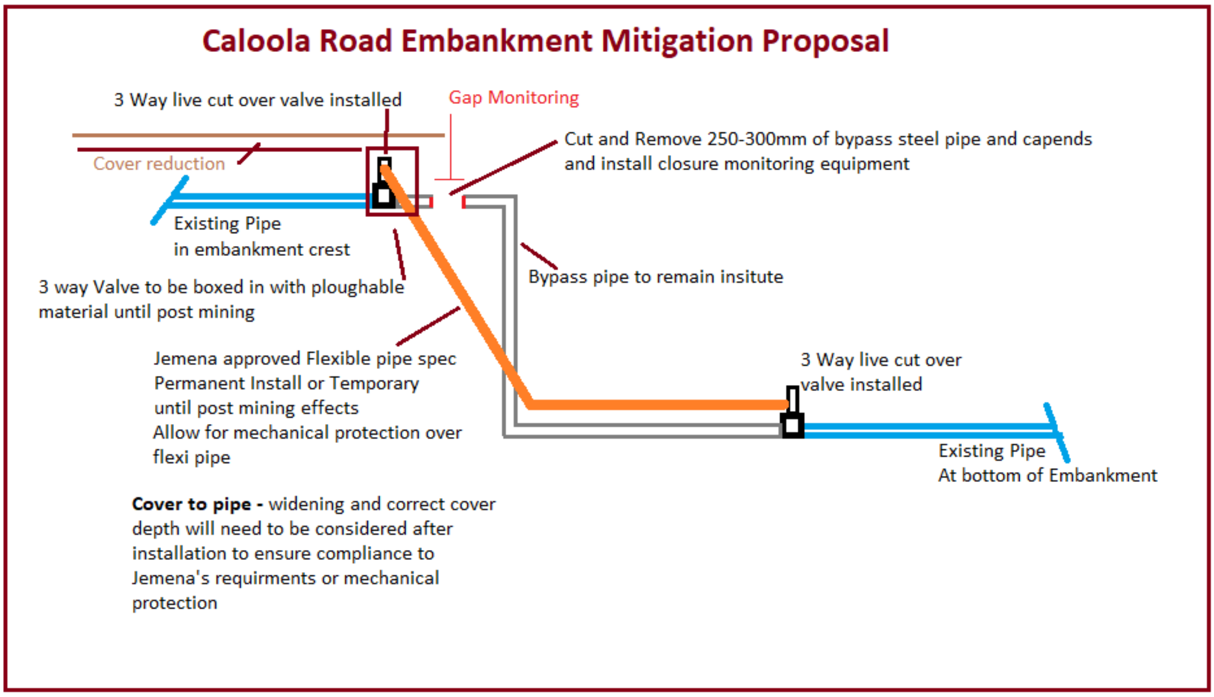


Figure 3 – Plane of Proposed Connection Details

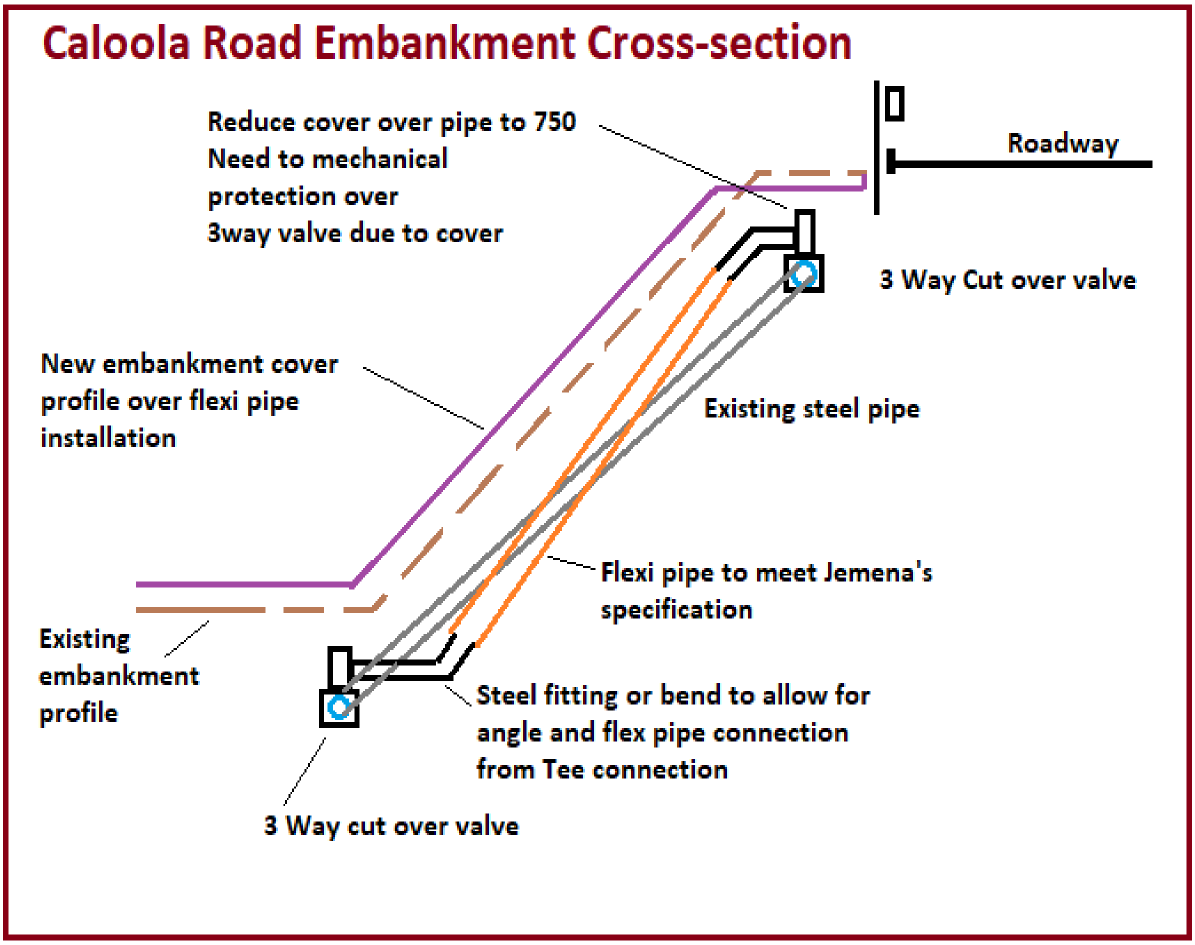


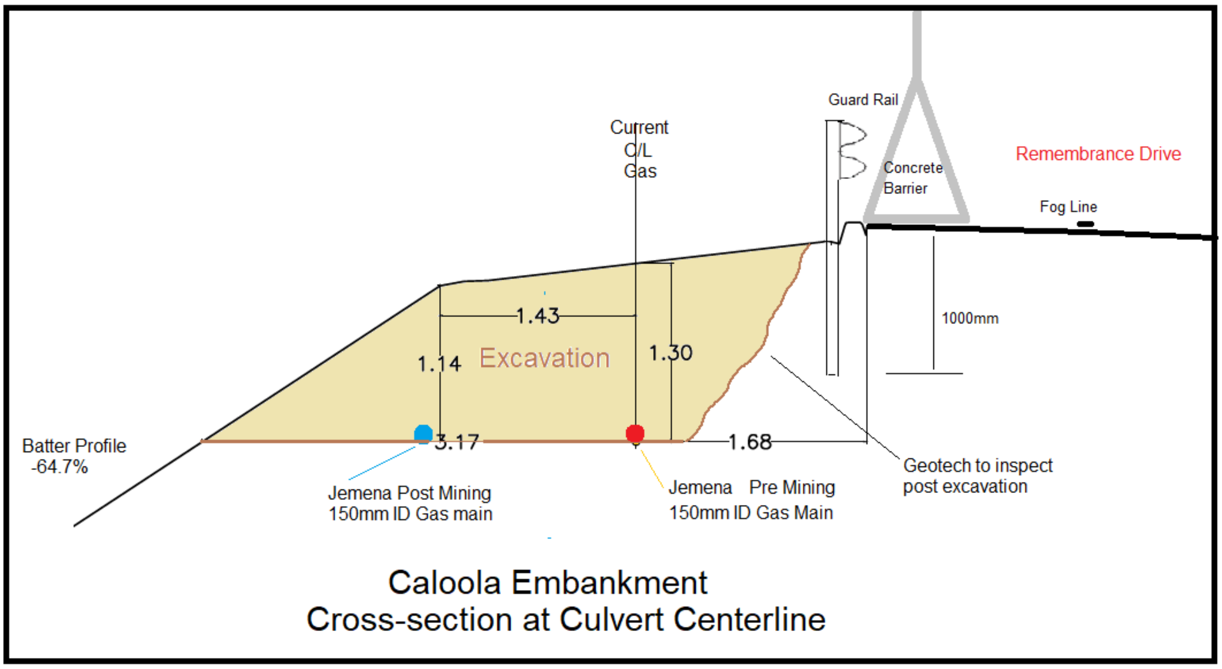
Figure 4 – Section of Proposed Connection Details

Or

Option 2.

Option 2 was to follow the existing uncoupling methodology and with recent potential sideways movement will now require widening of the embankment to support the potential pipe position post closure advise of 150mm and develop a Mitigation Plan to include the widening. This option is to include a review of existing roadway guardrail stability and mitigation controls.

The diagrams below show uncoupling proposal for Caloola Embankment.



Both options will include the review and implementation most appropriate to Caloola Road pipeline embankment monitoring programme. e.g. additional survey points and / or live monitoring.

4.3 UPDATE UNCOUPLING METHODOLOGY

An updated uncoupling methodology was recommended following the 'bump' in the roadway near 3030 remembrance drive petrol station Marker 46/47 during LW S1A:

- Update the Uncoupling methodology to include exposure and re-instating of the pipeline during active subsidence to reduce period of temporary speed restriction at Caloola Road embankment, Remembrance Drive.
- Update the Uncoupling methodology to include maintaining the creek bed and reducing pipe exposure to water flow.
- Update the Uncoupling Methodology to include exposure and re-instatement of the pipeline during active subsidence to reduce periods of temporary speed restriction at within the road surface along Remembrance Drive.

5 BACKGROUND

Steel gas pipelines of similar and larger diameter have been successfully mined directly beneath in the past in the Southern Coalfield (McGill, 2007) and Newcastle Coalfield (Robinson, 2007). Being of relatively small diameter, the pipe is expected to withstand considerable deformation if required.

The engineering analysis advises that the results indicate that the pipeline can tolerate the predicted conventional subsidence movements due to the extraction of LW's S3a-S7a.

Typical bending as a result of mine subsidence on the gas pipeline can be seen in Figure 5.

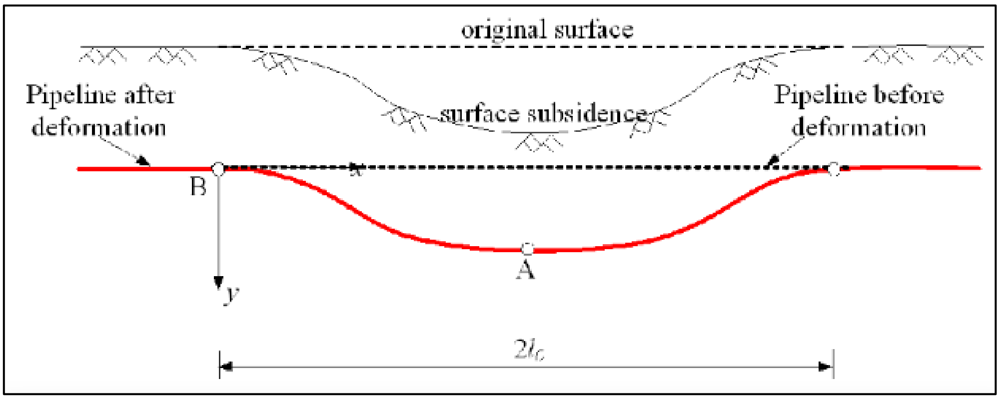


Figure 5 – Typical potential mine subsidence impact on pipe

Tahmoor Coal has developed a Subsidence Management Plan in consultation with Jemena to manage potential impacts on gas infrastructure within the study area. The current Management Plan covers only LW S1a and LW S2a. The Management Plan for LW S3a to S7a is being develop.

The Jemena Management Plan describes the monitoring and mitigation measures proposed to manage the gas main during active subsidence.

This uncoupling methodology is one of the proposed responses within the Jemena Management Plan.

A ground strain trigger of 5mm/m is a conservative limit that is proposed to enact this methodology to mitigate the steel gas main during subsidence induce ground movement.

To prevent any impact on the pipeline, 'uncoupling' the pipe infrastructure within the trench to relieve strain is a proven way to mitigate the effects of mining subsidence induce ground movement (see Fig. 6).

If observed ground strains or severe ground deformations are observed to develop during mining, the pipe can be exposed and adjusted to decouple the pipe from the differential ground movements. Pre-planned traffic control and security measures would be required to be implemented if these works are required.

If the steel gas pipeline cannot be managed within the uncoupled trench or the subsidence induced ground strains exceed the integrity limits of the pipe, then Jemena will need to complete a normal maintenance repair process and undertake a "live pipe" repair or replacement of the impacted section.

Figure 6 – Pipe exposed or 'uncoupled' to eliminate potential ground strain

Tahmoor Coal has previously developed Subsidence Management Plans in consultation with Jemena for the existing Longwalls 22 to 32 and LW W1-W4 at Tahmoor Mine to manage potential impacts on local gas infrastructure at Tahmoor.

A similar Subsidence Management Plan is being developed in consultation with Jemena to manage potential impacts on the local gas infrastructure within the Study Area. With the implementation of these management strategies, it would be expected that the local gas infrastructure could be maintained in a safe and serviceable condition during and after the extraction of the proposed longwalls.

With an appropriate management plan in place, it is considered that potential impacts on the local gas infrastructure can be managed during the extraction of the proposed longwalls, even if actual subsidence movements are greater than the predictions or substantial non-conventional movements occur.

6 PURPOSE AND SCOPE OF WORKS

Tahmoor Coal proposes to undertake longwall mining in Bargo beneath a 150 mm diameter steel gas main, which runs along Remembrance Drive and distributes gas to the townships north of Bargo, including Tahmoor, Thirlmere and Picton (see Fig. 1).

The 150mm HP gas main is owned and operated by Jemena. The proposed longwall mining by Tahmoor Coal has the potential to interact with and affect the integrity of the gas main. Tahmoor Coal propose to manage the integrity of the gas main during this uncoupling stage, on behalf of Jemena in accordance with the outcome of the risk assessments.

The purpose of this Contingency Plan is to provide confidence to the asset owner (Jemena) that their asset will be managed during the mining operations in accordance with the requirements of the risk assessments that is to provide the Excavate & Expose Methodology in this Plan for inclusion in the Tahmoor Coal – LWs S1A-S2A and LWS3A-S7A Management Plans (MP) for Potential Impacts to Jemena Gas Infrastructure, Report No. MSEC1348, Dec 2023, and gain Jemena pre-approval for this methodology.

The primary objectives of the MP are to establish procedures to identify, measure, control, mitigate and repair potential impacts that might occur on surface and sub-surface in the vicinity of the gas pipe that may be potentially or directly affected by operations as a result of the mining.

The objectives of the MP will be developed to: -

- Maintain the safe and serviceable operation of all affected Jemena gas infrastructure, with public and workplace safety paramount.
- Avoid, as far as practicable, any impediment to Jemena's business including impact on gas infrastructure and/or supply to their customers.
- Prevent significant disruption and inconvenience to Jemena's operations and minimise the maintenance effort required as a result of the impact of the mining during the course of the longwall mining operations adjacent to the gas pipeline.
- Avoid or minimise disruption and inconvenience to the Jemena and their customers.
- Monitor ground movements and the condition of surface infrastructure in the vicinity of the gas pipe prior to mining, during mining and for a period post mining as advised by the Tahmoor Coal's Management Group.
- Initiate action to mitigate or remedy potential impacts that are expected to occur during longwall mining affecting the gas main along the pipe route.
- Provide a plan of action in the event that the impacts of mine subsidence are greater than those that are predicted (contingency plan).
- Provide a forum to report, discuss and record impacts to the gas pipe infrastructure; and

- Establish lines of communication, emergency contacts, procedures and protocols.

7 METHODOLOGY

7.1 LOCATION OF EXISTING SERVICES

Tahmoor Coal have completed a comprehensive service locating and investigation process over the A series Study area on the gas main. The gas pipe has been located every 20ms, depth to top of pipe and survey co-ordinates taken. The pipe has also been located to the road fog line and a 1.5m survey offset peg installed to monitor ground movement has been installed at 20m intervals.

Slit trenching has positively located the gas service to confirm the construction techniques and a photo library report has been generated. The slit trenching showed that the gas pipe was not laid within a sand barrier as per the construction standards.

The service locating also revealed that the pipe is not consistent with the DBYD data in that the pipe has several angle changes that were not documented.

All other public utilities crossing or within a 3m Zone of the centre line or crossing of the gas main have also been located and survey data recorded.

The gas pipeline for LW S1a and LW S2a are within the road reserve and well clear of the road verge and trafficked area.

The gas pipeline for LW S3a – S7a is located in more challenging locations (than for LW S1A and S2A, including:

- Top of the road embankment
- Within a creek crossing
- Within a large narrow rock cutting
- Within or under the road verge

These areas will require a higher level of engagement with Council for road traffic and waterways if mitigation is required and the uncoupling plan initiated.

7.2 SETUP WORKSITE AREA

A worksite Notice Board will be placed at the site compound access boundary to define the site contact and, to ensure no unannounced access. Site Contact and emergency numbers will be clearly written on the worksite signage.

Tahmoor Coal's site Contractor, Bloor Rail (or similar) will ensure that teams are briefed on site safety, the daily works referenced against the work method statements and the stated controls.

Site Establishment will include the delineation of the location site with the installation of a min 1.8 - 2m high x 30-50m long F-type barrier with gawk screen high hoarding between the excavation and roadway to provide positive separation and worksite delineation to establish a visual separation between the works and the roadway (See Fig. 7). The barrier will be installed to ensure safe flow of road traffic during the extended uncoupling process.

Figure 7 - Barrier with gawk screen high hoarding

The remainder of the proposed work sites will be segregated from public access utilising a standard, temporary ATF fencing to secure the excavation site and traffic control for vehicles and pedestrians will be provided as required.

Figure 8 shows the proposed compound that may be installed adjacent to Remembrance Drive where the gas pipe runs parallel and close to the road alignment.

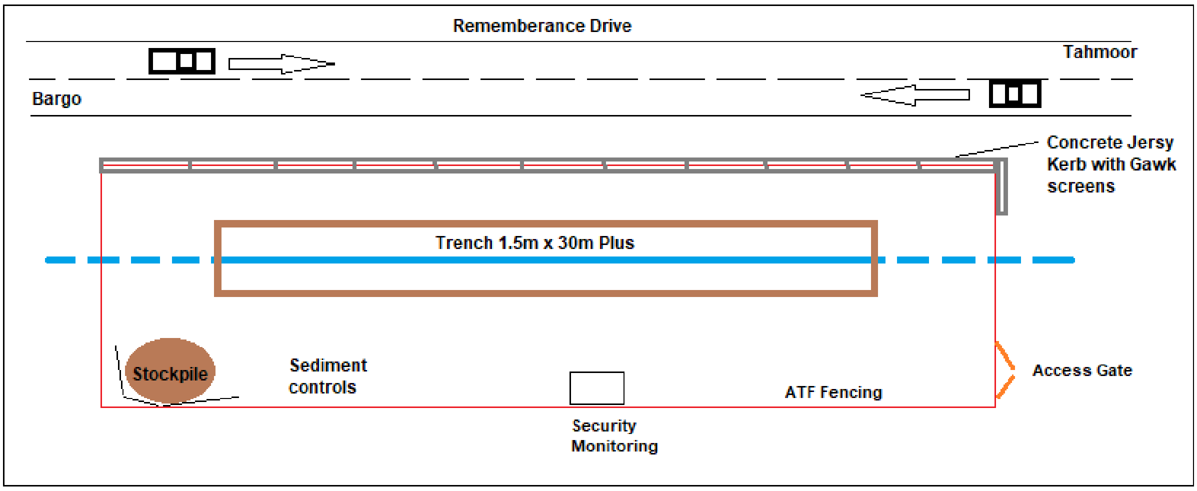


Figure 8 – Remembrance Drive Proposed Compound

7.3 Traffic Management Plan (TMP)

Road safety will be managed by an accredited Traffic Control Contractor, *Platinum Traffic Services* (or similar), who have been engaged by Tahmoor Coal, to ensure road safety and the safety of workers and public during the project.

Tahmoor Coal will manage and co-ordinate the S138 Wollondilly Council permit for the works.

Platinum Traffic Services have proposed Traffic Management Plans for several scenarios to manage inspection and any maintenance and management issues or requirements for the gas main along Remembrance Drive (Old Hume Highway), Bargo, that may present themselves in accordance with the Management Plan during the course of mining.

The three scenarios proposed to be implemented along Remembrance Drive are as follows:

1. Preparation for Work Zone – Site 1 On large road easement: two protection options for larger work that will require Speed Signs to be repeated.
2. Preparation for Work Zone – Site 2 On embankment near the guard rail: two protection options for larger work that will require Speed Signs to be repeated.
3. Preparation for Work Zone – Site 3 In the Cess Drain within the cutting: two protection options for larger work that will require Speed Signs to be repeated.

A copy of the TMP is included as Appendix A.

7.4 Gas main excavations/Uncoupling Options

All excavation and exposure of the gas service will be undertaken under the supervision of specialist Jemena Permit Issuing officers and/or standby officer in accordance with Jemena safety procedures for excavations on live high-pressure gas mains.

The uncoupling methodology has been submitted to Jemena for approval via the Jemena 3rd Party interface portal.

In accordance with the Advisian Report, the present analysis assumed the pipe has a constant depth of cover of 750 mm. The actual depth of the pipe is variable from 0.9 to 1.3m and logged via the service locating report as can be seen in Fig. 9.

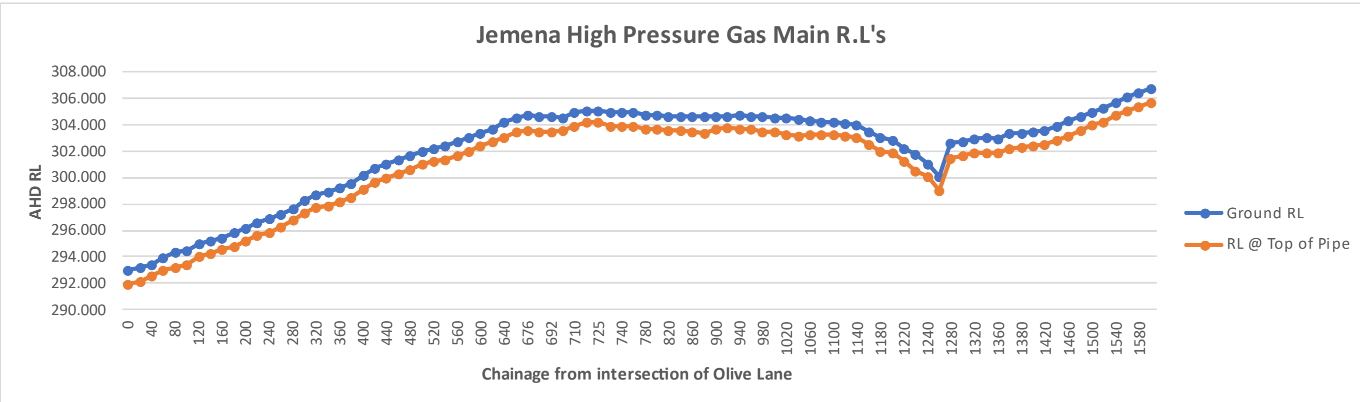


Figure 9 – Gas Main Depths

If there are faults/dykes that intersect the pipe alignment, relative movement across these discontinuities or weak zones may occur due to stress redistribution in the rock as coal extraction progresses. This could cause an abrupt ground deformation affecting the pipe stress.

As a result of the geological mapping by PSM, no features were observed in the defined area along Remembrance Drive.

The present analysis assumed the pipe is defect free and no wall thickness loss. It will be prudent to check with Jemena regarding the current condition of the gas main.

All other public utilities crossing or within 3ms Zone of the centre line of the gas main have also been located and survey data recorded.

No excavation works will be performed without the Supervision of a Jemena Standby officer.

7.5 Non Destructive Digging (NDD) Zone Excavation:

The Jemena Standby Officer will need to be present for NDD and all other excavation works.

Prior to any excavation the 150mm Gas main will be positively located at 10m intervals by NDD operator. This is needed to define the height of the pipe and then through controlled survey regulate the mechanical excavation over the pipe. From the initial investigation the pipe depth will vary between 900mm to 1100m to top of pipe.

7.6 Bulk Excavation Zone:

The initial bulk excavation zone to the 300mm No dig Zone clearance and total width of the designed trench will be completed by a 14-t excavator (or similar).

The bulk excavation level will be governed by the Site Surveyors / Project Supervisor and monitored by the Jemena officer.

The proposed excavator will be slew restricted to ensure separation to the road. The proposed temporary hoarding (F-type barrier and gawk screen) will provide a visual separation between excavation and the corridor fencing.

The excavation works will be carried out by Tahmoor Coal's nominated contractor, Bloor Rail (or similar).

The bulk excavation segment will continue and stop if any protective marker tape is reached in this area.

7.7 Final Mechanical Zone (trenched either side of the pipe):

On completion of the initial bulk excavation – the sides of the gas main will be located at the 10m locations, and the actual sides of the pipe marked out with paint on the ground and maintained. A second line on either side of the pipe in a different colour will define the 300mm No Dig Zone.

The final mechanical excavation element will be the 2 bulk out trenches either side of the pipe maintaining a 300mm No Dig Zone around the pipe.

These 2 trenches will be over excavated to a depth of approximately 250mm below the pipe and be the area where manually excavated material in the no dig zone is removed from.

The pipe needs to be uncoupled progressively along the excavation so that the excavator is not needing to move over or rework over an expose pipe. The segmented length will be determined by the reach of the machine and operator requirements. Slew restriction needs to be activated where necessary.

7.8 MANUAL EXCAVATION ZONE

All final excavation around the gas main within the 300mm No Dig Zone will occur by hand digging with hand tools. No impact with the pipe should occur only easing loose of the pipes original back fill as required. The material should be moved towards the bulk excavation trench for mechanical removal.

A 100mm clearance excavation under the pipe is also required without impact to the pipe.

The pipe will be supported every 5ms by a sandbag on either side and pushed under to support the pipe as the excavation continues.

Non-destructive (vacuum) excavation methods will also be used where necessary to assist in the No Dig Zone. – Primarily under the pipe

The depth of excavation proposed is up to 100mm below the existing pipe level and therefore the trench will be less than 1500mm in depth.

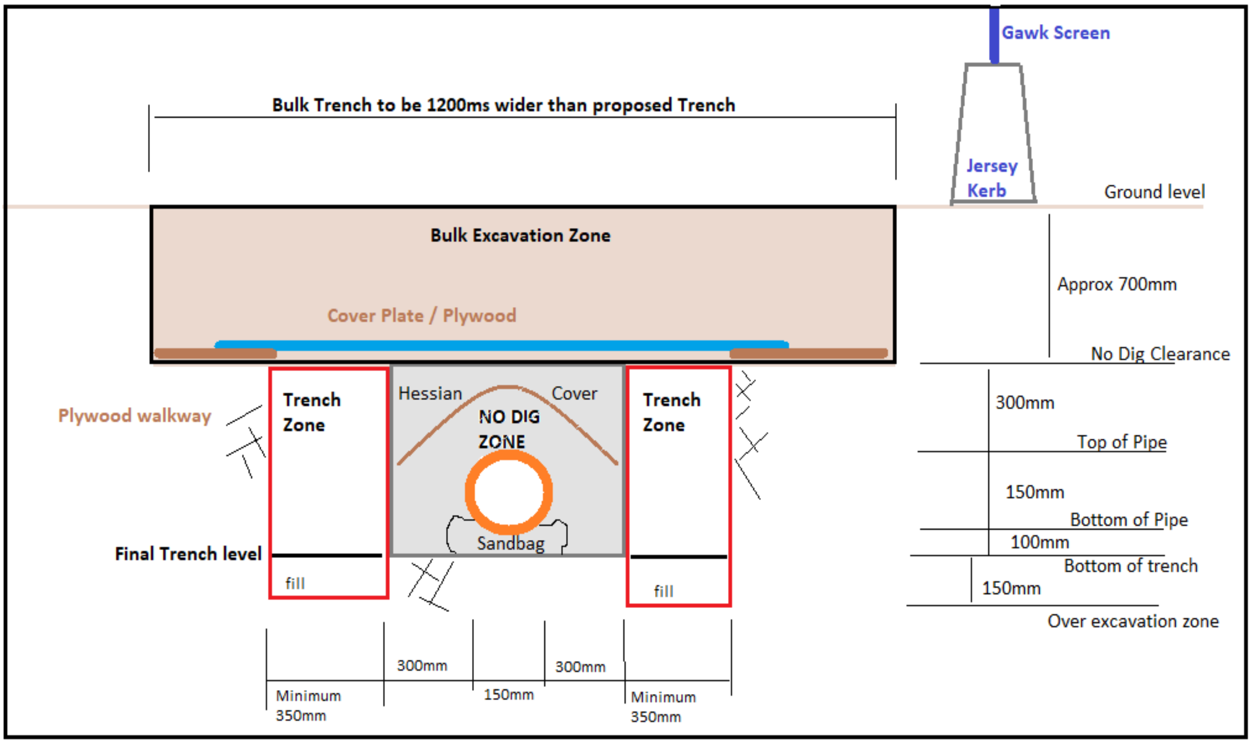
With the proposed benching via the bulk excavation zone no shoring is proposed.

Shoring Boxes or further benching maybe considered excavation depth reaches the soil holding ability or 1500mm.

The excavation will be monitored by a Geotechnical Engineering resource if required.

The actual final excavations will be approx. 1500 to 1800m mm wide and will vary in depth depending on location along the route to a level exposing the invert of the pipe (see Figs. 10 and 11).

Cut Plywood Foot plates or similar will be installed along the top of the bench as shown and plywood sheeting or similar cover placed over the opening when no works are being carried out for safety and general protection of the trench and the pipe within.



Cross-section of Proposed Trench

Figure 10 – Typical Trench Cross-Section

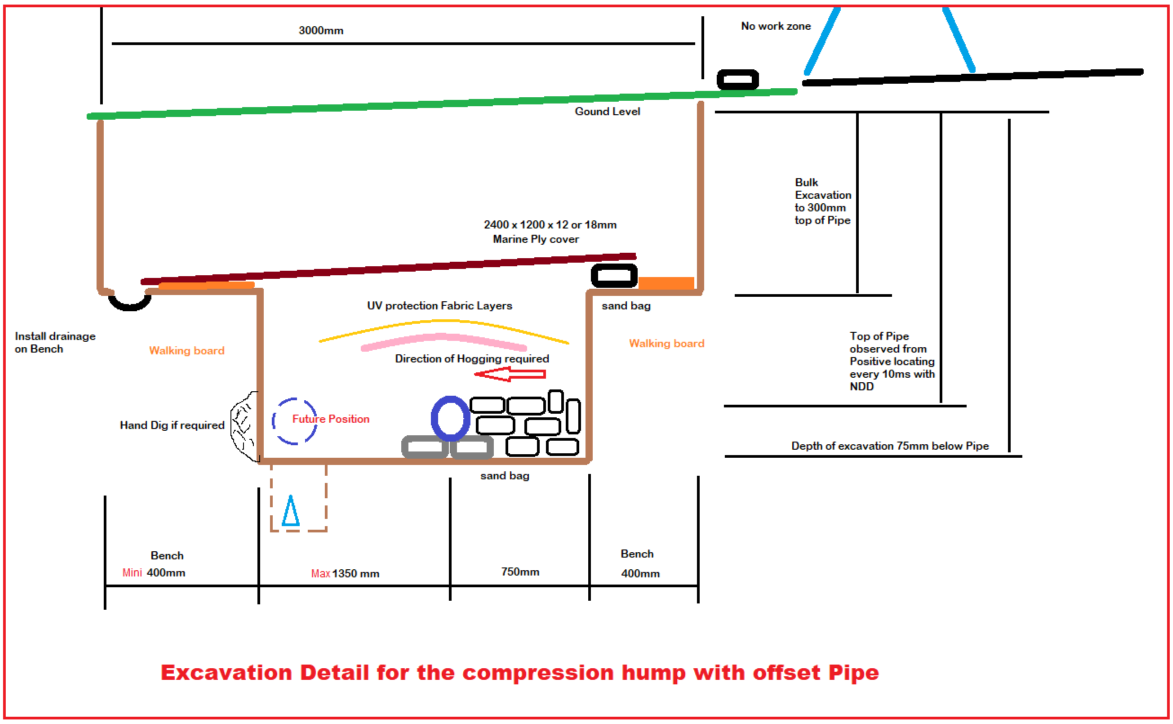


Figure 11 – Typical Excavation Details for Compression Hump with offset pipe

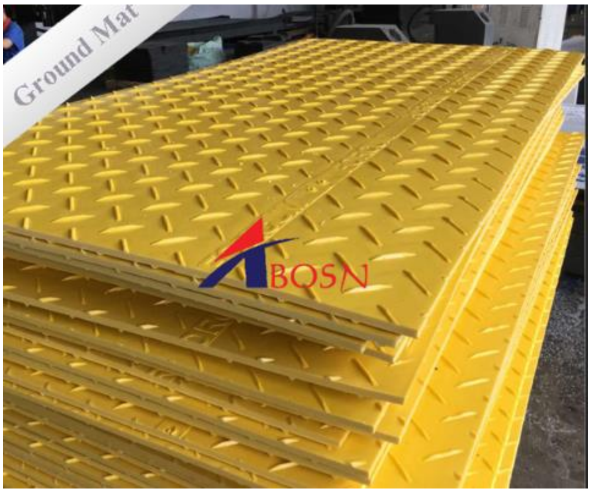


Figure 12 - Plastic road plates or ‘ground matting’

The pipe depth and lateral location in relation to Remembrance Drive varies along the length of the pipe route (see Fig. 10). The following typical cross sections, or scenarios may be applied when uncoupling the pipe adjacent to the road corridor.

8 Detail Pipe Inspection

During the pipe excavation the Jemena Standby Officer will complete a detail inspection of the pipe to check the current condition of the pipe and the existing alignment.

Tahmoor Coal will also complete a detailed video inspection of the pipe by drone and or remote camera.

9 VARIABLE SCENARIOS ALONG THE PIPE ROUTE

Specific locations and scope of works associated with each scenario will be detailed prior to commencement of any work.

Sketches of all anticipated scenarios are included as follows below:

- Figure 13 - Typical Scenario for pipe in cutting in Road Verge
- Figure 14 - Typical Scenario for pipe adjacent to Road Verge
- Figure 15 - Typical Scenario for pipe through embankment
- Figure 16 - Typical Scenario for pipe away from the roadway
- Figure 17 - Typical Scenario for pipe under the Road Verge
- Figure 18 - Typical Scenario for pipe in embankment
- Figure 19 - Typical Scenario for gas pipe under creek crossing

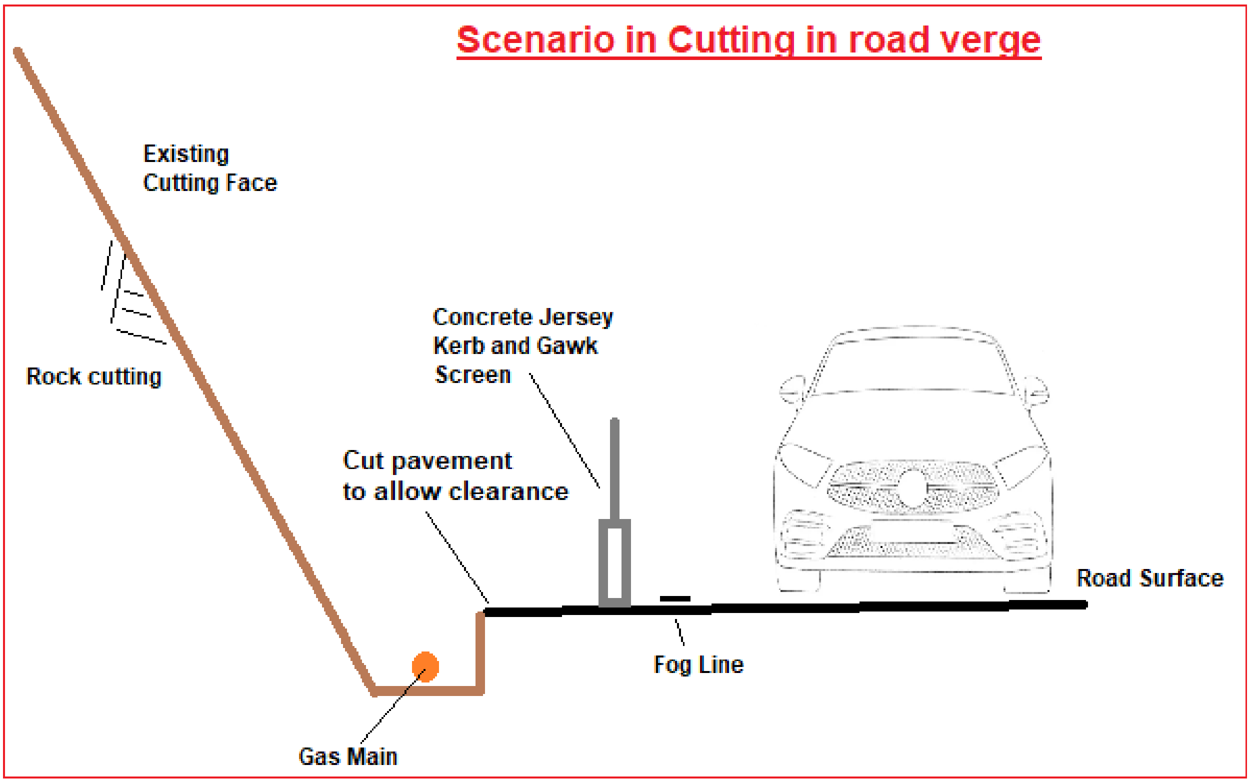


Figure 13 - Typical Scenario for pipe in cutting in Road Verge

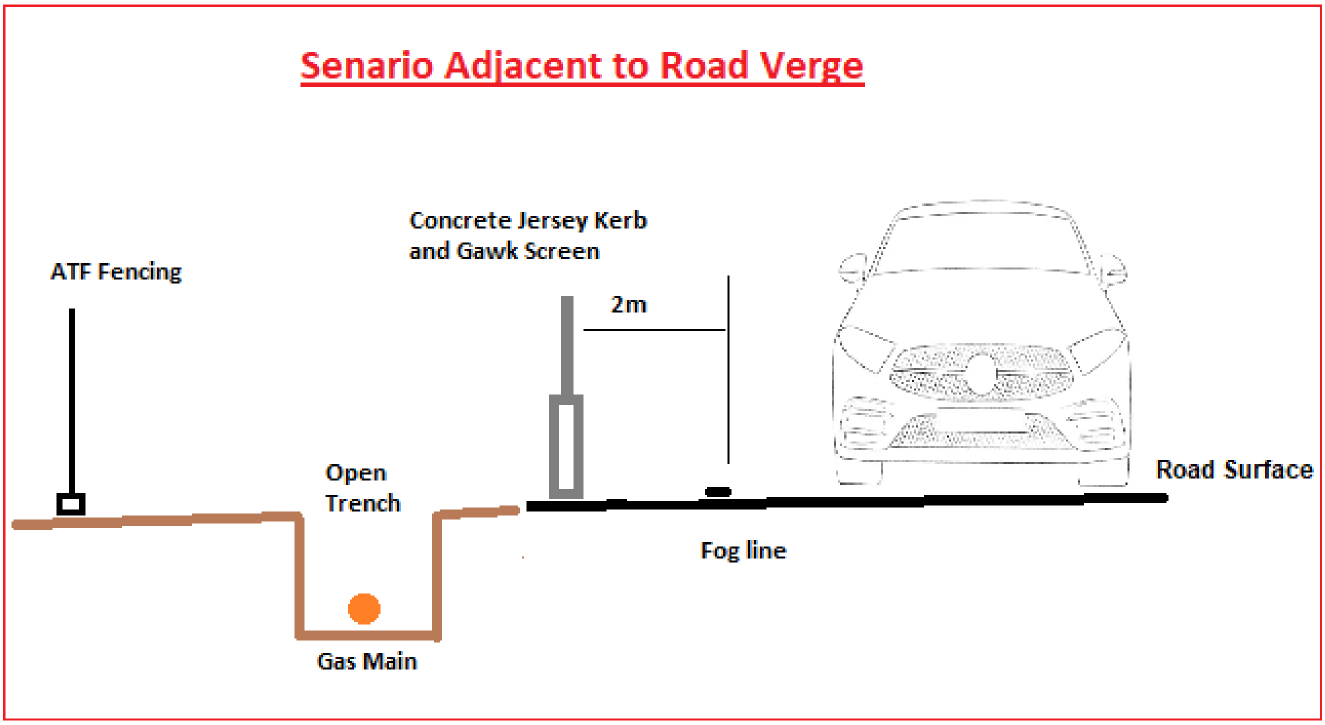


Figure 14 - Typical Scenario for pipe adjacent to Road Verge

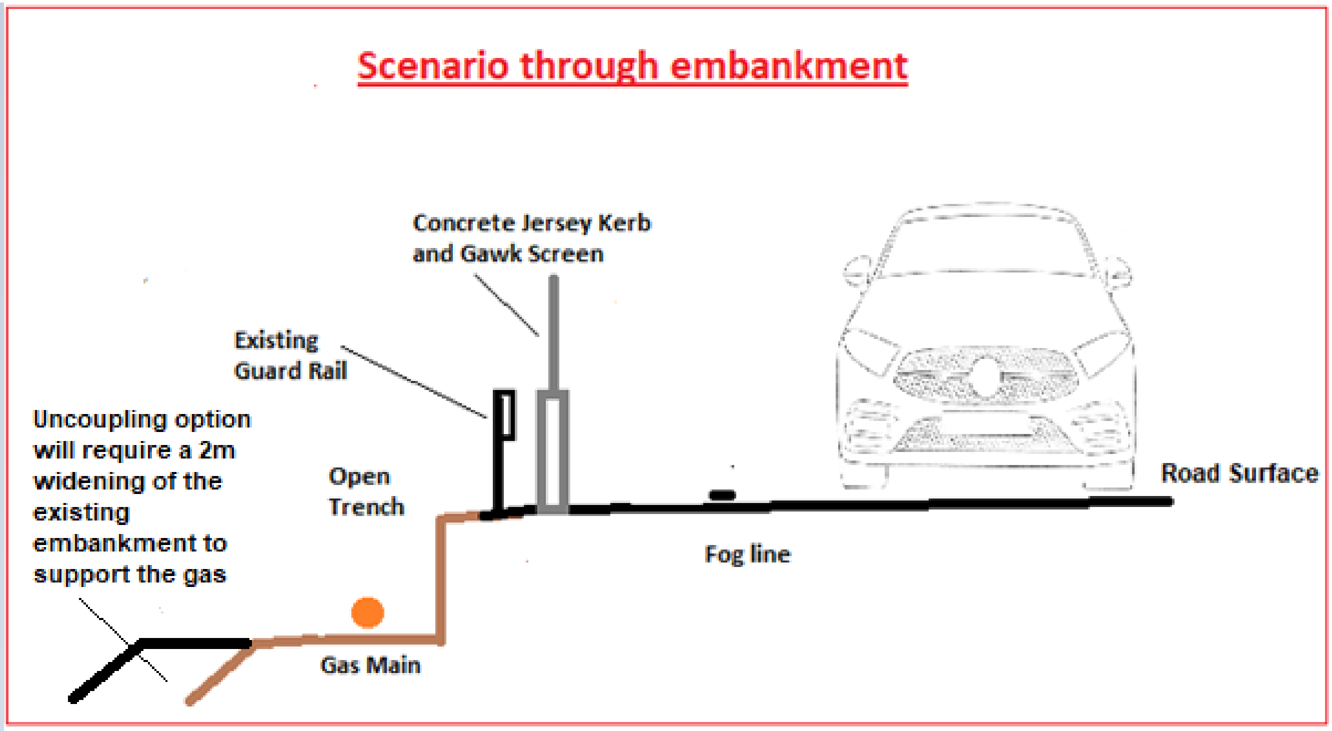


Figure 15 - Typical Scenario for pipe through embankment (showing widening if Option 1 is not approved)

SIMEC

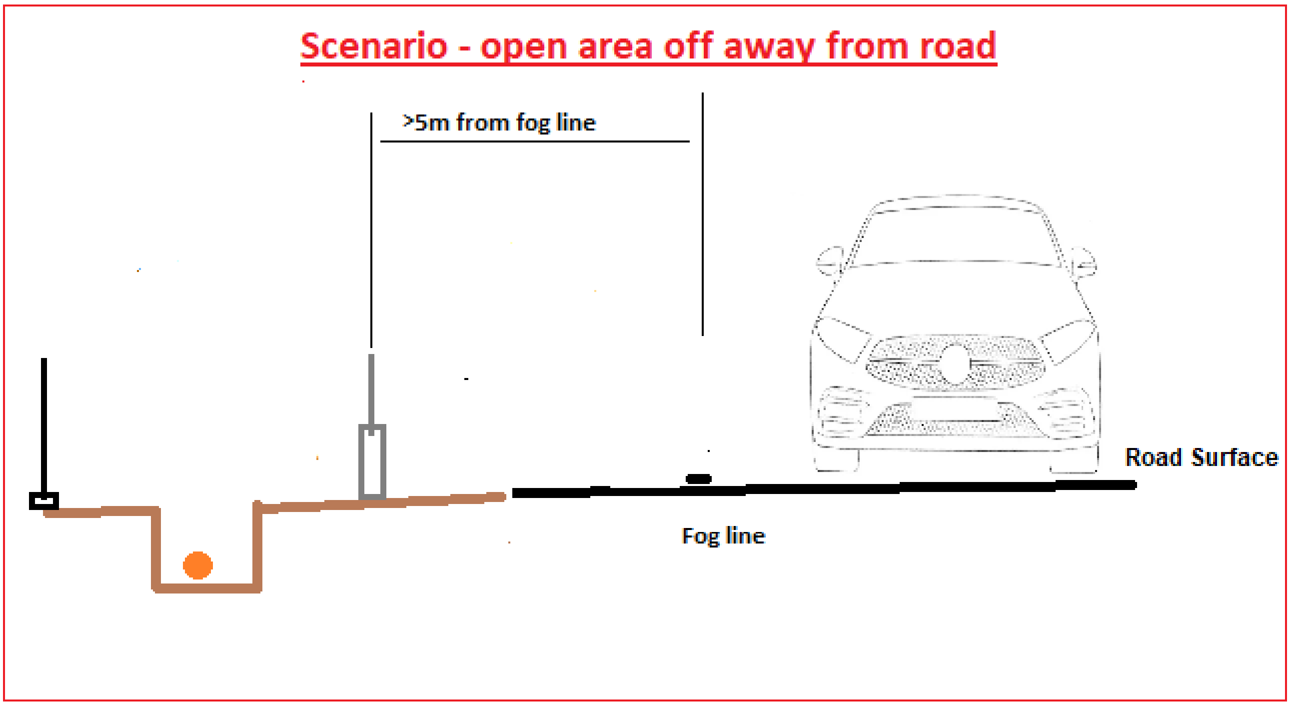


Figure 16 - Typical Scenario for pipe away from the roadway

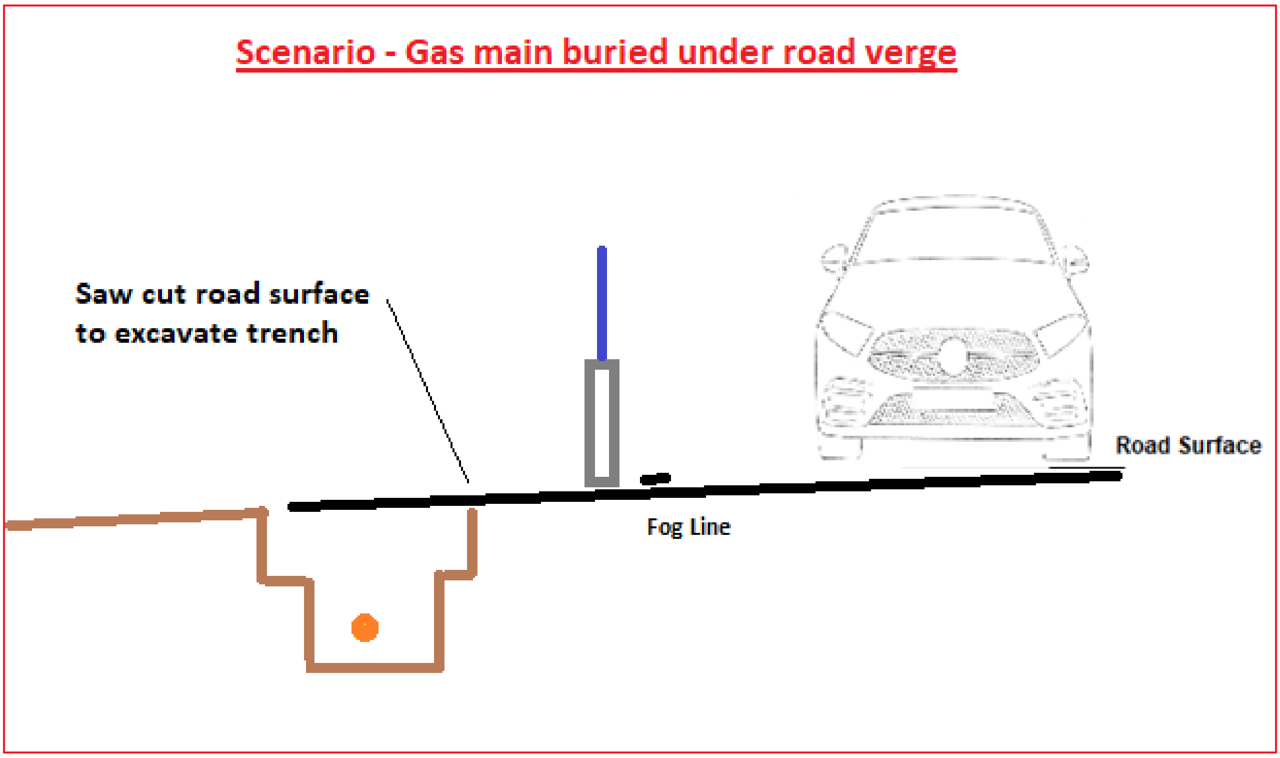


Figure 17 - Typical Scenario for pipe under the Road Verge

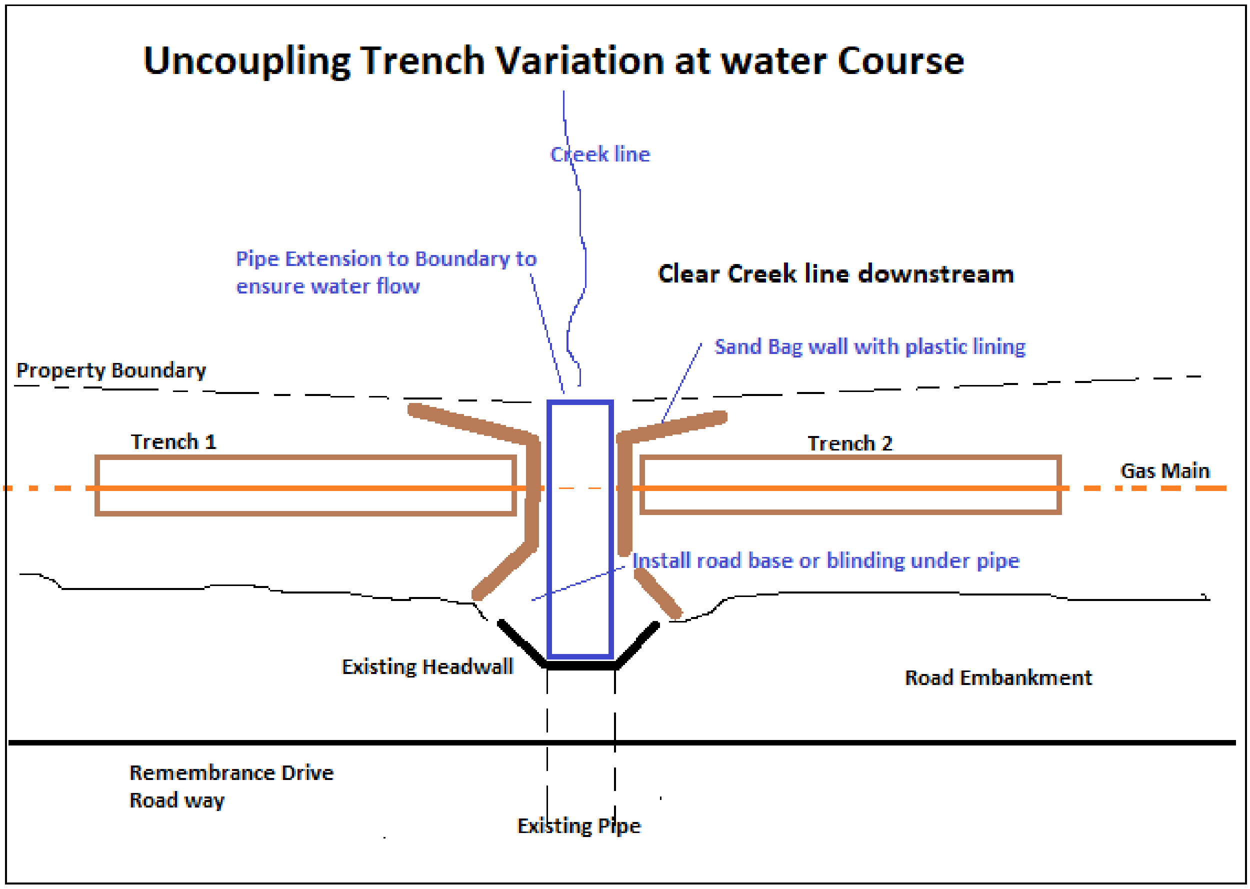


Figure 18 - Typical Scenario for gas pipe under creek crossing

Typical Scenario for pipe in embankment (Fig. 15) may be varied to enable the embankment to be widened if Option 1 is not approved to accommodate any potential horizontal movement of the pipe as a result of excessive ground movement, especially on curved sections of pipe or in sections as described in 4.2.1 Realignment of Tight Bends at Caloola Road.

Typical Scenario for gas pipe under creek crossing (Fig. 18) may vary depending on the creek crossing requirements in an effort to avoid water in the trench floating the pipe. There may be a need to slow down the water velocity by damming the creek with sandbags (or similar) and to install a submersible pump, if required, if the water level gets too high, with remote activation based on water level trigger.

10 Site Monitoring

Site security will be paramount during the entire project period. Priority sites along the route will be fitted security systems, either off the shelf or purpose built, and 24/7 power supplies provided to both pumping stations and security systems with backup power and alarms for the length of the project.

The site will be inspected and made secure daily. A remote monitoring system will be installed to protect the site when not in use and automated alarms will trigger SMS to those nominated on the callout register.

The approach safety signage and systems will also be inspected daily and rectified if necessary.

Status Reports with be distributed to the team during the course of mining in accordance with the Management Plan.

10.1 SEDIMENT CONTROL

Where necessary along the length of the pipe where excavation is necessary, sediment control fences will be installed (see Fig. 20) and any other environmental considerations will be carried out as required in accordance with Council requirements and the Management Plan.

Figure 20 – Typical Sediment Control Fence

10.2 WATER MANAGEMENT

Site water management has been considered during the project planning phase and Tahmoor Coal's Rail Contractor (Bloor Rail) will have the necessary pumps and pipes on standby in case of inclement weather to allow trenches to be kept dry and serviceable during construction and during impact from mine subsidence (see Fig. 21). A small plastic pit is proposed to be installed at the lowest point.

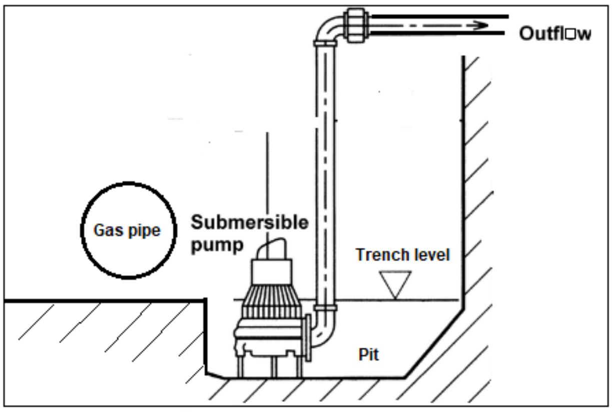


Figure 21 – Typical Trench Pumping Arrangement

10.3 TRENCH BACKFILLING

On completion of each segment of works, the excavation will be backfilled to Jemena backfill specifications.

Bedding sand would be installed to a minimum depth of cover of 150 millimetres above the top of the gas main.

New Marker tape to warn of the high-pressure gas main beneath will be laid at the 400mm clearance to top of pipe.

The trench will be backfilled with suitability reclaimed material and compacted in layers using an excavator.

10.4 SITE DEMOBILISATION

On completion of the proposed works, the project will demobilise and relocate to the next site on the programme. The site will be cleaned up with the removal of the ATF fencing and finally the hoarding will be removed.

11 WORKING ON OR AROUND A GAS MAIN ADJACENT TO A PUBLIC ROAD KEY ACTIVITIES, RISKS AND CONTROLS.

All work in the road easement will be performed under the controls listed below:

- Pre-work briefings will be undertaken daily. These briefings will outline the key risks and mitigation strategies for the tasks being undertaken.

Risk Assessment:
Key Activities, Potential Risks that may affect Infrastructure and Controls – **Cat 1**, **Cat 2**, **Cat 3**

Activities	Rick Category	Risk	Mitigation
Working within proximity of a major public road	**Category 3** Potential to encroach road carriage way.	Encroaching vehicle Impact Zone with Plant Workers exposed to road traffic	Develop and Implement a Road Traffic Management Plan (see Appendix A) Ensure all worksite personnel attend a Pre-works or prestart site briefing Ensure all work is performed under the supervision of Site Supervisor Develop a location specific worksite access strategy for the total length of the gas main between Wellers Road and Olive Lane Tahmoor Coal to ensure that they have Concrete jersey kerbs available to relocate to remembrance Drive when required Install concrete Barriers and Gawk screen to separate between traffic and worksite Tahmoor's works contractor (Bloor Rail) to ensure that excavator operates parallel to the road with slew restriction activated on the roadside. All material to be stored or levelled on site and away from trench Ensure all appropriate road signage is permanently in place.
Excavation on and around 150mm Gas Pipeline	**Category 3** Potential to come in contact gas pipeline with plant	Excavator makes contact with and damage 150mm gas pipeline when uncoupling from ground	Road Traffic Management Plan when plant is operating in proximity of live road Onsite Prestart and worksite signage Develop detail methodology to uncouple the pipe from the ground in a trench

Risk Assessment: Key Activities, Potential Risks that may affect Infrastructure and Controls – Cat 1, Cat 2, Cat 3			
Activities	**Rick Category**	**Risk**	**Mitigation**
			Ensure that all excavation is conducted under the supervision of an assigned Jemena standby Officer Ensure Jemena approved the Tahmoor Coal uncoupling methodology Tahmoor Coal ensure that Jemena carry the required pipe components to make a repair Tahmoor Coal obtain and brief their contractor (Bloorail) on the approved uncoupling methodology Tahmoor Coals contractor to have non-destructive resources available to expose the pipe every 10 m along the trench area and then make 300mm clearance lines on the ground to ensure no excavator can make contact with 150mm pipe Excavator to only remove soil to a clearance depth of 300 mm above the pipe Tahmoor's Contractor is to hand dig and relocate to the plant clearance 300 mm from 150m Pipe Slow plant movements during excavation and slewing to ensure greater plan control Onsite Prestart and worksite signage
Excavation on and around 150mm Gas Pipeline	Category 2 Potential to come in contact with gas	Workers causes impact to 150mm gas pipeline during uncoupling.	Tahmoor's Contractor to ensure that the 300 mm soil barrier clearance is maintained and is not excavated by plant. Tahmoor's contractor is to ensure that the soil removed from around the pipe is hand excavated with non-impact tools – dragging soil to the side of the trench for mechanical excavation Excavation under the pipe with hand tools Onsite Prestart and worksite signage
Open Trench with exposed 150mm gas main	**Category 3**	Unauthorised access to open gas infrastructure and construction site	Concrete barriers with gawk screen to be installed on the Remembrance Drive side of the excavation (see Figs. 5 and 6) Install ATP fencing with double clamps top and bottom. Supervisor to ensure construction site is made secure at the end of each shift Site to be checked at least 3 times Worksite signage

Risk Assessment: Key Activities, Potential Risks that may affect Infrastructure and Controls – Cat 1, Cat 2, Cat 3			
Activities	**Rick Category**	**Risk**	**Mitigation**
			Hire 24/7 monitoring tower to ensure site coverage Install security guard onsite at night-time in exposed locations if required Minimise uncoupling timeframe and re-bury the pipe as soon as possible.
Excavation on and around 150mm Gas Pipeline	Category 2 Potential to come in contact with gas	Exposure to latent Gas build up in excavation during trenching for unknown leak	Complete a Gas line leakage survey prior to Longwall mining. Jemena to advise of any existing defects in the existing pipeline prior to longwall mining. Tahmoor's contractor is to ensure that work stops if any worker advises the smell of Gas when in proximity of trench. Tahmoor's contractor to ensure that they are monitoring gas in the trench during excavation and when working in trench. No exposed flames or smoking within proximity of uncoupled pipe.
Open Trench Excavation	Category 2 – Potential to slip trip fall	Potential to slip and fall into trench or edge of trench collapse's	Ensure that the excavated material is removed from site and maintain safe distance to trench. Install trafficable plastic edge plates along the trench to ensure stable trench walls. Provide designated access points to trench. Cover trench when possible with plywood sheeting to prevent accidental or unlawful access to the trench and extreme weather conditions. Where possible divert water away from trench or activate pumps to empty trench in inclement weather. Install drainage outlet drains or pits if possible to keep trench dry.
Open trench with open access to 150m Pipeline	Category 2 – Potential for the pipe to be exposed to weather conditions	Increase in pipe stress from sun exposed to uncouple gas pipe	Install suitable shade covering over the trench to ensure minimal sunlight exposure during the day. Place hessian covering directly over the pipe and plywood sheeting across the trench to protect and to ensure no fall issues on site.
Open trench with 150mm gas main subject to high ground strains	**Category 3** Potential increased angle or bend in pipe	gas main to move or snake in trench area causes bend or cracking in pipe	Develop a pipe management plan that ensures that the uncoupled pipe is managed supported and restrained within the open trench at all times

12 Readiness and Contingency Plan

Based on the above information, SIMEC Management Group considered and selected engineering and management controls in accordance with WHS laws as contingency measures to enable readiness for any circumstance that arise from subsidence impacts on the pipeline.

12.1 Engineering Controls

The below engineering controls listed are all readily available industry items that can be purchased or hired within 7 to 14 days of notification of a high ground strain event. Early indication of increased ground strains will be through the weekly ground survey of the pipeline and the parallel rail survey line. Thus, this will allow time to precure the items to site.

Plant and equipment will be ordered and stored in the compound including but not limited to:

- Site huts for personnel and security staff if required.
- Earthmoving plant such as excavator, dump truck, hand tools and equipment
- Dewatering equipment, pumps, pipes, etc.
- Material stockpiles (gravel, road base, sand, etc)
- Sandbags
- Hessian, shade-cloth, plywood/steel sheeting
- Trafficable plastic edge plates
- Concrete barriers with gawk screens
- Spare signage
- Lighting
- ATP fencing and man-proof security fencing for boundary fence repairs.
- Security cameras
- Soil barriers

The awareness of the provision of these control mechanisms reduces the risk of damage to the pipe or danger to the public by reducing the response time to undertake contingency response measures in the event that monitoring detects the early signs of distress to the pipe or trench.

There is substantial time to detect early, monitor and respond to mining-induced differential subsidence movements during mining, if required. These experiences support the findings of the engineering assessments.

12.2 Administrative Controls

The following Administrative Controls were identified and selected that will put in place procedures on site to minimise the potential of impacts on the safety of the gas pipeline and/or public safety:

- Implementation of a Monitoring Plan and Trigger Action Response Plan (TARP). This control reduces the risk of pipe instability by detecting early the development of potential adverse subsidence movements and changes in the condition of the ground around the pipeline, so that contingency response measures can be implemented before impacts on the safety and serviceability develop.
- Visual inspections by SIMEC Contractor during periods of extreme wet weather. The SIMEC Contractor will attend site to inspect the pipeline in response to a forecast of extreme wet weather or if monitoring detects a build-up of stress along the pipeline. If severe impacts are observed to be developing along the pipeline, the SIMEC Contractor can make the necessary

arrangements to uncouple the pipe (if not already done) to reduce impacts or make arrangements to de-water the site and make safe during inclement weather.

- Tahmoor Coal may consider installing remote monitoring when the pipe has been uncoupled to enhance the pipe management process.
- An In-trench pipe management procedure will be developed by Advisian (Worley Group) to ensure that the pipe stresses are managed until subsidence induce ground strain effects cease.
- Advisian will complete periodic checks on the pipe to ensure that the adopted procedure is managing the pipe in the trench successfully.

Engineering assessments indicate that while mine subsidence movements could result in the gradual development of impacts on the pipeline, instability may develop over a short duration if the pipeline trench is exposed/uncoupled and is saturated. There may be a need to impose Traffic Controls have to minimise any risks to public using the adjacent roadway.

13 Emergency & Key Contacts

Name	Position	Contact Number
Emergency Services	Not Applicable	000
Camden Public Hospital	Not Applicable	(02) 4634 3000
Jemena 24/7	Faults and Emergencies	131 909
Ross Barber	SIMEC Project Manager	0419 466 143
Daryl Kay	MSEC	0416 191 304
Chris Bloor	Bloor Rail – Proposed Contractor	0422 807 231
Andrew Walker	Jemena Engineer - Distribution, Engineering Support	02 9867 8346
Ryan Juhyun Son	Zinfra Project Manager	0474 798 749
Mike Nelson	Council Rep	02 46779580
David Ho	Advisian (Worley Group)	0413 498 266

APPENDIX A – TRAFFIC MANAGEMENT PLAN

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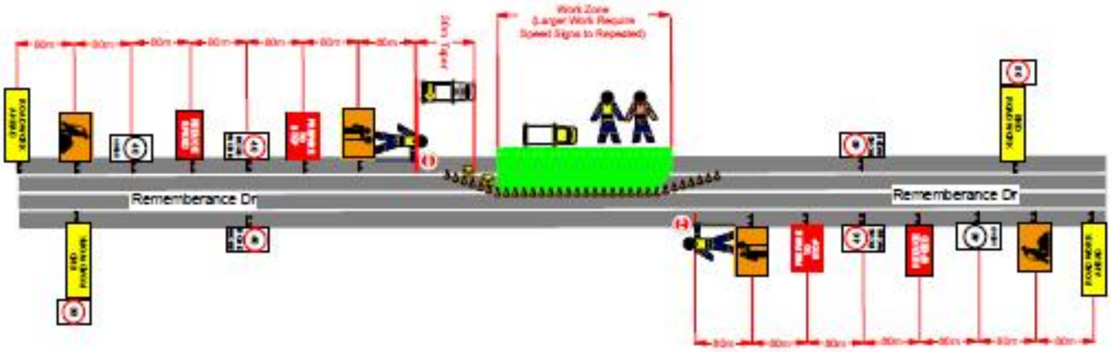
Remembrance Driveway, Tahmoor NSW 2573
Easement



Notes:

1: Local constraints may not allow signage and devices to be placed in accordance with this TCP. Signs and devices are to be positioned in accordance with tolerances shown in the TCAWS Manual Version 6.0 2020.

2: This TCP is suitable for short term works.

3: This TCP is based on RMS TCP recommendations from the TCAWS Manual Version 6.0 2020.

4: If not already noted, The existing speed limit is to be noted on this plan.

5: The value of speed limits displayed shall match the speed zone approval.

6: Ensure all approval requirements are met prior to commencing set up.

7: Cover all conflicting road signage where required.

8: If required cone spacing is to be no greater than 12m centres.

9: The site MUST comply with the TCAWS (Traffic Control at Worksites) Manual Version 6.0 2020.

Amendments:

All amendments to the TCP must be clearly documented on this plan. Amendments can only be made by the Traffic Control Supervisor holding a current PWZTMP card in consultation with the relevant project works supervisor.

Name:____________________

PWZTMP Card Number:____________

Exp Date:____________________

Date:__________ Sign:__________

Reason for modification:____________

LEGEND

- Platinum vehicle x2
- Work Zone
- Cones
- Team Leader x1
- Traffic Controller x2

Client Contact: Ross Barber

Contact Number: 0419 466 143

Revisions

No	By	Date	Description	Appr
1	BVR	7/11/2022	Issued for Implementation	[illegible]
2				
3				
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Original Size A3 | This TCP is not to scale

Job Location: Remembrance Driveway, Tahmoor NSW 2573

Work Activity: Pipe Excavation

Client: SIMEC

Drawing Number: TCP-BVR2201

Drawn By: Brendon Van Ryn | Prepare Work Zone Number :TCT1020784 | Signed:

Approved By: Thomas McKeir | Prepare Work Zone Number :TCT 0072729 | Signed:

Disclaimer:

SIMEC

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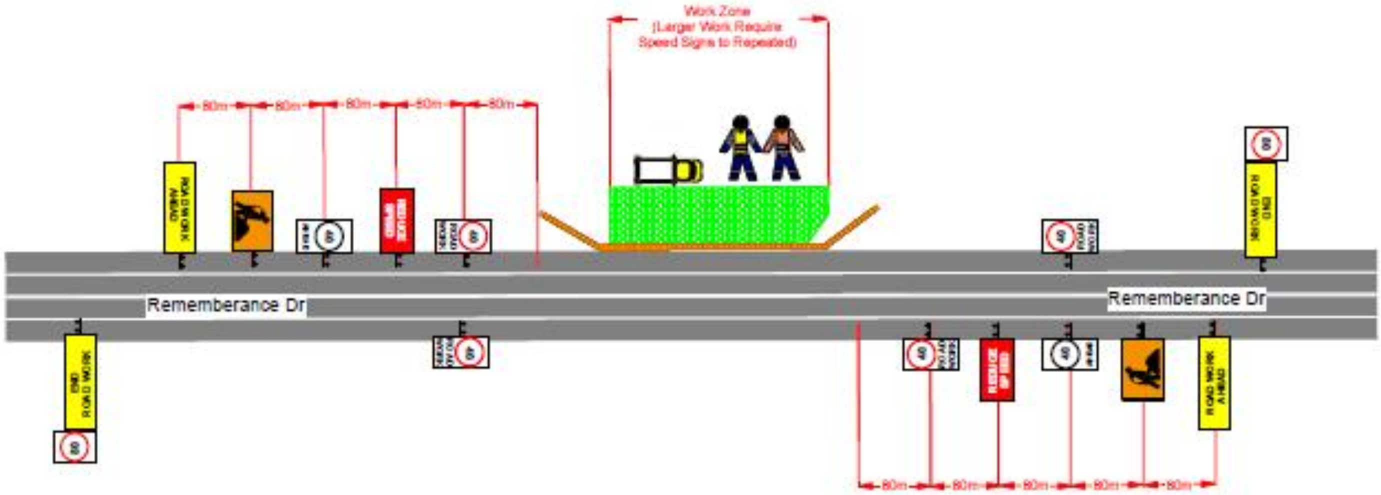
SIMEC

PLATINUM TRAFFIC SERVICES

Remembrance Driveway, Tahmoor NSW 2573
Easement



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Name:____________________

PWZTMP Card Number:____________

Exp Date:____________________

Date:__________ Sign:__________

Reason for modification:________________

LEGEND

- Platinum vehicle x2
- Work Zone
- Cones
- Team Leader x1
- Traffic Controller x2

PLATINUM TRAFFIC SERVICES

Client Contact: Ross Barber
Contact Number: 0419 480 143

Revisions

No:	By:	Date:	Description:	Appr:
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N S E W

Job Location:	Work Activity: Pipe Excavation
Client: SIMEC	Drawing Number: TCP-BVR2202
Drawn By: Brendon Van Ryn	Prepare Work Zone Number : Signed:
Approved By: Thomas McNair	Prepare Work Zone Number :TCT 007279 Signed:

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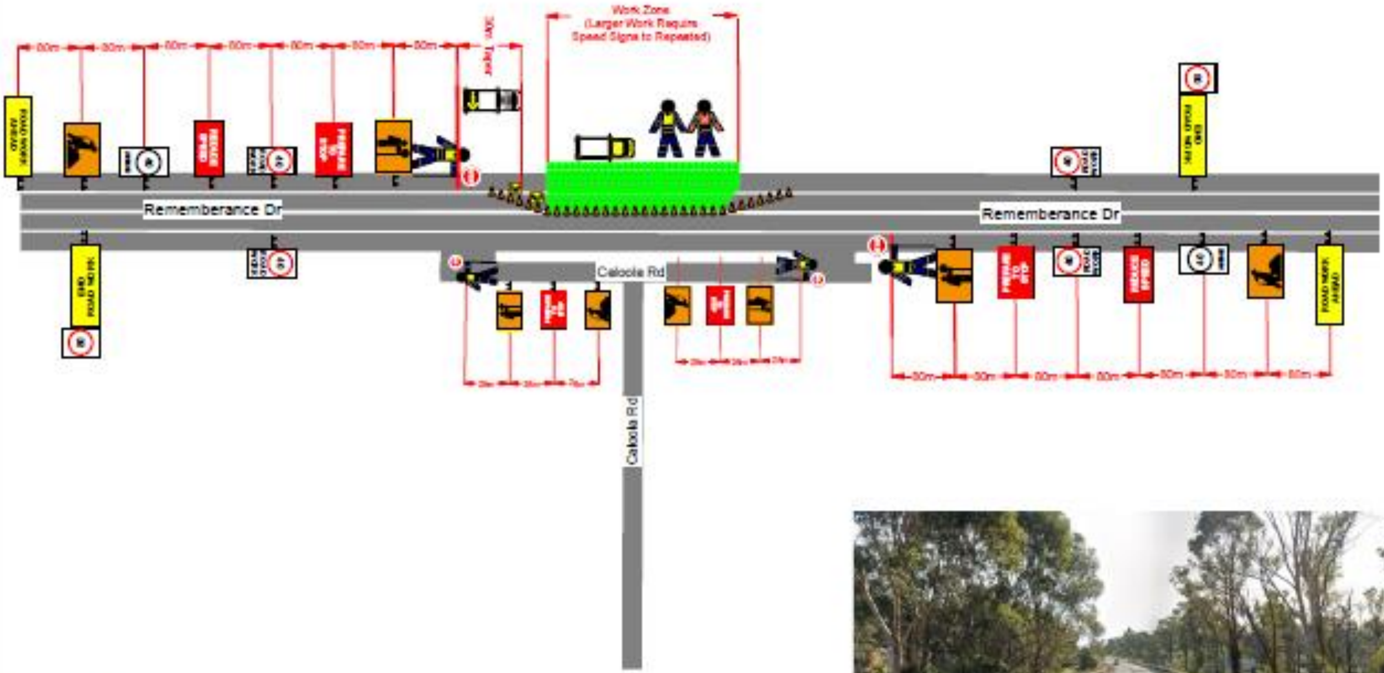
Remembrance Driveway, Tahmoor NSW 2573
Embankment



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Name: ______________________

PWZTMP Card Number: ____________

Exp Date: ______________________

Date: ____________ Sign: ____________

Reason for modification: ______________

LEGEND

- Platinum vehicle x2
- Work Zone
- Cones
- Team Leader x1
- Traffic Controller x2

PLATINUM TRAFFIC SERVICES

Client Contact: Ross Barber
Contact Number: 0418 466 143

No:	By:	Date:	Description:	Appr:
1	BVR 7/1/2023		Issued for Implementation	TM
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Original Size A3 — This TCP is not to scale

Job Location: Remembrance Driveway, Tahmoor NSW 2573
Work Activity: Pipe Excavation
Client: SIMEC
Drawing Number: TCP-BVR2208
Drawn By: Brendon Van Ryn — Prepare Work Zone Number: TCT1028794 — Signed:
Approved By: Thomas McNair — Prepare Work Zone Number: TCT 007279 — Signed:

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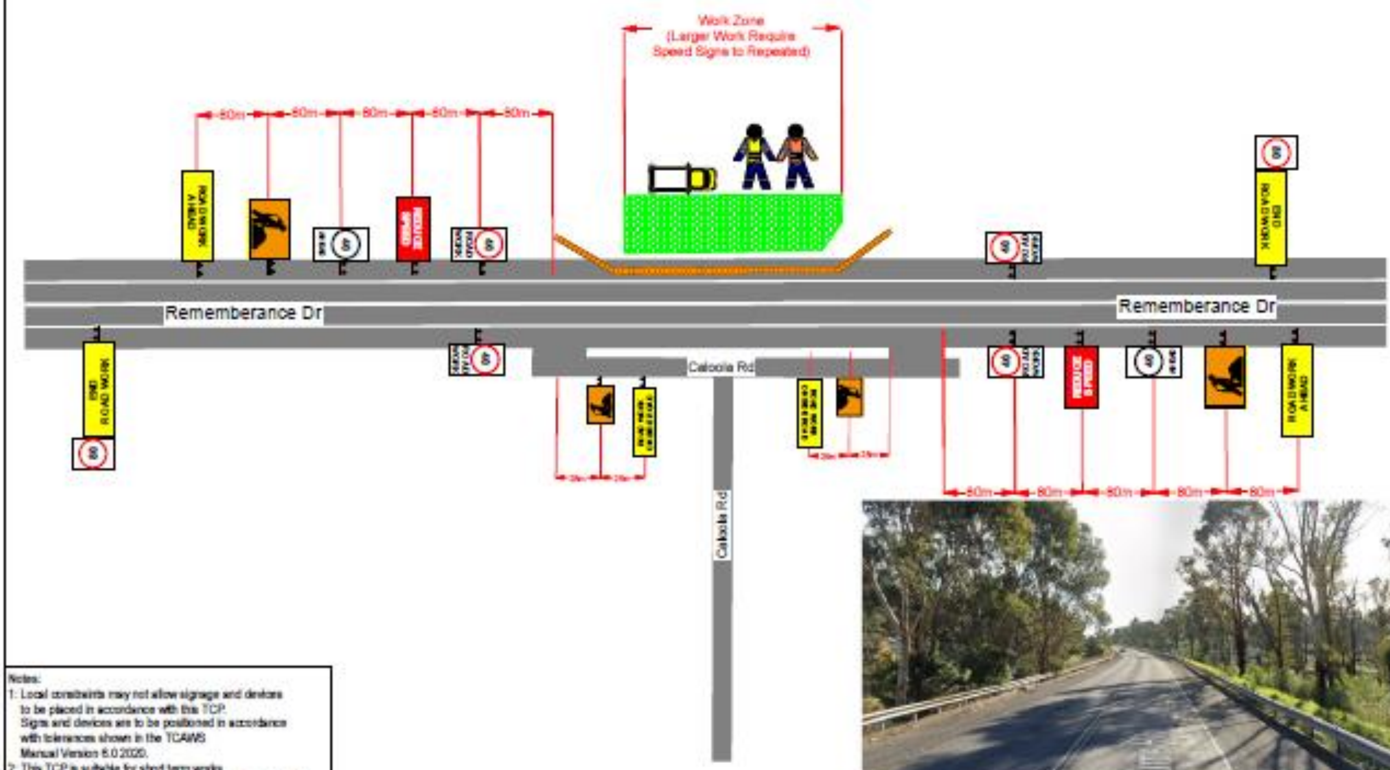
PLATINUM TRAFFIC SERVICES

Remembrance Driveway, Tahmoor NSW 2573
Embankment



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Name:____________________

PWZTMP Card Number:__________

Exp Date:____________________

Date:__________ Sign:__________

Reason for modification:____________________

LEGEND

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Client Contact: Ross Barber

Contact Number: 0419 496 143

Revisions

No:	By:	Date:	Description:	Appr:
1	BVR	7/11/2022	Issued for implementation	TM
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Original Size A3 | This TCP is not to scale

N W E S

Job Location:	Work Activity: Pipe Excavation
Client: SIMEC	Drawing Number: TCP-BVR2204
Drawn By: Brendon Van Ryn Prepare Work Zone Number :TCT1030794	Signed:
Approved By: Thomas McNair Prepare Work Zone Number :TCT 007278	Signed:

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SIMEC

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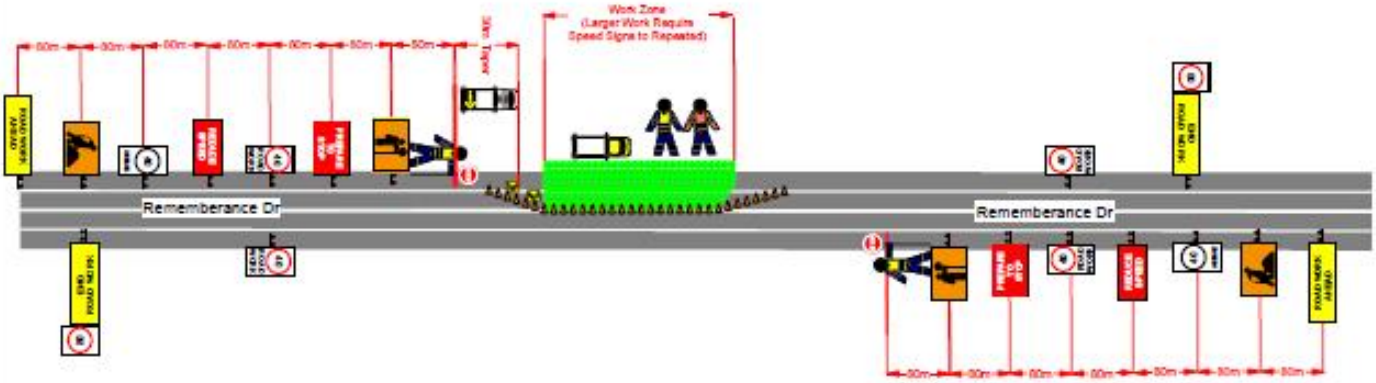
Remembrance Driveway, Tahmoor NSW 2573
Cutting



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Name:____________________

PWZTMP Card Number:__________

Exp Date:____________________

Date:__________ Sign:__________

Reason for modification:________________

LEGEND
- Platinum vehicle x2
- Work Zone
- Cones
- Team Leader x1
- Traffic Controller x2

THIS TGS MAY BE USED IN MIRROR REVERSE TO ALLOW WORKS ON EITHER SIDE OF A ROAD

PLATINUM TRAFFIC SERVICES

Client Contact: Ross Barber
Contact Number: 0419 460 140

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1	BVR	7/1/2022	Issued for implementation	TM
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N / S / E / W

Job Location: Remembrance Driveway, Tahmoor NSW 2573		Work Activity: Pipe Excavation	
Client: SIMEC		Drawing Number: TCP-BVR2206	
Drawn By: Brendon Van Ryn	Prepare Work Zone Number :TCT1020794	Signed:	
Approved By: Thomas McNair	Prepare Work Zone Number :TCT 0072759	Signed:	

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This guidance scheme is for Traffic Management purposes only. Platinum Traffic disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages and costs you might incur as a result of the information being inaccurate or incomplete in any way and for any reason. This plan is drawn in accordance with the TCAWS manual.

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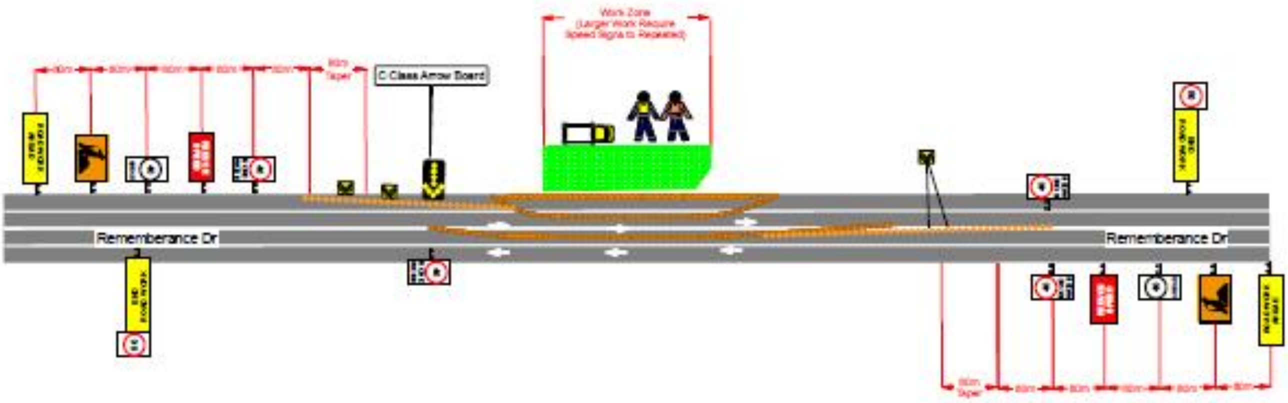
Remembrance Driveway, Tahmoor NSW 2573
Cutting



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Name:____________________

PWZTMP Card Number:__________

Exp Date: ____________________

Date:__________ Sign:__________

Reason for modification:________________

LEGEND

- Barrier
- Platinum vehicle x1
- Work Zone
- Cones
- Team Leader x1
- Traffic Controller x1

PLATINUM TRAFFIC SERVICES

Client Contact: Ross Barber
Contact Number: 0410 486 143

Revisions No:	By:	Date:	Description:	Appr
1	BVR	7/10/22	Issued for implementation	TM
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Original Size A3 — This TCP is not to scale

N S E W

Job Location:	Work Activity: Pipe Excavation
Client: SIMEC	Drawing Number: TCP-BVR2208
Drawn By: Brendon Van Ryn — Prepare Work Zone Number :TCT[illegible] — Signed:	
Approved By: Thomas McNair — Prepare Work Zone Number :TCT [illegible] — Signed:	

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