SIMEC Mining – Tahmoor Coal

Management Plan for extraction of Tahmoor South LW S4A-S7A adjacent to Wellers Road Overbridge

Revision A

Prepared by Mine Subsidence Engineering Consultants
on behalf of
Transport for NSW (Country Regional Network) and Tahmoor Coal
and the Rail Management Group

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AUTHORISATION OF MANAGEMENT PLAN

Authorised on behalf of Transport for NSW (Country Regional Network)	**Authorised on behalf of Tahmoor Coal Pty Ltd**
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Position: …………………………	**Position:** ………………………………………..
Date: ………………………………	**Date:** ……………………………………………..

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This Management Plan has been prepared by Mine Subsidence Engineering Consultants on behalf of the Railway Management Group. The Railway Management Group acknowledges contributions from a project team that is comprised of specialists in a variety of fields. The following organisations have contributed to this plan:

- Tahmoor Coal
- Transport for NSW (Country Regional Network)
- ARTC
- Bloor Rail
- Globetech
- JMA Solutions
- Michael Nicholson Consulting / Geomatix
- Mine Subsidence Engineering Consultants
- Newcastle Geotech
- Pidgeon Civil Engineering
- Robinson Rail
- Southern Rail Surveys
- Sweeting Consulting

ABBREVIATIONS AND DEFINITIONS

CRN	Country Regional Network
ARTC	Australian Rail Track Corporation
MSI	NSW Department of Regional NSW – Mine Safety Inspectorate – Resources Regulator
ONRSR	Office of the National Rail Safety Regulator
Globetech	Automated Monitoring Contractor for Track
SRS	Southern Rail Surveys (ground surveys within rail corridor)
SA NSW	Subsidence Advisory NSW
MSEC	Mine Subsidence Engineering Consultants
RMG	Rail Management Group
RMC	Rail Maintenance Contractor (Bloor Rail)
PCE	Pidgeon Civil Engineering
JMA	JMA Solutions (structural engineer)
SMEC	SMEC (ground surveys beyond rail corridor)
TC	Tahmoor Coal
ZTL	Zero toe load clips
Deed	Legally binding statement of commitments, in this case between ARTC and Tahmoor Coal
License	Formal permission to do something, in this case for Tahmoor Coal to access the Main Southern Railway corridor and undertake work
CWR	Continuously Welded Rail
Cess	Clear area at base of railway cuttings
First workings	Underground roadways (headings) to provide access for workers, conveyors and ventilation
Installation Heading	Underground roadway developed at the commencing end of the longwall panel to install the longwall equipment
Maingate	Underground roadway along the “solid coal” side of the longwall panel (leading edge of panel), where the main longwall panel conveyor is installed
Tailgate	Underground roadway along the opposite side of the longwall panel to the maingate
Chain pillar	A block of coal left unmined between the longwall extraction panels.

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Drawing No.	*Description*	*Revision*
MSEC1193-19-01	General Layout	A
MSEC1193-19-02	Wellers Road Overbridge Monitoring Plan	A
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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 38 longwalls and has finished extracting LW S3A.

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 (LWs S1A to S6A), which are the first of two series of longwall panels to be extracted in the Tahmoor South domain. The longwalls are located between Tahmoor's surface facilities to the north and the township of Bargo to the south.

Wellers Road Overbridge is located on the Main Southern Railway and is owned by Transport for NSW (TfNSW) as part of the Country Regional Network (CRN). A map showing the location of the Wellers Road Overbridge in relation to LW S1A-S7A is shown in Drawing No. MSEC1193-12. An aerial photograph showing the location of the Overbridge relative to LW S1A-S7A is shown in Fig. 1.1.

Tahmoor Coal has completed extraction of LW S3A. In November 2024, Tahmoor Coal received approval for an application to shorten the commencing (i.e. southern) end of LW S4A by 104 m from the position that was approved.

Tahmoor Coal has submitted an application to modify the development consent to extract LW S7A to the side of LW S6A.

Photograph courtesy Nearmap

Fig. 1.1 Location of Wellers Road Overbridge relative to LWs S1A to S7A

It can be seen from Drawing No. MSEC1193-19-01 that LWs S1A to S7A will not mine directly beneath the Overbridge.

A summary of the dimensions of LW S1A-S7A and closest distances to the Overbridge are provided in Table 1.1.

Table 1.1 Longwall dimensions and closest distances to Wellers Road Overbridge

Longwall	Overall void length including the installation heading (m)	Overall void width including the first workings (m)	Overall tailgate chain pillar width (m)	Closest distance to Wellers Road Overbridge (m)
LW S1A (extracted)	1,711	283	-	1,534
LW S2A (extracted)	1,768	285	38	1,224
LW S3A (extracted)	1,704	285	36	945
LW S4A	1,756	285	36	690
LW S5A	1,949	285	36	415
LW S6A	1,999	285	36	365
LW S7A (submitted for approval)	1,918	285	36	520

Whilst not covered by this Management Plan, it is noted that Wellers Road Overbridge is predicted to experience greater mine subsidence movements during the extraction of the B series of longwalls for the Tahmoor South Project.

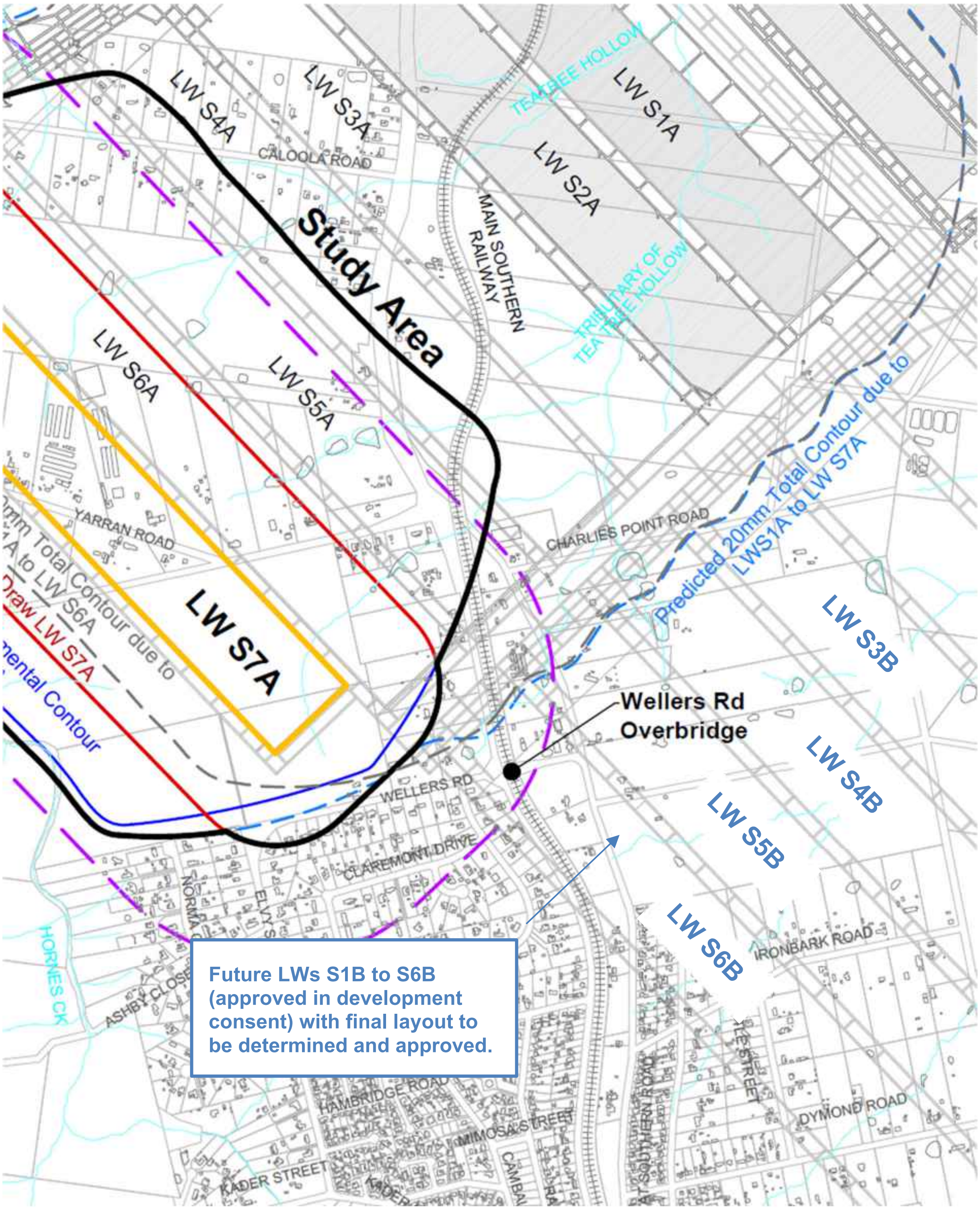
While development consent for the B series has been approved, a final mine layout has not yet been determined and the Extraction Plan for the B Series has not yet been submitted for approved. A draft layout was displayed in Tahmoor Coal's application for LW S7A, as shown in Fig. 1.2.

It can be seen that the north-western, finishing end of LW S6B is planned extracted directly beneath the Overbridge. A separate Management Plan is planned to be developed to manage the potential for mine subsidence impacts on the Overbridge due to the future extraction of LWs S1B to S6B.

This Management Plan provides detailed information about how the risks associated with mining adjacent to Wellers Road Overbridge will be managed by Tahmoor Coal and TfNSW.

The TfNSW Management Plan for Wellers Road Overbridge will be implemented in parallel with the Management Plan that has been developed between Tahmoor Coal and the Australian Rail Track Corporation (ARTC) for the Main Southern Railway.

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



Marked up extract from MSEC Drawing No. MSEC1348-01

Fig. 1.2 Location of Wellers Road Overbridge relative to future LWs S1B to S6B

1.2. Transport for NSW (TfNSW) and Country Regional Network (CRN)

As advised on its website, the Country Regional Network (CRN) is owned by Transport for NSW and is operated and maintained by its rail infrastructure manager, United Group Regional Linx (UGL RL).

The CRN links broad areas of regional NSW to interstate and metropolitan rail systems and in addition supports, customers transporting coal, grain, cotton, minerals and containerised freight to domestic and export markets.

The network covers 2,386 route kilometres of operational passenger and freight rail lines and 3,139 route kilometres of non-operational lines. It comprises 27,000 hectares of land and infrastructure including:

- 1,312 level crossings
- 1,200 property assets
- 600 rail under-bridges and 384 road over-bridges, with a proportion integrated into the ARTC managed network, including Wellers Road Overbridge

About 996 km of branch line track is used predominantly for haulage of grain, with lower mass and speed limits than other parts of the network.

TfNSW's primary role is to ensure management of the CRN assets provide a safe, reliable and sustainable rail network and supporting operational services to meet customer needs. This includes ensuring maintenance works and services provide value for money to Government.

1.3. Australian Rail Track Corporation (ARTC)

The Australian Rail Track Corporation (ARTC) is a company created as a result of the Commonwealth and mainland State Governments Inter-Government Agreement in 1997 for the establishment of a 'one-stop shop' for rail operators seeking access to the interstate standard gauge rail network between Brisbane and Perth. The company organisation commenced operations on 1 July 1998.

Australian Rail Track Corporation Ltd (ARTC) is a company under the Corporations Act whose shares are owned by the Commonwealth and overseen by the Minister for Transport and Regional Services and Minister for Finance and Administration on behalf of the Commonwealth.

On September 4th, 2004, ARTC agreed to a 60 year lease of designated NSW State owned railway lines and infrastructure of which the Main Southern Line is part. As part of the lease, ARTC have assumed responsibility for the maintenance of leased tracks.

In December 2022, ARTC and Tahmoor Coal developed and agreed a Management Plan for the extraction of LWs S1A to S6A beneath the Main Southern Railway (Plan No. MSEC1201, Revision C). The plan includes the management of Wellers Road Overbridge from a rail operations perspective.

The risk control measures in this TfNSW Management Plan are consistent with, or are addition to the management measures that are described in the ARTC Management Plan.

1.4. Wollondilly Shire Council (WSC)

Wollondilly Shire Council (WSC) is the local government area that manages road infrastructure at Wellers Road Overbridge.

In October 2022, WSC and Tahmoor Coal developed and agreed a Management Plan for the extraction of LWs S1A to S6A beneath Council infrastructure, which will be extended to include LW S7A in future. The WSC Management Plan includes measures to manage potential impacts to Council infrastructure on both sides of the Overbridge, including the development of traffic management plans.

The risk control measures in this Management Plan are consistent with, or are addition to the management measures that are described in the WSC Management Plan.

1.5. Rail operations along the Main Southern Railway potentially affected by LW S1A-S7A

The area to be potentially affected by the extraction of LW S1A-S7A includes part of the Main Southern Line rail corridor, which extends from Sydney to Albury. The original Main Southern line extended from Picton to Mittagong in 1867. The railway through Tahmoor and Bargo was constructed around 1919, when the new railway alignment from Picton to Mittagong was opened.

During the 1990's, construction commenced on upgrading the Up and Down tracks to strengthen the track infrastructure. This has included replacing timber sleepers with concrete sleepers and resurfacing, regrading and realigning the existing 53 and 60 kg/m track. The dual track is configured as dedicated Up and Down lines, with all signals being remotely controlled by ARTC Train Control located at Junee. The track between Tahmoor and Bargo is an automatic signalled area.

The Up and Down tracks service a range of rail traffic including:

- Heavy haul coal and minerals traffic;
- Containerised traffic;
- Grain and agricultural products; and
- Local, Interstate and Intrastate passenger traffic.

A map showing the location of the Main Southern Railway infrastructure, including Wellers Road Overbridge in relation to LW S1A-S7A is shown in Drawing No. MSEC1193-19-01.

The railway line is a dual track consisting of 60 kg rail on concrete sleepers with a mix of straight and curved track sections within the Study Area. The maximum speed limits on both tracks are 95 km/h for normal services and 105 km/h for XPT services.

1.6. Wellers Road Overbridge

The Wellers Road Overbridge spans across the Main Southern Railway at 101.162 km. The 8.27 metre single-span dual lane masonry arch bridge is comprised of a concrete arch on masonry abutments with masonry vehicle barrier parapet walls. The concrete arch appears to have been reinforced with old steel rails as per design but they have not been exposed to confirm they exist. The concrete arch has, therefore, been conservatively assessed as unreinforced (JMA, 2022b). A photograph of the Overbridge is shown in Fig. 1.3.

Fig. 1.3 Wellers Road Overbridge

The overbridge was constructed in 1919 as part of the major duplication of the Main Southern Railway. The Bridge is listed as an Item of Heritage Significance on the Wollondilly Local Environmental Plan (2011).

1.7. Objectives

The primary objectives of this Management Plan are to establish procedures to identify, measure, control, mitigate and repair potential impacts that might occur on the Wellers Road Overbridge which may be potentially or directly affected by mining operations as a result of the mining of Tahmoor LW S1A-S7A.

The objectives of the Management Plan have been developed to:

- Maintain the safe and serviceable operation of all affected rail infrastructure, with public and workplace safety paramount;
- Avoid, as far as practicable, any impediment to ARTC's business including impact on speed or frequency of passenger or freight trains;
- Prevent significant disruption and inconvenience to ARTC 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 Wellers Road Overbridge;
- Avoid or minimise disruption and inconvenience to the travelling public along the rail and on the local roads;
- Monitor ground movements and the condition of the Overbridge prior to mining, during mining and for a period post mining as advised by the Rail Management Group;
- Initiate action to mitigate or remedy potential impacts that may occur during longwall mining affecting the Overbridge;
- 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 Overbridge; and
- Establish lines of communication, emergency contacts, procedures and protocols.

1.8. Scope

The Management Plan is to be used to protect and monitor the condition of the Wellers Road Overbridge which has been identified to potentially be at risk due to mine subsidence.

This Management Plan describes measures that will be undertaken as a result of the mining of LW S4A-S7A only.

1.9. Limitations

This Management Plan is based on the predictions of the effects of mining on surface infrastructure as provided in Report No. MSEC1192 for the extraction of LWs S1A to S6A and Report No. MSEC1348 for the extraction of LW S7A by Mine Subsidence Engineering Consultants (MSEC, 2022 and MSEC, 2024, respectively). Predictions are based on the planned configuration of LW S4A-S7A at Tahmoor South (as shown in Drawing No. MSEC1193-19-01), along with available geological information and data from numerous subsidence studies for longwalls previously mined in the area.

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

The impacts of mining on surface and sub-surface features have been assessed in detail. However, it is recognised 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 and MSEC1348 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. The Plan includes measures to detect early potential increased subsidence, so that additional monitoring and response measures can be implemented before potentially severe impacts occur.

1.10. Consultation

1.10.1. Consultation with TfNSW

From 2019, Tahmoor Coal has consulted with TfNSW in relation to the development and implementation of a subsidence management plan to manage potential impacts during the extraction of LWs W1 to W4 adjacent to the Victoria Bridge in Picton.

In February 2023, Tahmoor Coal initially consulted with representatives from JHR, who were the previously contracted maintainer of the Wellers Road Overbridge. At that stage the mine layout was different and future LW S6B was planned to be extracted directly beneath and past the Wellers Road Overbridge.

The condition of consent for the Extraction Plan for LWs S1A to S6A requires a management plan to be developed prior to the effects of LW S4A.

Tahmoor Coal will continue to consult regularly with TfNSW during the extraction of LW S4A-S7A in relation to mine subsidence effects from mining.

1.10.2. Consultation with ARTC

Tahmoor Coal regularly consults with ARTC in relation to mine subsidence effects. This includes consultation during the development of subsidence management plans for previous LWs 22 to 32 and LWs W1 to W4.

Tahmoor Coal currently consults with ARTC in relation to management potential mine subsidence effects on the Main Southern Railway during the mining of LWs S1A to S6A, which includes the dual tracks running through the Wellers Road Overbridge structure. ARTC receives regular reporting of subsidence movements and impacts during the mining of LWs S1A to S3A.

1.10.3. Consultation with Government Agencies & Key Infrastructure Stakeholders

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

1.11. Proposed mining schedule

It is planned that LWs S4A to S6A will extract coal working northwest from the southeastern ends. 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 (complete)	October 2022	July 2023
LW S2A (complete)	August 2023	April 2024
LW S3A (complete)	May 2024	December 2024
LW S4A	February 2025	September 2025
LW S5A	October 2025	June 2026
LW S6A	July 2026	February 2027
LW S7A	March 2027	October 2027

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

1.12. Legal framework

Tahmoor Coal received development consent for the Tahmoor South Project in April 2021 and approval of the Extraction Plan for LW S1A-S6A in October 2022.

The Development Consent includes Condition C5, which requires that Tahmoor Coal must ensure that the Main Southern Railway be:

- "*Always Safe and Serviceable*"; and
- "*Damage that does not affect safety or serviceability must be fully repairable, and must be fully repaired at the cost of the Applicant*" (i.e. Tahmoor Coal).

This Management Plan has also been developed in accordance with Tahmoor Coal's Built Features Management Plan, which was submitted as part of the Extraction Plan for LW S1A-S6A.

Continuing consultation during the extraction of LW S4A-S7A between Tahmoor Coal and TfNSW is via the Management Plan and the Rail Management Group was established to carry out the objectives of the Management Plan between Tahmoor Coal, ARTC and TfNSW.

This Management Plan was reviewed by the Rail Management Group and endorsed by each member in their area of expertise before joint authorisation by TfNSW / Tahmoor Coal. This plan builds upon the investigations and knowledge gained from the successful implementation of Management Plans for the mining of LWs 22 to 32, LWs W1 to W4 and LWs S1A to S3A beneath and adjacent to the Main Southern Railway, including various similar brick arch structures.

1.13. 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) 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 (now NSW Department of Regional NSW - Mine Safety Inspectorate – Resources Regulator):

"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) (now NSW Department of Regional NSW - Mine Safety Inspectorate – Resources Regulator). 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 S4A-S7A adjacent to the Wellers Road Overbridge in accordance with the WHS laws.

2.1. Observed movements at Wellers Road Bridge during the mining of LW S1A to S3A

Tahmoor Coal is currently monitoring ground movements at Wellers Road Overbridge in accordance with the ARTC Management Plan since the commencement of LW S1A.

The purpose of the monitoring was to collect regional far field horizontal movement data and baseline measurements of the Overbridge. The following monitoring measures are being conducted:

- Continuous Absolute 3D Global Navigation Satellite System (GNSS) monitoring of a ground mark on the Up / Country side of the Overbridge (GNSS Site S15);
- Absolute 3D survey of a ground mark on the Down / Country side of the Overbridge (Peg WR1);
- Local 3D survey of abutments, arch and spandrel walls on the Overbridge structure and in the ground at the bridge approaches;
- Since June 2024 during the mining of LW S3A, continuous laser distancemeter and draw wire displacement monitoring of distances along and across the Overbridge abutments;
- Baseline visual inspection of the Overbridge; and
- Monitoring of crack gauges on Overbridge, as recommended by structural engineer.

The observations experienced during the mining of LWs S1A to S3A are presented below.

Absolute horizontal and vertical movements at the Overbridge

Observed absolute 3D horizontal and vertical movements for Peg WR1 and GNSS S15 are provided in Fig. 2.1. It can be seen that the ground on both sides of the Overbridge have gradually moved to the north, towards the mined longwalls.

The magnitude of observed horizontal movements at the Overbridge has gradually increased as subsequent longwalls are extracted closer to the Overbridge. As discussed later in Section 2.4, observed horizontal movements during the mining of LWs S1A to S3A at the Overbridge were within the normal observed range.

The measured height (Reduced Level) of the Overbridge has been measured to gradually decrease by approximately 10 mm. The measured changes are within the normal observed range for changes in height due to seasonal changes in moisture and may not be mine subsidence.

Differential horizontal and vertical movements at the Overbridge

Survey prisms were placed on the Overbridge base and top of abutments, top of arch and ends of spandrel walls and in the ground at the bridge approaches. The plan locations of the survey marks are shown in Drawing No. MSEC1193-19-02. The positions of the prisms are measured in local 3D, to remove the effect of survey tolerance from measuring their absolute 3D positions.

Measured changes in horizontal distances along and across the abutments are shown in Fig. 2.2. It can be seen that very little change has been observed, with survey tolerances. The local 3D survey results can also be used to calculate sideways shear of one abutment relative to the other and are currently within survey tolerance.

After the extraction of LW S2A, four laser distancemeters and two draw wire displacement sensors were installed at the tops of the Overbridge abutments to measure changes in distances along and across the abutments, including the diagonals.

Very gradual changes in the order of 1 mm have been observed by the laser distancemeters, as shown in Fig. 2.2. The changes may be due to seasonal thermal variations. Further monitoring is required to confirm trends.

The laser distancemeters can also be affected by the accumulation of diesel particulates and spider webs, as shown in Fig. 2.2, requiring occasional maintenance cleaning.

The results of surveys of the spandrel walls are within survey tolerance of ± 3 mm. Greater variations in the horizontal and vertical positions have been observed at the ground marks due to seasonal changes in moisture.

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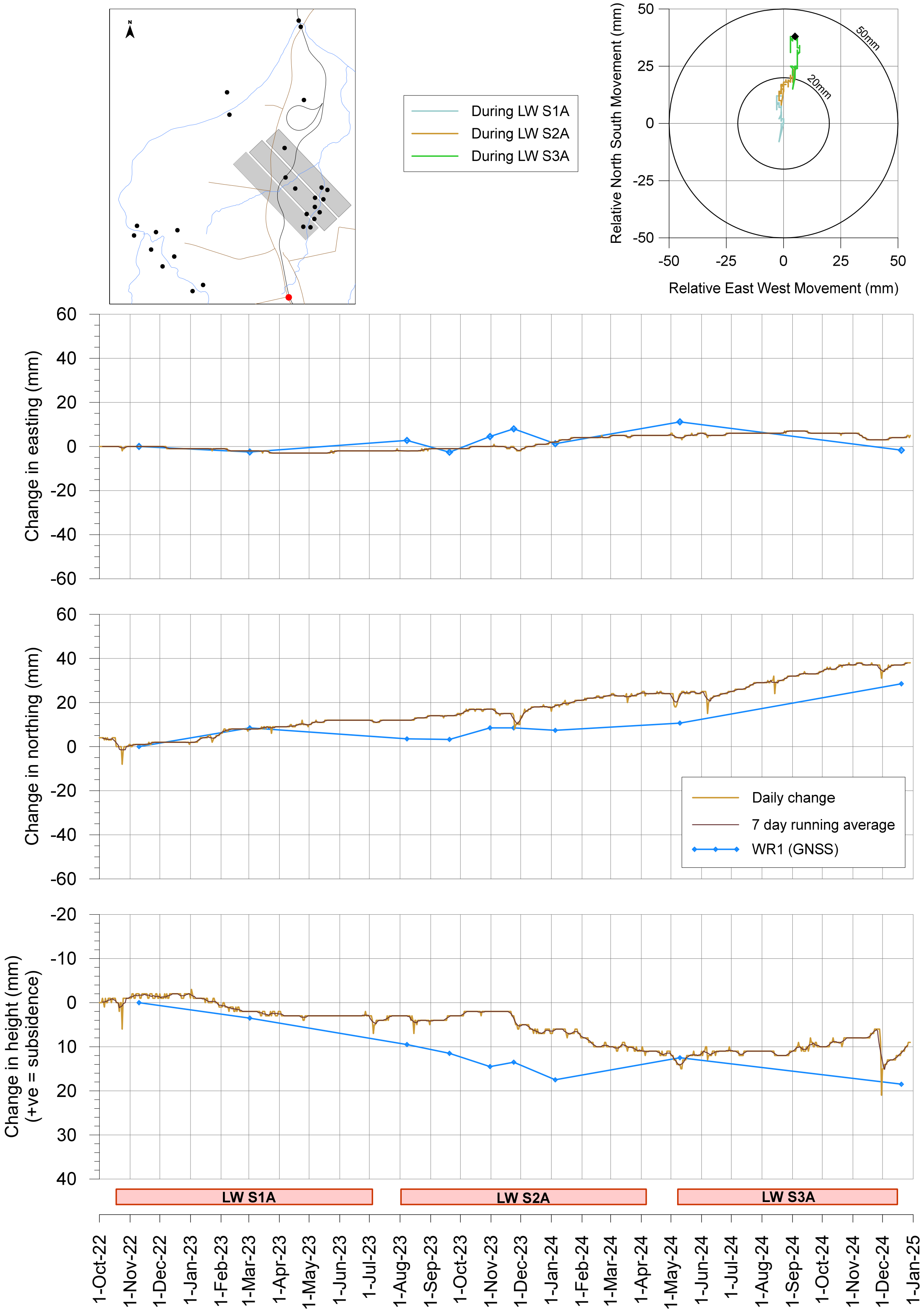


Fig. 2.1 **Observed changes in easting, northing and height at GNSS S15 at Wellers Road Overbridge**

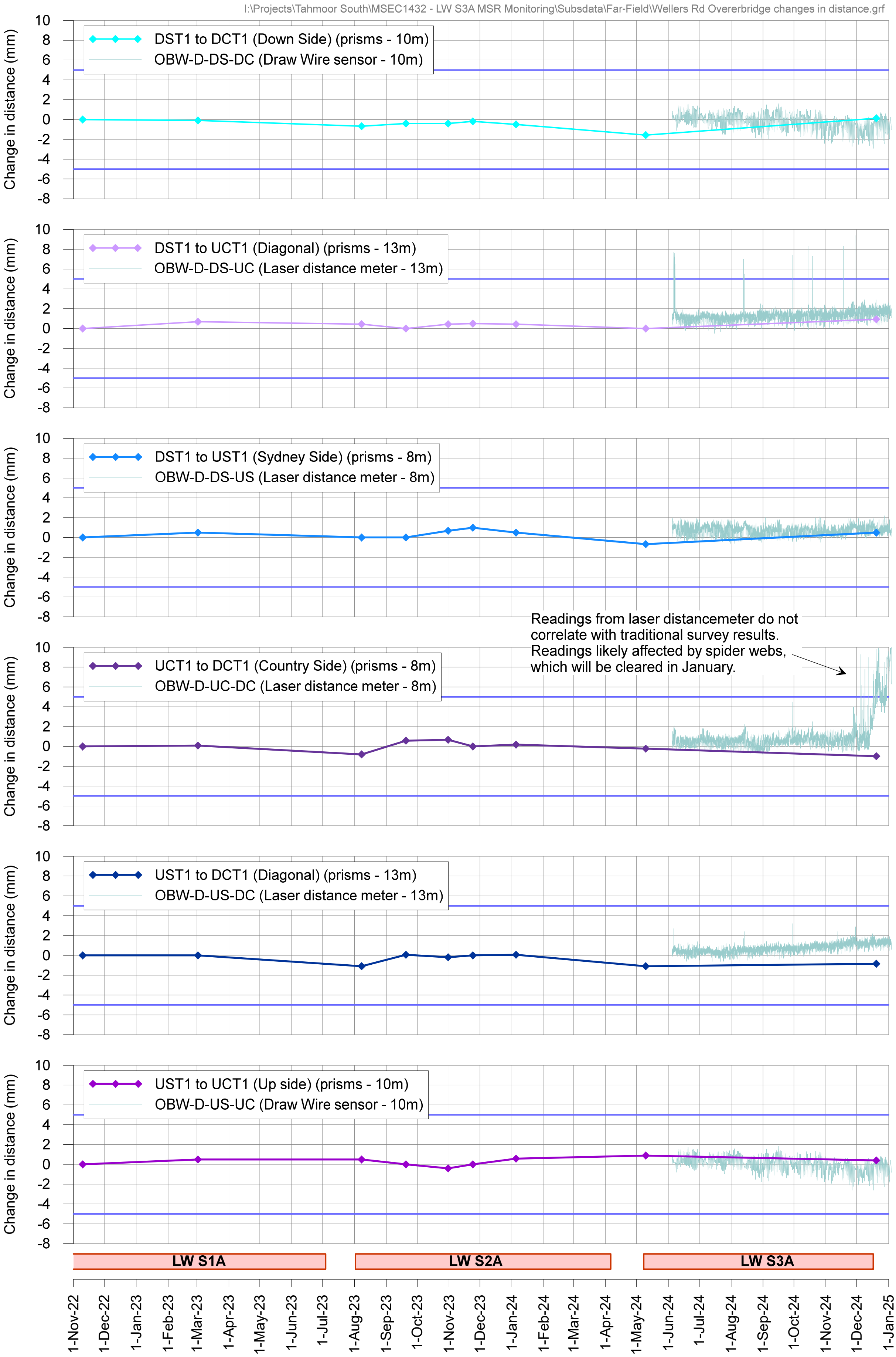


Fig. 2.2 **Observed changes in distance at Wellers Road Overbridge**

2.2. Predicted conventional subsidence parameters

The Wellers Road Overbridge is located approximately 365 metres from LW S6A at its closest point. As shown in Drawing No. MSEC1193-19-01, the Overbridge is located outside the predicted limit of subsidence and is, therefore, predicted to experience negligible conventional subsidence movements.

The predicted profiles of conventional subsidence and tilt along the alignment of Main Southern Railway, resulting from the extraction of the proposed longwalls, are shown in Fig. 2.3. The location of Wellers Road Overbridge is shown in the figure.

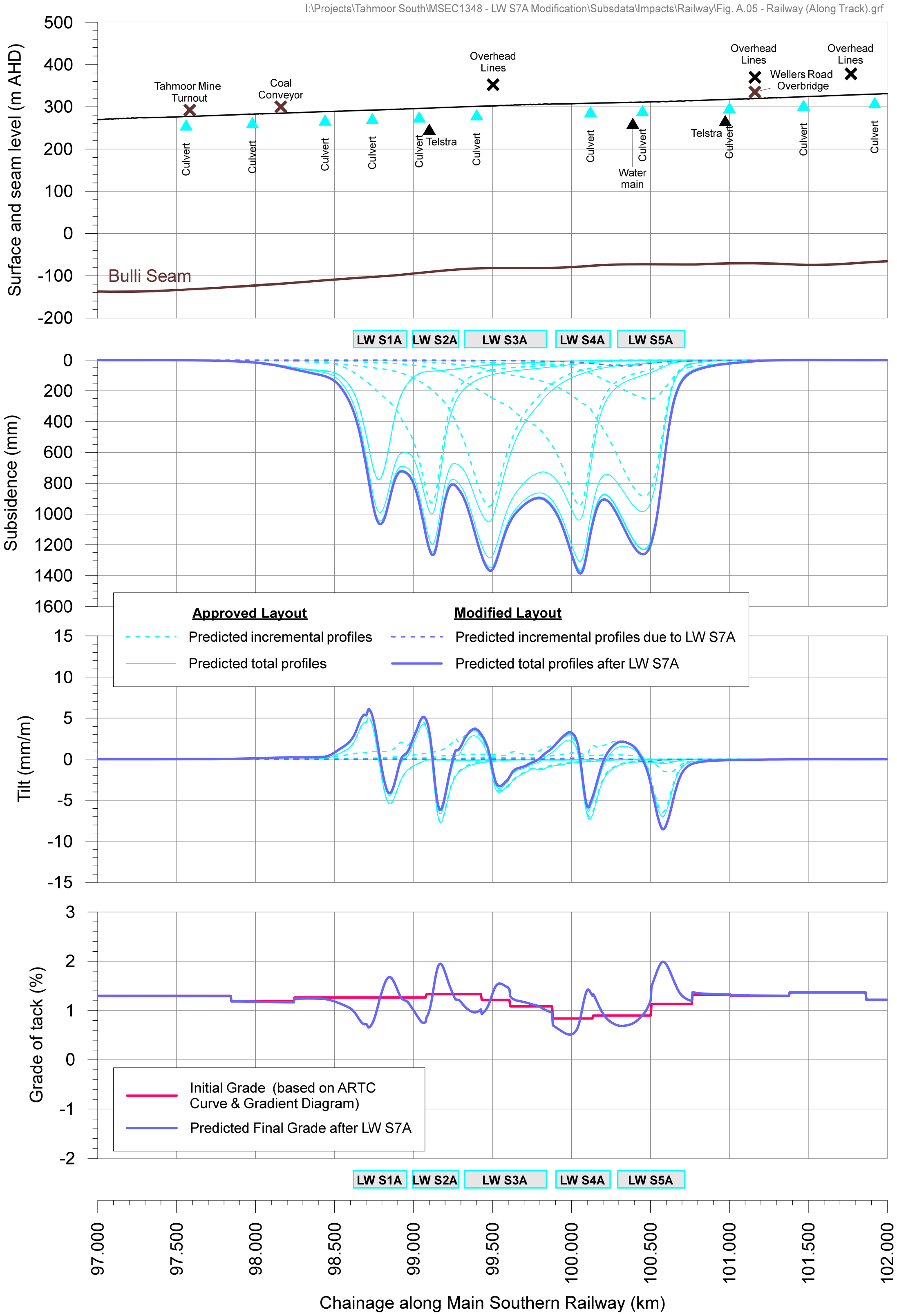


Fig. 2.3 **Predicted profiles of conventional subsidence, tilt and change in grade along the Main Southern Railway due to the extraction of LW S1A-S7A**

2.3. Development of subsidence movements over time

Monitoring of subsidence movements during the mining of previously extracted longwalls at similar depths of cover in the Southern Coalfield have shown that subsidence movements develop gradually over time, and with no observed indication of large or sudden step changes. This has been observed consistently along the Railway during previous mining at Tahmoor Mine.

In each case, the observations have shown that subsidence movements develop gradually over time, with no obvious indication of large and sudden step changes, as inferred from the large database of weekly survey data, or high frequency automated continuous monitoring. Importantly, rail monitoring at Tahmoor Mine has shown that the rails move differentially in a gradual manner.

An example of the gradual development of subsidence is shown in Fig. 2.4, which shows the observed development of horizontal movement and subsidence of a continuously operating Global Navigation Satellite System (GNSS) unit along the Main Southern Railway that is located above the centreline of LW S3A.

The gradual development of subsidence movements allows potential impacts on surface features to be managed effectively. This is because with the implementation of an effective monitoring program, unexpected or anomalous subsidence ground movements can be detected early and actions taken in response well before potentially severe impacts occur.

I:\Projects\Tahmoor South\MSEC1432 - LW S3A MSR Monitoring\Subsdata\GNSS\Fig. S27 GNSS.grf

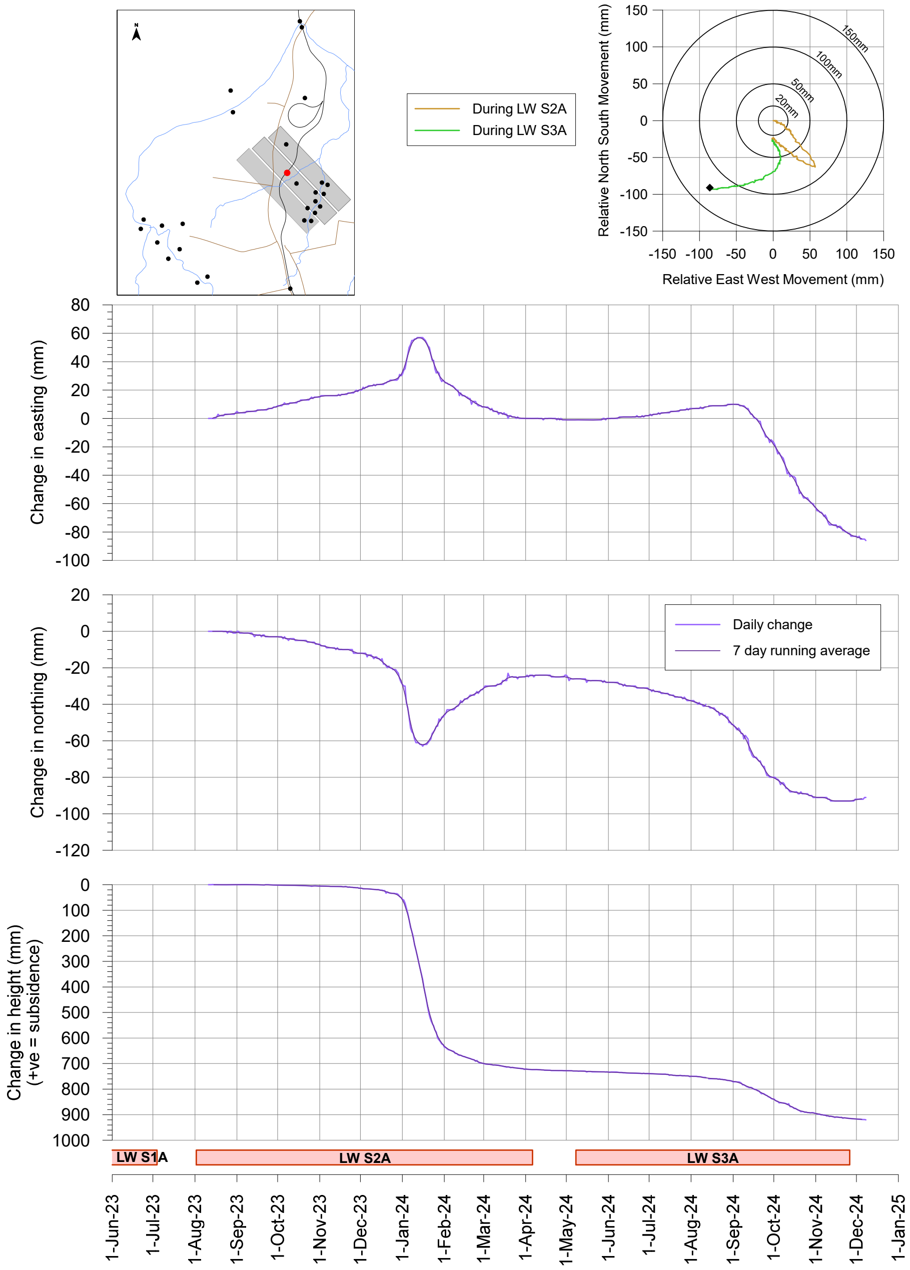


Fig. 2.4 Observed development of horizontal movement and subsidence at GNSS Site 27 on the Main Southern Railway above LW S3A

2.4. Predicted far-field horizontal movements

The measured horizontal movements at survey marks which are located beyond the longwall goaf edges and over solid unmined coal areas are often much greater than the observed vertical movements at those marks. These movements are often referred to as *far-field movements*.

Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low-levels of strain. These movements generally do not result in impacts on natural features or built environments, except where they are experienced by large structures which are very sensitive to differential horizontal movements.

In some cases, higher levels of far-field horizontal movements have been observed where steep slopes or surface incisions exist nearby, as these features influence both the magnitude and the direction of ground movement patterns. Similarly, increased horizontal movements are often observed around sudden changes in geology or where blocks of coal are left between longwalls or near other previously extracted series of longwalls. In these cases, the levels of observed subsidence can be slightly higher than normally predicted, but these increased movements are generally accompanied by very low levels of tilt and strain.

In addition to the conventional subsidence movements that have been predicted above and adjacent to the proposed longwalls, far-field horizontal movements will also be experienced during the extraction of the proposed longwalls.

The observed incremental far-field horizontal movements resulting from the extraction of individual longwall panels, in any location above goaf, i.e. above the currently mined or previously mined panels, or above solid coal, i.e. unmined areas of coal, are provided in Fig. 2.5.

The observed incremental far-field horizontal movements above solid coal only, i.e. outside the extents of extracted longwalls, are provided Fig. 2.6. Survey lines have been selected from Tahmoor, Appin, West Cliff and Tower Collieries.

Observed incremental far-field horizontal movements during the extraction of LWs S1A to S3A are overlaid in Fig. 2.6, along with the offset distances of Wellers Road Overbridge relative to the Tahmoor South longwalls. It can be seen that observed horizontal movements during the mining of LWs S1A to S3A, including at Wellers Road Overbridge, were within the normal observed range.

The confidence levels, based on fitted *Generalised Pareto Distributions* (GPDs), have also been shown in these figures to illustrate the spread of the data. It can be seen from Fig. 2.5 and Fig. 2.6 that the magnitudes of the observed far-field horizontal movements over solid unmined areas of coal are lower and more consistent than the observed far-field horizontal movements over previously extracted panels.

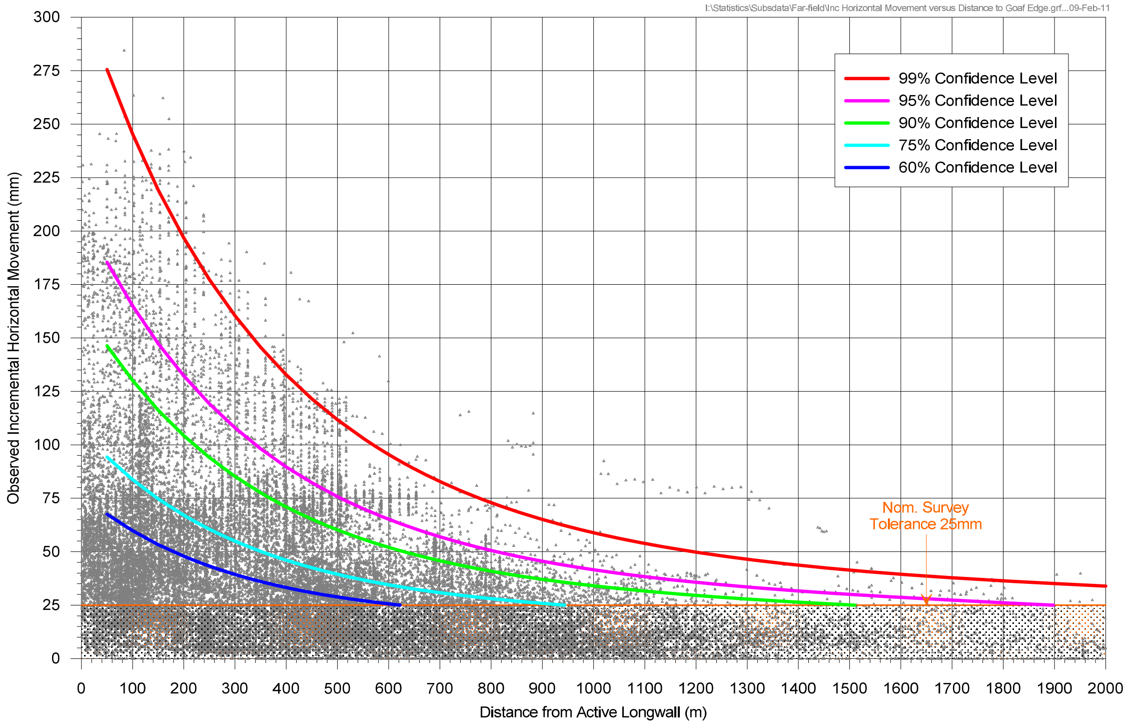


Fig. 2.5 Observed incremental far-field horizontal movements above goaf or solid coal

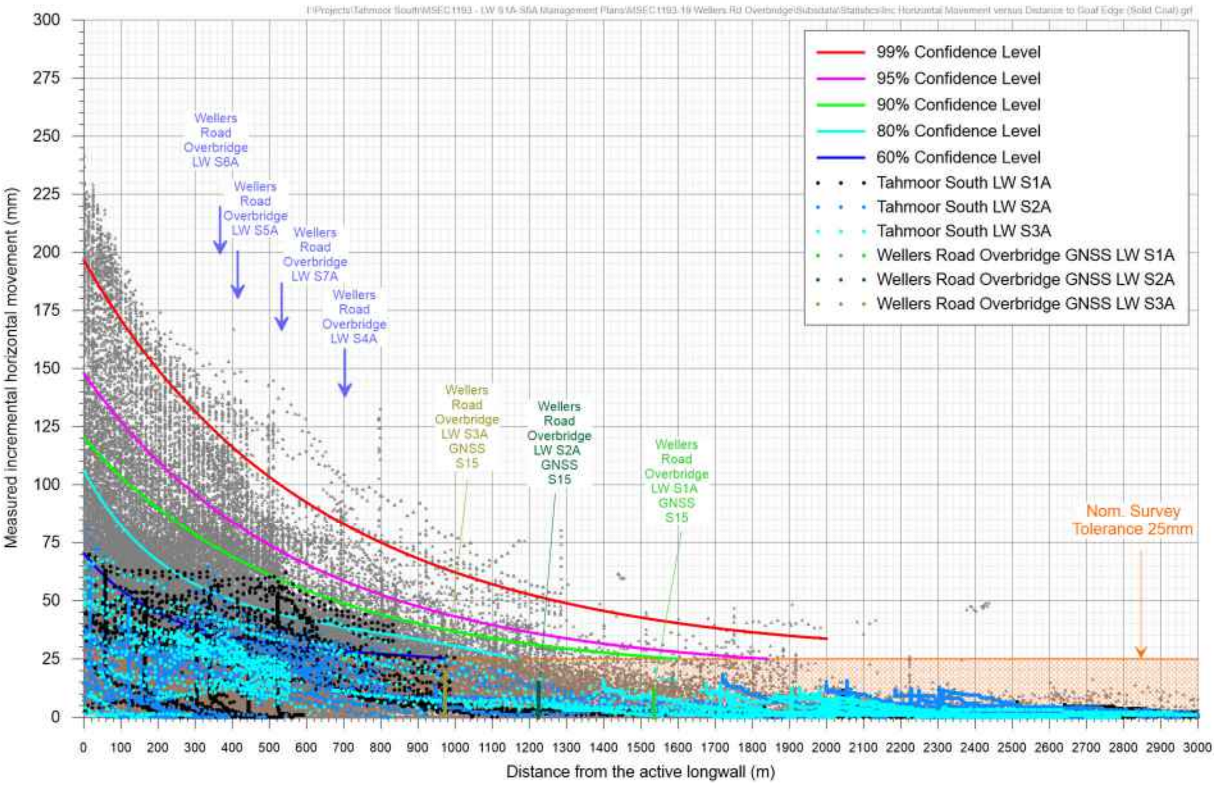


Fig. 2.6 Observed incremental far-field horizontal movements above solid coal only

Confidence levels have been determined from the selected empirical horizontal movement data from Tahmoor, Appin, West Cliff and Tower Collieries, using the fitted GPDs. In the cases where survey bays were measured multiple times during a longwall extraction, the maximum measured horizontal movement was used in the analysis. A summary of incremental horizontal movements within the 95% and 99% confidence levels are shown in Table 2.1.

The Overbridge will experience far-field horizontal movements as a result of the extraction of LWs S4A to S7A. Such movements tend to be bodily movements towards the extracted goaf area, and are accompanied by very low levels of strain, which are generally less than the order of survey tolerance (i.e. less than 0.3 mm/m). This is discussed further in the following section.

Table 2.1 Confidence levels for incremental horizontal movement for survey marks above solid coal for monitoring lines at Tahmoor, Appin, West Cliff and Tower Collieries

Distance from active longwall (m)	Incremental horizontal movement within 95% confidence level (mm)	Incremental horizontal movement within 99% confidence level (mm)
200	110	145
400	90	120
600	75	100
800	60	80
1000	50	65
1200	40	50
1400	30	45
1600	26	35
1800	23	30
2000	22	27

2.5. Predicted differential far-field horizontal movements

The potential for impacts on the Overbridge does not result from absolute far-field horizontal movements, but rather from differential horizontal movements over the length of the structure.

Observed changes in horizontal distances between pegs spaced between 10 and 30 metres apart are shown in Fig. 2.7. The 10 to 30 metre bay length was selected as the span of Wellers Road Overbridge is approximately 8 metres and the standard spacing of ground survey pegs in the Southern Coalfield at similar depths of cover is 20 metres. It can be seen that potential for differential horizontal movements increases with each successive longwall as the mine approaches the Overbridge. 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.

Observed incremental changes in horizontal distances across the span of Wellers Road Overbridge during the extraction of LWs S1A to S3A are overlaid in Fig. 2.7, along with the offset distances of Wellers Road Overbridge relative to the Tahmoor South longwalls. It can be seen that observed differential horizontal movements at Wellers Road Overbridge were within the normal observed range and within survey tolerance during the mining of LWs S1A to S3A.

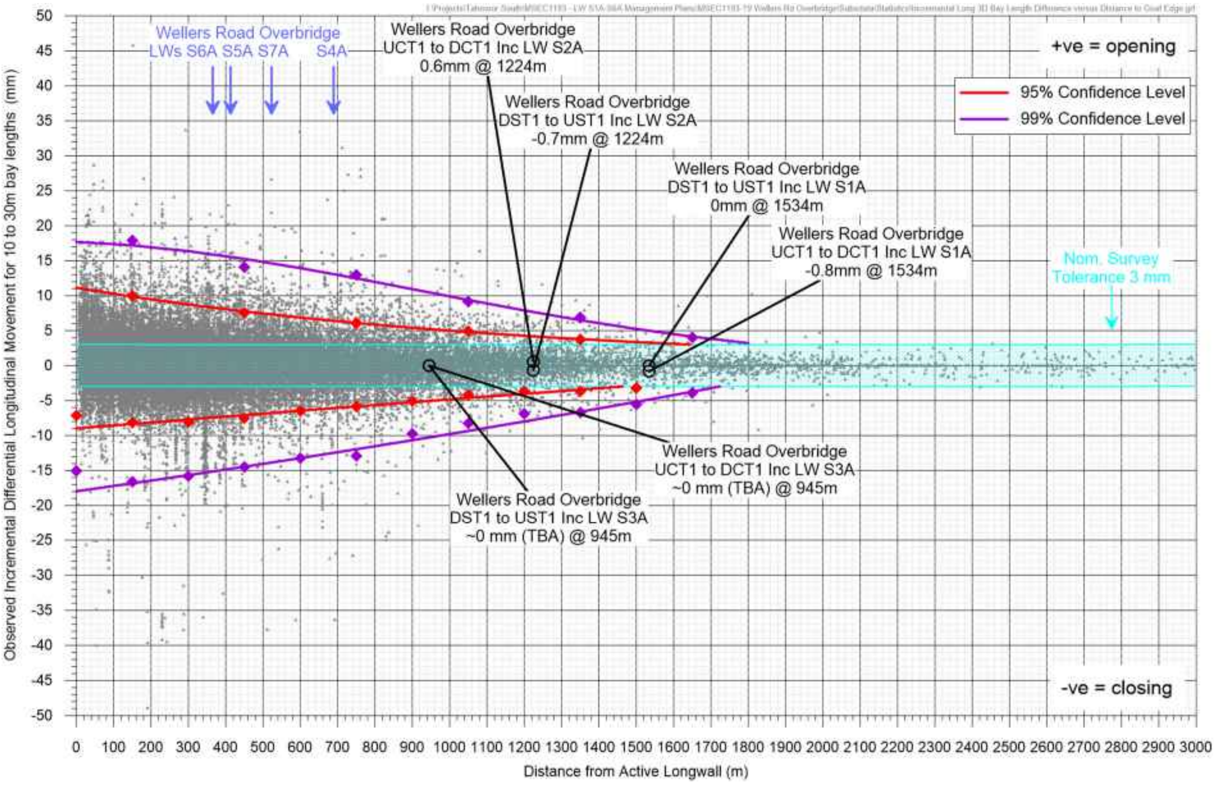


Fig. 2.7 Observed incremental differential longitudinal horizontal movements versus distance from active longwall for marks spaced between 10 and 30 metres

A summary of the probabilities of exceedance for incremental differential horizontal movements for survey bays, based on the fitted General Pareto Distribution function, is provided in Table 2.2.

Table 2.2 Probabilities of exceedance for incremental differential horizontal movements for survey bays located from the nearest goaf edge at Wellers Road Overbridge

LW	Offset distance from Wellers Road Overbridge (m)	Probability of Exceedance			
		1 in 20 (0.05)		1 in 100 (0.01)	
		Opening (mm)	Closure (mm)	Opening (mm)	Closure (mm)
LW S4A	690	6	6	13	12
LW S5A	415	8	7	16	15
LW S6A	365	9	8	17	14
LW S7A	520	7	7	15	14

It is possible that Wellers Road Overbridge could experience shear deformations as a result of differential far field movements. In this report, horizontal mid-ordinate deviation has been used as the measure for shear deformation, which is defined as the differential horizontal movement of each survey mark, perpendicular to a line drawn between two adjacent survey marks. The frequency distribution of the maximum incremental horizontal mid-ordinate deviations measured at survey marks above solid coal, for previously extracted longwalls in the Southern Coalfield, is provided in Fig. 2.8.

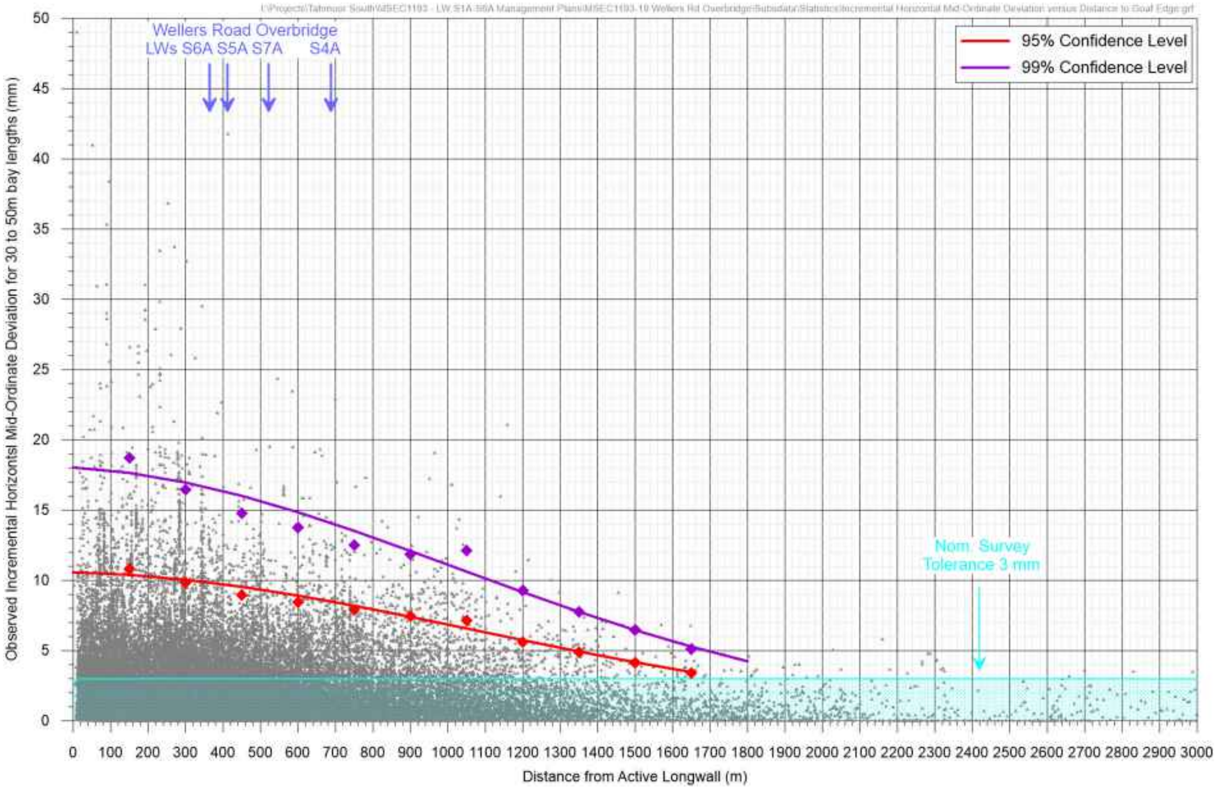


Fig. 2.8 Observed incremental differential horizontal mid-ordinate deviation versus distance from active longwall for marks spaced between 30 and 50 metres

Being a single span bridge, survey results measured on the abutments of the Wellers Road Overbridge cannot be used to measure horizontal mid-ordinate deviations. Survey results, however, indicate that no measurable transverse shear has been observed at the Overbridge to date.

A summary of the probabilities of exceedance for incremental horizontal mid-ordinate deviations at the Wellers Road Overbridge, based on the fitted General Pareto Distribution function, is provided in Table 2.3.

Table 2.3 Probabilities of exceedance for incremental horizontal mid-ordinate deviations for survey bays located from the nearest goaf edge at Wellers Road Overbridge

LW	Offset distance from Wellers Road Overbridge (m)	Probability of Exceedance	
		1 in 20 (0.05)	1 in 100 (0.01)
		Incremental horizontal mid-ordinate deviation (mm)	Incremental horizontal mid-ordinate deviation (mm)
LW S4A	690	9	14
LW S5A	415	9	16
LW S6A	365	10	17
LW S7A	520	9	15

Calculating probabilities of exceedance for total differential horizontal movements due to the extraction of multiple longwalls is a complex statistical exercise. It would not be appropriate to simply sum the values for each longwall in Table 2.2 and Table 2.3 together and assign the same probability as they can be considered to be statistically independently events. On the other hand, the probability of exceeding the sum of the values in the tables may be higher than the product of the probabilities.

It is also noted that survey tolerance contributes a significant proportion of the values in the tables, such that summing them together would effectively be doubling, tripling or quadrupling the influence of survey tolerance.

To address this issue, it is recommended to consider the probability of exceedance on a longwall by longwall basis. It is noted that there is a significant period of time of approximately 8 months between the commencement of each longwall. Potential impacts on the Overbridge will be managed during the extraction of each longwall. In the event that higher than expected differential movements are observed, there is time for Tahmoor Coal, TfNSW and ARTC to assess the latest monitoring results and consider implementing additional controls, or modifying the start position of the next longwall, in accordance with this Management Plan.

3.1. Description and setting of Wellers Road Overbridge

The Wellers Road Overbridge spans across the Main Southern Railway at 101.162 km. The 8.27 metre single-span dual lane masonry arch bridge is comprised of a concrete arch on masonry abutments with masonry parapet walls. The concrete arch appears to have been reinforced with old steel rails but they have not been exposed to confirm they exist. The concrete arch has, therefore, been conservatively assessed as unreinforced (JMA, 2022b and 2024). A photograph of the Overbridge is shown in Fig. 3.1.

Fig. 3.1 Wellers Road Overbridge

The overbridge was constructed in 1919 as part of the major duplication of the Main Southern Railway. The Bridge is listed as an Item of Heritage Significance on the Wollondilly Local Environmental Plan (2011).

A photograph of the road pavement over the Overbridge is shown in Fig. 3.2. The brick parapet walls have experienced impacts from vehicle traffic.

Photograph courtesy JMA Solutions (2022b) with blue lines where crack gauges are recommended

Fig. 3.2 Wellers Road pavement on Overbridge

Newcastle Geotech (2022) has conducted a geotechnical investigation and advised the following:

- The Bridge is founded on a cutting that is 3 metres high, with approximately 2 m high engineered fill over the crest of the cutting at the bridge abutments.
- The cutting is listed in the ARTC Geotechnical Risk Site database with a very low risk classification of 6 (non-active site).
- A site inspection at the Overbridge found no obvious evidence of current or past cutting instability or fault structures.

3.2. Current condition of Overbridge

The Wellers Road Overbridge is owned by Transport for NSW. The Bridge is currently maintained under contract by UGL RL.

Tahmoor Coal has conducted structural inspections to assess the existing condition of the Bridge:

- Structural inspection by JMA Solutions (2022b), who advises that the Bridge has been inspected from ground level and Elevated Work Platform (EWP) and appears to be in serviceable condition but cracking is observed on the brick parapet walls. Horizontal bed joint cracks were observed along the parapet walls on the Sydney and Country spandrel wall on the upside, which could be related to transient live load and earth pressure acting against the spandrel walls.
- The concrete arch was tested with 300-400 hammer sounding blows from the EWP and found to return crisp return sound.
- As recommended by JMA, crack gauges have been installed on the parapet walls, at the locations shown in Fig. 3.2. The gauges have been inspected after the mining of LWs S1A and S2A with no measurable changes observed.

3.3. Kinematic envelope study

A kinematic envelope study at the Overbridge was conducted by Southern Rail Surveys in November 2022. A kinematic envelope diagram was prepared by Pidgeon Civil Engineering (PCE) in December 2022 and the results are shown in Fig. 3.3.

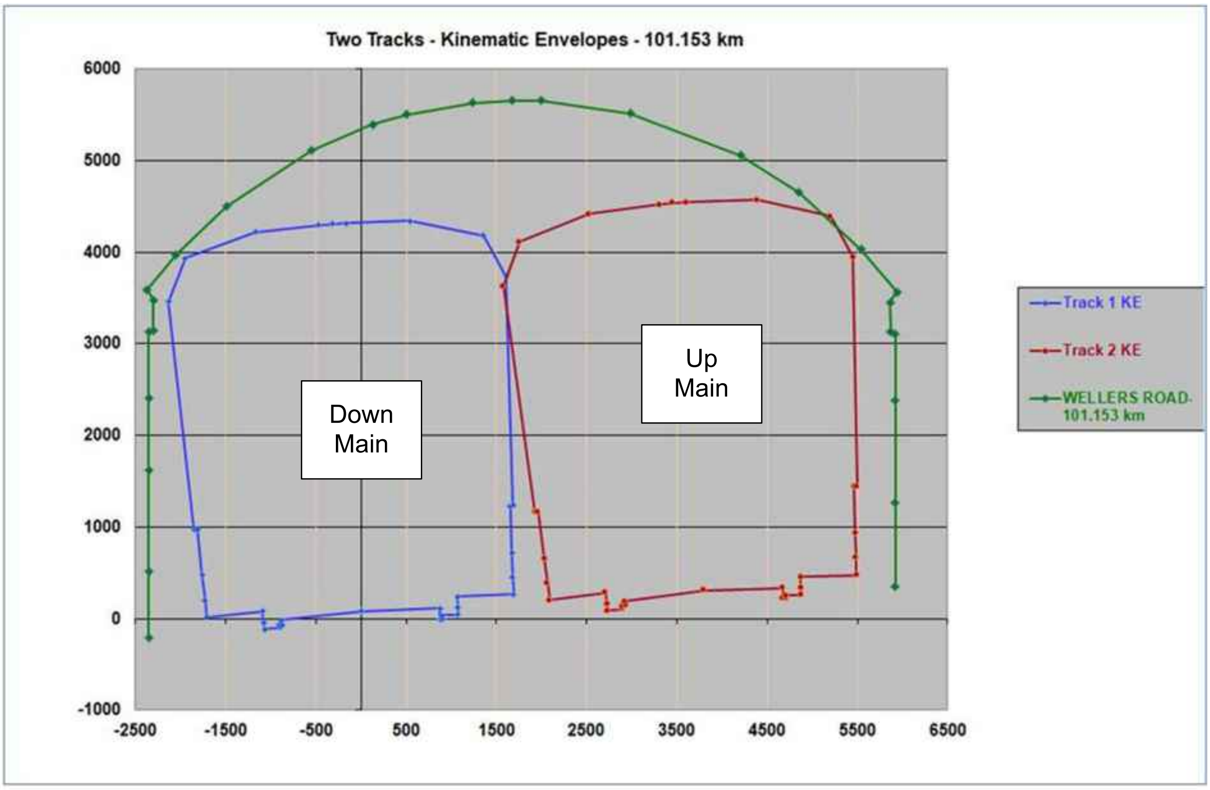


Diagram courtesy PCE

Fig. 3.3 Kinematic Envelope Study of Wellers Road Overbridge in November 2022

The study measured an infringement on the Up Main due to the elevation of the track. The kinematic envelope defines the outer shape of a theoretical maximum rolling stock with allowances for poor track geometry and track speeds. A measured infringement does not necessarily imply imminent train strike but notifies the rail maintainer (ARTC) to rectify the track within a defined timeframe, depending on the severity of the infringement roughness of the track on the approaches to the Overbridge. While track geometry surveys measured Cant to be within tolerances, PCE noted that rough track was present on the approaches in November 2022.

ARTC re-railed the track through the Overbridge in November 2024 and at the request of ARTC, Tahmoor Coal has monitored changes in height between the track and the underside of the arch for ARTC on a fortnightly basis since the track re-railing works were completed.

As there has been negligible change in heights since the re-railing works, ARTC has requested that survey frequency for future surveys be in accordance with planned frequency of local 3D bridge surveys in accordance with this Management Plan. ARTC has also developed a works plan to lower the Up Main to remove the infringement.

Whilst the extraction of LWs S4A to S7A is unlikely to adversely affect kinematic envelope clearances, Tahmoor Coal will continue to monitor changes in span and changes in height between the rails and the arch during the mining of LWs S4A to S7A in accordance with the frequencies for local 3D surveys, as described in this Management Plan.

3.4. Structural investigation and assessment

JMA Solutions (2024) has conducted a structural investigation and assessment of the Bridge and advised the following:

- The Bridge has been inspected and appears to be in a serviceable condition;
- Structural assessments for the Bridge were developed based on the geometry of the structure and material properties gathered from previous investigations of nearby concrete arch, masonry railway bridges, particularly the former Bridge Street Overbridge at Picton and the Thirlmere Way Overbridge at Tahmoor;
- A targeted structural analysis of the arch has been conducted, using material properties that were sampled and tested from the nearby Thirlmere Way Overbridge at Tahmoor that was built at the same time as the Wellers Road Overbridge. The structural modelling was built from lessons learnt during the structural assessment for the Bridge Street Overbridge at Picton prior to the extraction of LW 28;
- The analysis has identified mining-induced opening or closure across the span of the arch as the primary mechanism that could adversely impact on the structural integrity of the Overbridge, and that the capacity of the arch to accommodate the changes would be reduced if one abutment moved laterally or sideways relative to the other abutment. The structural analysis incrementally applied increasing opening and closure between the base of the abutment walls up to 25 mm of opening and closure, with up to 3 mm sideways shear displacement and found that the Wellers Road Overbridge would experience cracking but remain serviceable; and
- Notwithstanding the above, an early warning trigger of 5 mm opening or closure is recommended to be adopted in the Management Plan to initiate further inspections and assessments. The trigger level is sufficiently low that response measures can be implemented early before severe impacts develop, to ensure that the Overbridge remains safe and serviceable during and after mining.
- A number of feasible measures were identified that could be implemented to strengthen or repair the Overbridge if required, which are listed in the following section.

Following consultation between Tahmoor Coal and the Resources Regulator during the Regulator's review of the ARTC Management Plan, Tahmoor Coal appointed a Bridge Technical Committee to review the findings from site investigations and structural assessments. A peer review of the structural assessment for the Wellers Road Overbridge was completed by Arcadis in November 2022, who advised that the conclusions and recommendations in the structural assessment report were acceptable.

3.5. Selection of risk controls for Overbridge

Based on recommendations in the structural assessment, Tahmoor Coal has developed and selected risk control measures in consultation, co-ordination and co-operation with TfNSW and ARTC in accordance with WHS legislation to manage mining-induced changes on the Bridge due to the extraction of LWs S1A to S7A.

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

In this instance, no reasonably practicable controls could be identified to prevent or minimise risks.

Administrative Controls

The following Administrative Control was identified and selected that will put in place procedures on site to minimise the potential of impacts on the safety of the Bridge:

- Continuous GNSS monitoring adjacent to the Wellers Road Overbridge (GNSS unit S15);
- Local 3D surveys of structure and ground marks on the Bridge, as shown in Drawing No. MSEC1193-19-02;
- Continuous laser distancemeter and draw wire displacement monitoring along and across the abutments, including the diagonal;
- Measurement of crack gauges, as recommended by structural engineer;
- Visual inspections of the Bridge; and
- Implementation of planned responses, if triggered by monitoring results. These may include:
    - Inspections by structural engineer;
    - Assess the latest results and observations and consider management actions;
    - Increase monitoring and reporting procedures;
    - Install rolled steel reinforcement straps to the underside of the concrete arch;
    - Install mesh to underside of the arch to catch potential falling pieces of concrete;
    - Install shear reinforcement into brickwork in response to shear movements across the brick arch;
    - Install a temporary support structure within the road pavement to provide temporary support to the arch;
    - Provide additional support to parapet walls;
    - Repair cracked brickwork; and/or
    - As a last resort emergency response measure, reduce the operational load capacity of the structure until repairs can be made.

With the implementation of the above management strategy, Tahmoor Coal will ensure that the health and safety of people in the vicinity of the Wellers Road Overbridge will not be put at risk due to differential mine subsidence movements due to the extraction of LWs S4A to S7A.

It is noted that planned measures to control risks to the Bridge will be continuously reviewed during the extraction of LW S4A-S7A. As each longwall progressively extracts closer to the Bridge it will be possible to introduce additional controls if required in the event that unexpected adverse changes are observed.

It will also be possible to adjust the start position of successive longwalls if greater than expected differential movements or impacts are observed at the Overbridge.

4.1. Main Risk Assessment

A risk assessment for the mining of LWs S1A to S6A beneath and adjacent to the railway was conducted in August 2021 via MSTeams, which was facilitated by Hawcroft Miller Swan Consultants (HMS). The risk assessment was built upon the experience gained from the mining of Tahmoor Longwalls 25 to 32 in addition to the experience gained during the mining of Appin Longwalls 703 to 708 and Appin Longwalls 901 and 902.

Details of the methods and results of the risk assessment is provided in a report by HMS (2021). A brief summary is provided below.

The risk assessment was attended by representatives from the following organisations, companies and consultants:

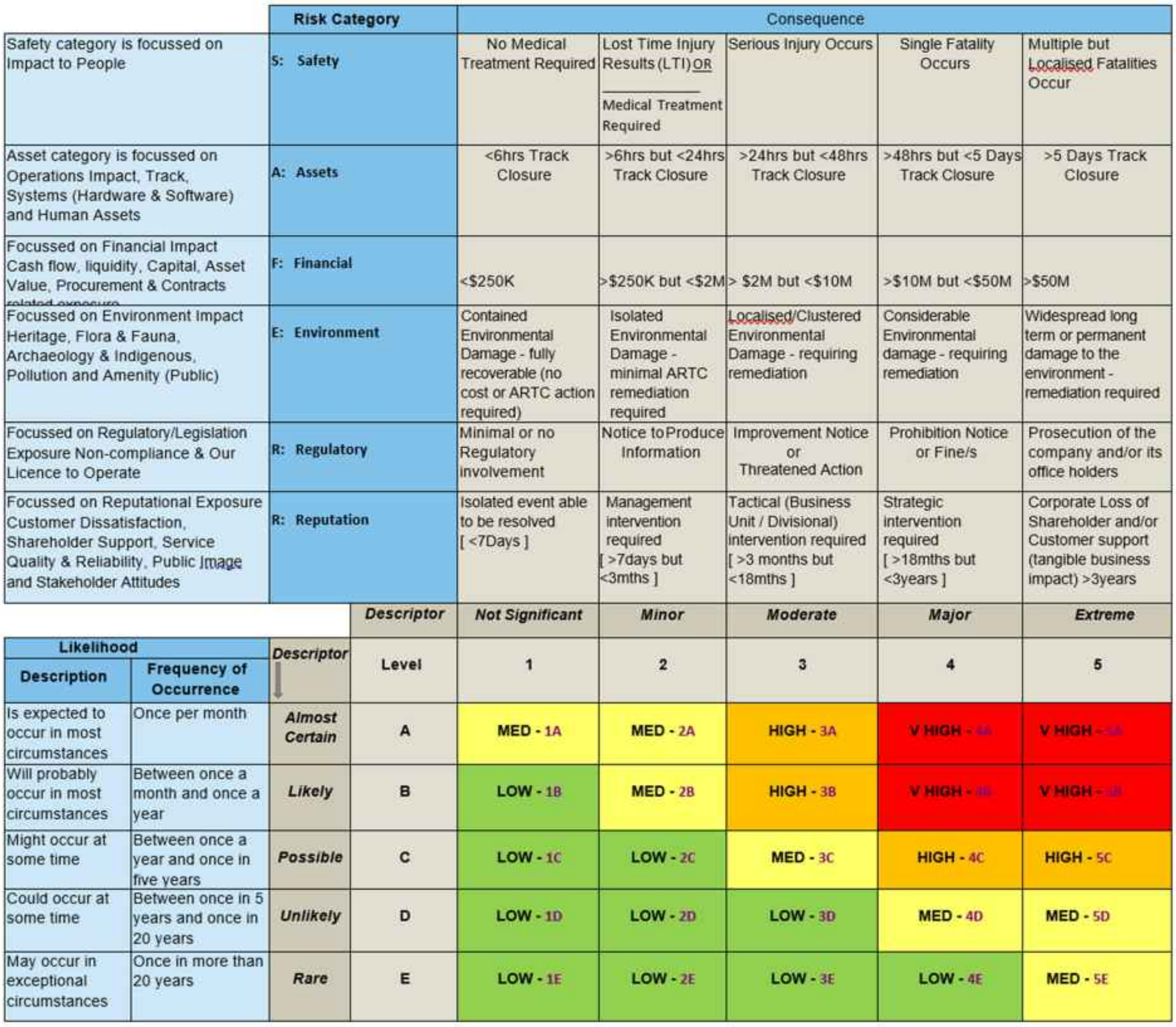
- Australian Rail Track Corporation
- Robinson Rail
- Globetech
- John Matheson & Associates
- Mine Subsidence Engineering Consultants
- Newcastle Geotech
- Pidgeon Civil Engineering
- Bloor Rail
- Tahmoor Coal

The Structures Specialist and Track Specialist from the ONRSR attended the risk assessment as an observer.

The risk analysis was conducted with the purpose of identifying risks associated with the mining of LWs S1A to S6A beneath and adjacent to the Main Southern Railway infrastructure. The risk assessment was conducted in accordance with AS/NZS ISO 31000:2018, using the ARTC Risk Management Procedure, dated 26 May 2016. The risk matrix and definitions are shown in Fig. 4.1.

The risks were assessed taking into account existing and planned controls. The risks were ranked as Low (L), Medium (M), High (H) or Very High (VH).

Wellers Road Overbridge was included in the risk assessment and the results for the Overbridge are shown in Table 4.1. These results are used as a basis for the development of risk control procedures, which are provided in Chapter 4.



	Risk Category	Consequence				
Safety category is focussed on Impact to People	**S: Safety**	No Medical Treatment Required	Lost Time Injury Results (LTI) OR Medical Treatment Required	Serious Injury Occurs	Single Fatality Occurs	Multiple but Localised Fatalities Occur
Asset category is focussed on Operations Impact, Track, Systems (Hardware & Software) and Human Assets	**A: Assets**	<6hrs Track Closure	>6hrs but <24hrs Track Closure	>24hrs but <48hrs Track Closure	>48hrs but <5 Days Track Closure	>5 Days Track Closure
Focussed on Financial Impact Cash flow, liquidity, Capital, Asset Value, Procurement & Contracts	**F: Financial**	<$250K	>$250K but <$2M	> $2M but <$10M	>$10M but <$50M	>$50M
Focussed on Environment Impact Heritage, Flora & Fauna, Archaeology & Indigenous, Pollution and Amenity (Public)	**E: Environment**	Contained Environmental Damage - fully recoverable (no cost or ARTC action required)	Isolated Environmental Damage - minimal ARTC remediation required	Localised/Clustered Environmental Damage - requiring remediation	Considerable Environmental damage - requiring remediation	Widespread long term or permanent damage to the environment - remediation required
Focussed on Regulatory/Legislation Exposure Non-compliance & Our Licence to Operate	**R: Regulatory**	Minimal or no Regulatory involvement	Notice to Produce Information	Improvement Notice or Threatened Action	Prohibition Notice or Fine/s	Prosecution of the company and/or its office holders
Focussed on Reputational Exposure Customer Dissatisfaction, Shareholder Support, Service Quality & Reliability, Public Image and Stakeholder Attitudes	**R: Reputation**	Isolated event able to be resolved [<7Days]	Management intervention required [>7days but <3mths]	Tactical (Business Unit / Divisional) intervention required [>3 months but <18mths]	Strategic intervention required [>18mths but <3years]	Corporate Loss of Shareholder and/or Customer support (tangible business impact) >3years
	Descriptor	***Not Significant***	***Minor***	***Moderate***	***Major***	***Extreme***

Likelihood		***Descriptor***	**Level**	**1**	**2**	**3**	**4**	**5**
Description	**Frequency of Occurrence**							
Is expected to occur in most circumstances	Once per month	***Almost Certain***	**A**	**MED - 1A**	**MED - 2A**	**HIGH - 3A**	**V HIGH - 4A**	**V HIGH - 5A**
Will probably occur in most circumstances	Between once a month and once a year	***Likely***	**B**	**LOW - 1B**	**MED - 2B**	**HIGH - 3B**	**V HIGH - 4B**	**V HIGH - 5B**
Might occur at some time	Between once a year and once in five years	***Possible***	**C**	**LOW - 1C**	**LOW - 2C**	**MED - 3C**	**HIGH - 4C**	**HIGH - 5C**
Could occur at some time	Between once in 5 years and once in 20 years	***Unlikely***	**D**	**LOW - 1D**	**LOW - 2D**	**LOW - 3D**	**MED - 4D**	**MED - 5D**
May occur in exceptional circumstances	Once in more than 20 years	***Rare***	**E**	**LOW - 1E**	**LOW - 2E**	**LOW - 3E**	**LOW - 4E**	**MED - 5E**

Source: HMS (2021)

Fig. 4.1 ARTC Risk Matrix and Definitions

Table 4.1 Summary of Risk Assessment

Aspect, Consideration Risk Issue	Potential Consequence Description	Consequence	Likelihood	Level of Risk
Wellers Road Bridge at 101.162 km – due to impacts on bridge serviceability	Speed restrictions Road traffic control Unplanned maintenance response	Not significant	Rare	Low

4.2. 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 2, which could rise to risks to health and safety of people in the vicinity of the Main Southern Railway.

Mine subsidence hazards have been identified, investigated and analysed in a systematic manner by examining each aspect of the Overbridge, as described in Section 3.0 of this Management Plan.

The following mine subsidence hazards were identified that could give rise to risks to health and safety due to the extraction of LW S1A-S7A.

- Falling concrete or brickwork onto the track

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 2.3 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 railway infrastructure, as discussed in Section 1.9 and Chapter 2 of this Management Plan. In this case, geotechnical inspections have not identified the presence of geological structures in the cutting that supports the Overbridge.

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 in the vicinity of the Wellers Bridge Overbridge. These are described in Chapter 5 of this Management Plan.

5.1. Roles and Responsibilities

5.1.1. Transport for NSW

Transport for NSW (TfNSW) is the owner of Wellers Road Overbridge as part of the Country Regional Network (CRN). TfNSW has awarded a contract to United Group Regional Linx (UGL RL) to maintain the Overbridge.

5.1.2. UGL RL

UGL RL are TfNSW's maintenance contractor for the Overbridge and are responsible for maintaining the structure inspection cycle, structure reporting, completing minor repairs and providing capital works.

5.1.3. ARTC Manager – Ingleburn

The ARTC Manager – Ingleburn Is responsible for taking the necessary actions required to manage the potential for impacts to rail infrastructure due to the development of mine subsidence movements.

5.1.4. ARTC Train Control - Junee

The ARTC Train Control – Junee is responsible for controlling the passage of trains along the Main Southern Railway and recording track protection activities. There is a routine communication protocol between the ARTC Ingleburn, ARTC Train Control and qualified track certifiers. All rail traffic management activities required to address the potential impacts of mine subsidence will be undertaken in accordance with this communication protocol.

5.1.5. Rail Maintenance Contractor

Tahmoor Coal has appointed Bloor Rail as its self-performing operator to act as its Rail Maintenance Contractor (RMC). The RMC acts as the site safety manager for the section of rail corridor that will be affected by mine subsidence during the mining of each longwall.

The Rail Maintenance Contractor is responsible for:

- Assessing and certifying of track within the affected area, which includes inspecting the Overbridge;
- Coordinating responses to issues that occur on site, whether they are mining or non-mining related, including reporting and closing out of alarms;
- Ensuring that site work is undertaken safely in the accordance with relevant OH&S legislation and ARTC Network rules and procedures by its employees and other contractors working for Tahmoor Coal on site;
- Undertaking track-related work; and
- Direct point of contact to ARTC for rail maintenance.

5.1.6. Track Certifier

As part of the Rail Maintenance Contractor's obligations, it will provide a Track Certifier who is qualified to certify the track and railway structures. The RMC Track Certifier is responsible for:

- Visual inspections of track and structures within the rail corridor, including railway structures;
- Assessing and certifying the track;
- Undertaking manual track geometry measurements using standard ARTC methods, if required;
- Direct point of contact with ARTC Area Manager (Ingleburn) and Train Control at Junee, and Tahmoor Coal Control Centre.

ARTC may directly implement speed restrictions or stop trains. The RMC Track Certifier also has authority to take these actions. Communications with ARTC Train Control and ARTC Ingleburn will be conducted via the RMC Track Certifier.

The RMC Track Certifier will implement an action (such as a corrective action, or a speed restriction or stop trains) based on the following:

- Observations or measurement of a track exceedent; or
- Instructions from the RRG and/or RSRG; or
- Instruction from ARTC.

5.1.7. Rail Management Group (RMG)

The RMG is responsible for taking the necessary actions required to manage the risks that are identified from monitoring of the rail infrastructure. Members of the RMG include:

- ARTC Manager – Ingleburn
- ARTC Property Manager Wagga Wagga
- Tahmoor Coal Project Manager
- Bloor Rail (Rail Maintenance Contractor, RMC)
- Globetech (Automated Monitoring Contractor for track)
- Newcastle Geotech (geotechnical engineer)
- Graeme Robinson (Project Manager);
- JMA Solutions (structural engineer)
- Mine Subsidence Engineering Consultants (subsidence engineer);
- Pidgeon Civil Engineering (rail engineer);
- Sweeting Consulting (Automated Monitoring Contractor for Overbridge);
- Tahmoor Coal appointed inspector of Wellers Road and parapet walls.

TfNSW, MSI, ONRSR and Subsidence Advisory NSW may participate in Rail Management Group meetings as observers.

The RMG will meet in person or via teleconference at regular intervals during mining. The RMG will review the monitoring results and consider whether any additional actions are required.

The purpose of the reviews are to:

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

5.1.8. Bridge Technical Committee

Following consultation between Tahmoor Coal and the Resources Regulator, Tahmoor Coal appointed a Technical Committee to review the findings from site investigations and structural assessments, which was completed in November 2022.

The Bridge Technical Committee will be reconvened if triggers for the Overbridge are exceeded to review the latest monitoring results and planned response measures.

5.1.9. Alternative contacts

All members of the RMG have provided alternative contacts during the mining period. The alternative contacts can be contacted should the primary contact be unavailable.

Members of the RMG may arrange substitutes to attend RMG meetings on their behalf.

5.2. 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 infrastructure owner 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 5.3. 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 S4A-S7A.

5.3. Selection of Risk Controls for Railway Infrastructure

Based on the above assessments, Tahmoor Coal considered Method A and Method B risk control measures, in accordance with the process described in Section 5.2.

Based on recommendations in the structural assessment, Tahmoor Coal has developed and selected risk control measures in consultation, co-ordination and co-operation with TfNSW and ARTC in accordance with WHS legislation to manage mining-induced changes on the Bridge due to the extraction of LWs S4A to S7A.

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

In this instance, no reasonably practicable controls could be identified to prevent or minimise risks.

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 Overbridge:

- Implementation of a Monitoring Plan and Trigger Action Response Plan (TARP)
  As described in the Management Plan, Tahmoor Coal, TfNSW and ARTC have 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 safety and serviceability develop.

  Monitoring measures are described in Section 5.4. Trigger levels are described in Section 5.5. Planned responses are described in Section 5.6. Risk control procedures (TARP) are described in Section 5.7 and Table A.1 in Appendix A. A summary is provided below.

- Continuous GNSS monitoring at the Wellers Road Overbridge (GNSS unit S15);
- Local 3D surveys of structure and ground marks on the Bridge, as shown in Drawing No. MSEC1193-19-02;
- Continuous laser distancemeter and draw wire displacement monitoring along and across the abutments, including the diagonal;
- Measurement of crack gauges, as recommended by structural engineer;
- Visual inspections of the Bridge; and
- Implementation of planned responses, if triggered by monitoring results. These may include:
  - Inspections by structural engineer;
  - Assess the latest results and observations and consider management actions;
  - Increase monitoring and reporting procedures;
  - Install rolled steel reinforcement straps to the underside of the concrete arch;
  - Install mesh to underside of the arch to catch potential falling pieces of concrete;
  - Install shear reinforcement into brickwork in response to shear movements across the brick arch;
  - Install a temporary support structure within the road pavement to provide temporary support to the arch;
  - Provide additional support to parapet walls;
  - Repair cracked brickwork; and/or
  - As a last resort emergency response measure, reduce the operational load capacity of the structure until repairs can be made.

With the implementation of the above management strategy, Tahmoor Coal will ensure that the health and safety of people in the vicinity of the Wellers Road Overbridge will not be put at risk due to differential mine subsidence movements due to the extraction of LWs S4A to S7A.

It is noted that planned measures to control risks to the Bridge will be continuously reviewed during the extraction of LW S4A-S7A. As each longwall progressively extracts closer to the Bridge it will be possible to introduce additional controls if required in the event that unexpected adverse changes are observed.

It will also be possible to adjust the start position of successive longwalls if greater than expected differential movements or impacts are observed at the Overbridge.

5.4. Monitoring Plan

A plan showing the monitoring locations above and around LWs S1A to S7A is shown in Drawing No. MSEC1193-01-01. A detailed plan showing the locations of survey pegs and laser distancemeters at the Wellers Road Overbridge is shown in Drawing No. MSEC1193-19-02.

Should adverse movements develop at the Overbridge during mining, it is considered that, with the measures that are described in this Management Plan, they can be detected early before they exceed trigger levels.

While very rapid changes have not previously been recorded in the Southern Coalfield, it is considered that the prime inspection and monitoring systems of daily visual inspections will initiate planned responses, including the immediate slowing or stopping of trains if required. Data from automated, continuous laser distancemeter monitoring can also be downloaded at shorter intervals of time, if required.

5.4.1. 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 Drawing No. MSEC1193-01-01 and the GNSS units that are relevant to managing Wellers Road Overbridge are summarised below:

- Wellers Road Overbridge - GNSS unit S15 has been installed at the western end of Wellers Road Overbridge to measure absolute 3D movements. The results will trigger surveys of the Bridge if they exceed trigger levels.
- GNSS unit S28 at 100.700 km – A GNSS unit has been installed on the Upside of the rail corridor above the centreline of LW S5A. The GNSS unit will monitor the initial development of subsidence following the commencement of LWs S4A to S6A.

5.4.2. Absolute 3D survey at the Overbridge

Ground survey mark WR1 has been installed on the Down Country side of the Bridge. The peg is surveyed in absolute 3D and provides a method of comparison with the results from the GNSS unit S15 and redundancy in the unlikely event that S15 is damaged during the monitoring period.

5.4.3. Local 3D Ground and Structure Surveys at the Bridge

Tahmoor Mine will conduct local 3D surveys of the abutments, arch and spandrel walls on the Overbridge structure and in the ground at the bridge approaches. The plan locations of the survey marks are shown in Drawing No. MSEC1193-19-02. In addition to the above, the survey will also measure changes in height between the track and the underside of the arch, as requested by ARTC.

A long-section view showing the locations of survey marks on the Overbridge is shown in Fig. 5.1.

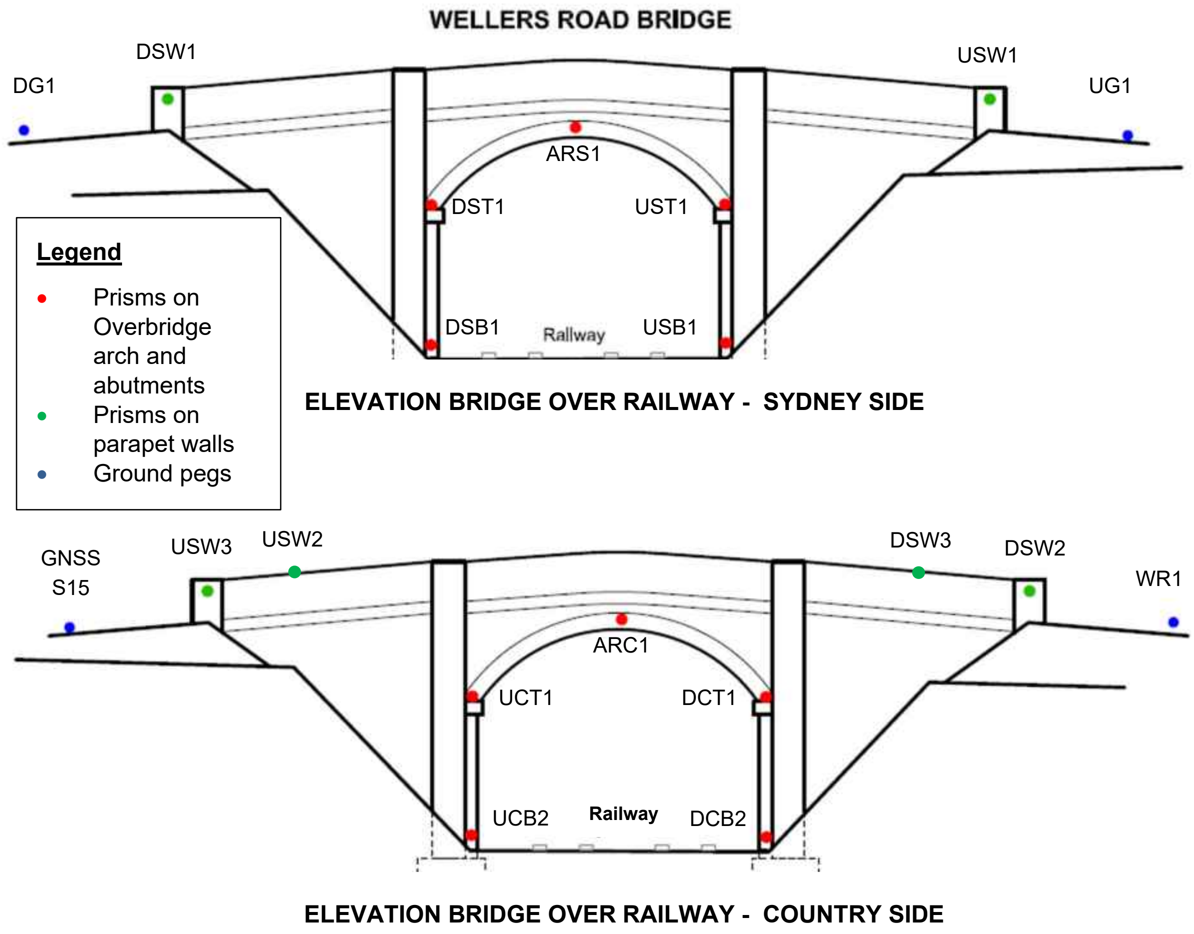


Fig. 5.1 Long-section showing locations of survey marks on Overbridge

5.4.4. Laser Distancemeters and Draw Wire Displacement Sensors

Four laser distancemeters and two draw wire displacement sensors have been placed to continuously measure distances across the abutments. The sensors are mounted at the tops of the abutments, near the base of the arch as recommended by structural engineer John Matheson & Associates. The locations are shown on Drawing No. MSEC1193-19-02. A photograph showing two laser distancemeters, a draw wire sensor and survey prism DST 1 on the Down / Sydney side are shown in Fig. 5.2.

Photograph courtesy Sweeting Consulting

Fig. 5.2 Two laser distancemeters, a draw wire sensor and survey prism DST1 on Down Sydney side of Overbridge

5.4.5. Ground Monitoring along the Main Southern Railway

2D and 3D ground surveys will be undertaken along the rail corridor during mining by Tahmoor Coal. The survey results will provide general information on the magnitude and development of subsidence along the railway to the north of the Overbridge:

The main survey lines along the Railway consist of short posts nominally every 20 metres on which small mini-prisms are placed for each survey. The southernmost survey peg will be located at 101.160 km, in accordance with the ARTC Management Plan.

5.4.6. Monitoring of Cuttings

The following monitoring will be undertaken during the mining of LW S4A-S7A at the Cutting at 101.162 km:

- Absolute 3D and 2D surveys along a monitoring line along the rail corridor;
- Absolute 3D surveys every 20 metres along the toes and crests of the cutting;
- Visual inspections by Track Certifier and geotechnical engineer.

5.4.7. Ground Surveys along streets

Survey lines have been installed along the Main Southern Railway, Remembrance Drive, Caloola Road, Yarran Road, Charlies Point Road and Great Southern Road, as shown in Drawing No. MSEC1193-01-01 The surveys are relevant to Wellers Road Overbridge in that they provide general information on subsidence behaviour above and adjacent to the longwall panels.

The survey lines consist of pegs spaced nominally every 20 metres. 2D surveys will measure levels and horizontal distances between adjacent pegs. Survey pegs along Remembrance Drive will be surveyed in 2D and 3D (level, eastings and northings). The purpose of the 3D surveys is primarily to assist with monitoring potential impacts on pipelines that run along the road.

Any work within the road reserve, including survey, must be done under an approved Road Occupancy Permit (under Section 138 of the Roads Act) via an application to Council. Tahmoor Coal will ensure that its surveyors will apply to Council prior to conducting surveys within the road reserves.

5.4.8. Visual inspections

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

- Visual inspections of the Bridge from a safe vantage point;
- Visual inspections of the surrounding cutting from a safe vantage point; and
- Measure changes in crack width at crack gauges that have been installed on the parapet walls, as recommended by structural engineer John Matheson & Associates.

5.4.9. Provision of Raw Monitoring Data

Ground monitoring data will be provided by Tahmoor Coal to all members of the RMG and MSI within 48 hours of survey. Automated monitoring data is available to all members of the RMG, TfNSW and ARTC personnel via a password secured website. All other raw monitoring data is available to all members of the RMG upon request.

5.4.10. Changes to Monitoring Frequencies

Monitoring frequencies will continue at the Bridge during the extraction of LW S4A-S7A. Monitoring will continue after mining until observed rates of change reduce to negligible levels.

5.5. Trigger Levels

Trigger levels have been divided into four categories, which relate to the safe operation of the trains as shown in Table 5.1.

Table 5.1 Trigger Levels

Trigger Level	Description
GREEN	Observations within operating tolerance. Operate as normal.
BLUE	Observations within operating tolerance but nearing limits. Investigate cause. Some action may be required to prevent operating restrictions. Immediately inspect site unless it is obvious that the cause of the trigger cannot be due to physical damage to rail infrastructure. Otherwise inspect within 24 hours. Return status to Green level.
YELLOW	Restrictions on operations. Immediate inspection required. Action required within 6 hours. Appropriate speed restriction may apply until altered to Green or Blue Level.
RED	Stop trains, inspect prior to next train, repair to lower category, pilot trains if safe.

The YELLOW and RED triggers are directly related to the safe operation of the trains and are linked to ARTC rail safety standards.

The BLUE trigger level is designed to provide an early warning to provide adequate time to assess and respond and is not linked to rail safety standards. The RMG can review the adequacy of the BLUE trigger level during mining and adjust as agreed, without amending this management plan. Tahmoor Coal will inform TfNSW, ARTC, MSI and ONRSR of the details concerning changes to BLUE triggers made by the RMG. Tahmoor Coal will follow the recommendations of the RMG unless directed to the contrary by TfNSW, ARTC, MSI and ONRSR in relation to these matters.

Early warning trigger levels for Wellers Road Overbridge are included as part of the Risk Control Procedures, which are shown in Appendix A. The trigger levels have been adopted to provide adequate time to respond before impacts occur.

5.6. Response Plan

The following responses are available to reduce the potential for impacts of mining-induced ground movements on the railway. These will be implemented in response to the monitoring data.

The general management strategy is to detect changes in ground movements and structure condition early, monitor the behaviour of the track in response to ground movements and, if necessary, undertake planned additional management measures within the GREEN level to avoid exceeding a BLUE trigger. This is achieved by regular assessment of monitoring results by the Rail Management Group during the mining period, including the forecast of possible exceedences of triggers due to the continued extraction of the longwall.

Immediate Site Inspection

A site inspection will be undertaken by the Track Certifier and Structural Engineer if a trigger is exceeded.

Review by Bridge Technical Committee

The Bridge Technical Committee will be reconvened in the event that a trigger for the Overbridge is exceeded. The Bridge Technical Committee will review the latest monitoring results and review planned response measures by the Rail Management Group.

Wellers Road Overbridge

The following responses are planned in the event of exceedance of trigger levels or observations of impacts on the Wellers Road Overbridge:

- Install rolled steel reinforcement straps to the underside of the concrete arch;
- Install mesh to underside of the arch;
- Install shear reinforcement into brickwork in response to shear movements across the brick arch;
- Install a temporary support structure within the road pavement to provide temporary support to the arch;
- Provide additional support to parapet walls; and/or
- Repair cracked brickwork.

Rail Traffic Management

While the above responses are expected to be undertaken without affecting the operation of the railway, rail traffic can be managed by ARTC if required.

Speed restrictions can be introduced rapidly through the ARTC communications system. Contact is made to ARTC Train Control via a phone call and ARTC Train Control can make contact with train drivers via a direct communications link. In addition to the direct communications link, Train Control can remotely operate the signals via the automated signalling system to stop trains at controlled signals within 5 minutes of being contacted by a Track Certifier.

Reduce operational load capacity of the structure

As for rail traffic management, these are last resort management measures. If required, the operational load capacity of road traffic for the structure can be temporarily reduced until repairs can be made.

Amend start position of future longwalls

As conducted during the mining of LWs S1A to S3A, the Rail Management Group will regularly review monitoring results during the extraction of LWs S4A-S7A.

In the event of greater than expected differential movements or impacts on the Overbridge, the Rail Management Group may recommend to Tahmoor Coal consider adjust the start position of successive, future longwalls to reduce the potential for impacts. As for rail traffic management and operational load capacity management, adaptive management of the mine plan is a last resort management measure.

5.7. Risk Control Procedures

The risk control procedures are discussed in detail throughout this Management Plan and are summarised in Appendix A.

6.1. Reporting of Results

All monitoring results are analysed by designated members of the RMG. The following reports will be provided to the RMG:

Monitoring Measure	Monitoring By	Report By
Ground surveys	SRS	MSEC
GNSS monitoring	Geomatix	MSEC
Structure monitoring	SRS	MSEC
Rail stress, rail temperature and switch displacement	Globetech	PCE
Track geometry	RMC	PCE
Laser distancemeter	Sweeting Consulting	MSEC
Visual track inspections	RMC	RMC
Other railway infrastructure inspections and safety related matters	RMC	RMC
Longwall position	TC	MSEC
Summary Status Report	-	MSEC
RMG Meeting Minutes	-	Robinson Rail

The reports will provide the following information:

- Analysis of results;
- Identify trends and irregularities;
- Compare with predictions (where relevant);
- Forecast possible exceedence of triggers; and
- Recommend whether any further actions are required.
- The timing of reports will vary during the mining period, with frequency aligned with stages of subsidence management.

A one to two page status report will periodically provide the following information:

- Position of longwall relative to railway;
- Summary of management actions since last report;
- Summary of consultation with stakeholders 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 by the RMG whether there will be any subsidence impacts to the operation and safety of the Railway in the next monitoring period due to the continued extraction of LW S1A-S7A.

6.2. Web-based reporting of results

Electronic monitoring data will be posted on the project website, for which access is available to all members of the RMG.

6.3. Communication with MSI and ONRSR

MSI and ONRSR will be kept informed during and after mining via monitoring reports and status reports.

MSI and ONRSR will be informed of changes to management measures separately in writing or by email following authorisation by ARTC. The notification will describe what changes have or will be undertaken to management measures and/or monitoring measures.

Tahmoor Coal will inform TfNSW, ARTC, MSI and ONRSR of the details concerning the loss of monitoring data and decisions taken by the RMG in the monitoring and/or status reports.

7.0 REHABILITATION PLAN

Any damage that occurs due to mining will be repaired by Tahmoor Coal in consultation with TfNSW, ARTC and Subsidence Advisory NSW. Funding of the repairs shall be in accordance with *Coal Mine Subsidence Compensation Act 2017*.

8.0 AUDITING 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.
- 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.
- Observation of significant variation between observed and predicted subsidence.
- Identification of improved methods of managing the identified risks.
- A request by TfNSW to conduct a review.

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APPENDIX A. Risk Control Procedures for LW S4A to S7A

Table A. 1 Risk Control Procedures for LW S4A-S7A

RISK ISSUE	TRIGGER	CONTROL PROCEDURES	TIMING & FREQ	BY WHOM?
General Procedures				
	GREEN	**EARLY WARNING MONITORING**		
		Continuous GNSS monitoring for S1 to S15 as shown in Drawing No. MSEC1201-03	GNSS units S1 to S15 installed Continuous readings, with data averaged over 24 hours and recorded once per day until end of LW S6A.	Tahmoor Coal (Geomatix)
		Continuous GNSS monitoring at 100.70 km (S28)	Install prior to start of LW S4A Continuous readings, with data averaged over 24 hours and recorded once per day until end of LW S6A.	Tahmoor Coal (Geomatix)
		RAILWAY TRACK		
		3D ground survey along rail corridor *Extents for 3D surveys:* LW S4A: *101.16km to 100.14km (AP6) and then extend to the north to include pegs that are at least 400 metres in front of the LW face, up to 98.74 km. (End of LW from 100.90km to 98.38km)* LW S5A: *101.16km to 100.14km (AP6) and then extend to the north to include pegs that are at least 400 metres in front of the LW face, up to 99.10 km. (End of LW from 101.16km to 98.92km)* LW S6A: *101.16km to 100.14km (AP6) and then extend to the north to include pegs that are at least 400 metres in front of the LW face, up to 99.46 km. (End of LW from 101.16km to 99.28km)* LW S7A: *101.16km to 100.14km (AP6) and then extend to the north to include pegs that are at least 400 metres in front of the LW face, up to 99.46 km. (End of LW from 101.16km to 99.28km)*	Monthly 3D surveys commencing as per below: LW S4A: at LW start LW S5A: at LW start LW S6A: at LW start LW S7A: at LW start Surveys continue until 800m of extraction of each LW unless ongoing adverse changes are observed End of LW S4A-S7A.	SRS
		Focussed 2D ground survey along rail corridor *Extents for focussed 2D surveys:* LW S4A: *101.16km to 100.14km (AP6) and then extend to the north to include pegs that are at least 200 metres in front of the LW face, up to 98.74 km. (End of LW from 100.90km to 98.38km)* LW S5A: *101.16km to 100.14km (AP6) and then extend to the north to include pegs that are at least 200 metres in front of the LW face, up to 99.10 km. (End of LW from 101.16km to 98.92km)* LW S6A: *101.16km to 100.14km (AP6) and then extend to the north to include pegs that are at least 200 metres in front of the LW face, up to 99.46 km. (End of LW from 101.16km to 99.28km)* LW S7A: *101.16km to 100.14km (AP6) and then extend to the north to include pegs that are at least 200 metres in front of the LW face, up to 99.46 km. (End of LW from 101.16km to 99.28km)*	Weekly 2D surveys commencing as per below: LWs S4A-S7A: start after GNSS at 100.70km subsides more than 20mm after LW start or 200m extraction, whichever occurs first Surveys continue until 800m of extraction of each LW unless ongoing adverse changes are observed End of LW S4A-S7A.	SRS
		Continuously monitor rail stress, rail temperature and switch displacement *Extents for active subsidence monitoring:* LW S4A: *101.10km to 100.14km (AP6) and then extend to the north to include gauges that are at least 200 metres in front of the LW face, up to 98.74 km.* LW S5A: *101.10km to 100.14km (AP6) and then extend to the north to include gauges that are at least 200 metres in front of the LW face, up to 99.10 km.* LW S6A: *101.10km to 100.14km (AP6) and then extend to the north to include gauges that are at least 200 metres in front of the LW face, up to 99.46 km.* LW S7A: *101.10km to 100.14km (AP6) and then extend to the north to include pegs that are at least 200 metres in front of the LW face, up to 99.46 km. (End of LW from 101.16km to 99.28km)*	Readings every 5 minutes LWs S4A-S7A: at LW start	Globetech
		Track geometry surveys using Amber track mounted device or equivalent *Extents for track geometry surveys as per focussed 2D surveys*	Weekly as per focussed 2D surveys	RMC
		Track inspection by qualified track certifier. The inspection will check ARTC infrastructure within the rail corridor, including the track, integrity of monitoring systems, cuttings and Wellers Road Overbridge *The extent of visual inspections is the same as the extent of track geometry surveys plus dormant expansion switches*	Daily LWs S4A-S7A: start after GNSS at 100.70km subsides more than 20mm after LW start or 200m extraction, whichever occurs first Inspections continue until 800m of extraction of each LW unless ongoing adverse changes are observed	RMC
		CUTTINGS		
		Absolute 3D surveys every 20 metres along the crests and/or toes of the cuttings *Install Cutting at 101.162 km prior to start of LW S5A*	Monthly / weekly as described for railway track Surveys continue until 800m of extraction of each LW unless ongoing adverse changes are observed End of LW S4A-S7A	SRS
		Visual inspection of cuttings by geotechnical engineer	Monthly / weekly as described for railway track Inspections continue until 800m of extraction of each LW unless ongoing adverse changes are observed	Newcastle Geotech

GENERAL TRIGGER LEVELS

Trigger Level	Description
GREEN	Observations within operating tolerance. Operate as normal.
BLUE	Observations within operating tolerance but nearing limits. Investigate cause. Some action may be required to prevent operating restrictions. Immediately inspect site unless it is obvious that the cause of the trigger cannot be due to physical damage to rail infrastructure. Otherwise inspect within 24 hours. Return status to Green level.
YELLOW	Restrictions on operations. Immediate site inspection. Action required within 6 hours. Appropriate speed restriction may apply until altered to Green or Blue Level.
RED	Stop trains, inspect prior to next train, repair to lower category, pilot trains if safe.

ABBREVIATIONS WITHIN THESE TABLES:

CRN = Country Regional Network

ARTC = Australian Rail Track Corporation

MSI = NSW Department of Regional NSW – Mine Safety Inspectorate – Resources Regulator

ONRSR = Office of the National Rail Safety Regulator

SRS = Southern Rail Surveys (ground surveys within rail corridor)

SA NSW = Subsidence Advisory NSW

MSEC = Mine Subsidence Engineering Consultants

RMG = Rail Management Group

RMC = Rail Maintenance Contractor

PCE = Pidgeon Civil Engineering

JMA = JMA Solutions (structural engineer)

SMEC = SMEC (ground surveys beyond rail corridor)

TC = Tahmoor Coal

<table>
<tr><th>RISK ISSUE</th><th>TRIGGER</th><th>CONTROL PROCEDURES</th><th>TIMING & FREQ</th><th>BY WHOM?</th></tr>
<tr><td rowspan="14">General Procedures (continued)</td><td rowspan="14">GREEN</td><td colspan="3">BRIDGES</td></tr>
<tr><td>Pre-mining inspection and structural assessment of Wellers Road Overbridge</td><td>Complete</td><td>JMA</td></tr>
<tr><td>Geological inspection and mapping at Cutting at Wellers Road Overbridge</td><td>Complete</td><td>Newcastle Geotech</td></tr>
<tr><td>Continuous GNSS monitoring including S15 (Wellers Road Overbridge) as shown in Drawing No. MSEC1193-01-01</td><td>GNSS units installed
Continuous readings, with data averaged over 24 hours and recorded once per day until end of LW S7A.</td><td>Tahmoor Coal (Geomatix)</td></tr>
<tr><td>Conduct Local 3D survey of structure and ground marks on the Wellers Road Overbridge as per Drawing No. MSEC1193-19-02. Survey will include measurement of change in height between track and underside of arch, as requested by ARTC.</td><td>Install and baseline survey prior to LW S1A.
Monthly after 200m extraction of LWs S4A to S7A
Surveys continue until 800m of extraction of each LW unless ongoing adverse changes are observed
End of LW S1A-S7A.</td><td>Tahmoor Coal (SRS)</td></tr>
<tr><td>Automated, continuous monitoring of laser distancemeters and draw wire displacement sensors along and across the Overbridge at base of arch</td><td>Installed and operating
Readings every 15 minutes</td><td>Tahmoor Coal (Sweeting Consulting)</td></tr>
<tr><td>Monitoring of existing cracks with crack gauges on Wellers Road Overbridge</td><td>Install and baseline survey prior to LW S4A.
Monthly after 200m extraction of LWs S4A to S7A
Inspections continue until 800m of extraction of each LW unless ongoing adverse changes are observed
End of LW S1A-S7A.</td><td>TC</td></tr>
<tr><td colspan="3">OTHER MEASURES</td></tr>
<tr><td>Undertake investigations as required to assist in identifying potential locations of non-conventional movement. Reconsider management measures in light of new information that becomes available.</td><td>Ongoing</td><td>RMG</td></tr>
<tr><td>Dilapidation inspections</td><td>Complete</td><td>Various</td></tr>
<tr><td>Standard ARTC maintenance and control procedures
- Twice weekly track patrol
- AK track recording car
- Base Operating Standards Mandatory Responses
- Driver reports and temporary speedboards
- Signalling and Communications procedures
- Ultrasonic rail test (high rail)</td><td>As per ARTC procedures</td><td>ARTC</td></tr>
<tr><td>Analyse and report results to RMG</td><td>Monthly</td><td>Section 6.1</td></tr>
<tr><td>RMG discuss results and consider whether any additional management measures are required</td><td>Monthly
LWs S4A-S7A: start after GNSS at 100.70km subsides more than 20mm after LW start or 200m extraction, whichever occurs first</td><td>RMG</td></tr>
<tr><td>RMG discuss progress with MSI and ONRSR</td><td>As required</td><td>RMG</td></tr>
<tr><td rowspan="3">Bridges
Impact on serviceability of bridge resulting in unplanned maintenance.
<table>
<tr><th>Trigger Level</th><th>Measured opening or closure between bridge abutments (beyond seasonal fluctuation)</th></tr>
<tr><td>GREEN</td><td>-</td></tr>
<tr><td>MONITORING REVIEW POINT TRIGGER</td><td>Wellers Road Overbridge > 5 mm
Increase in crack widths by more than 3 mm in widths</td></tr>
</table></td><td rowspan="3">Monitoring Review Point Trigger</td><td>Notify RMG, Bridge Technical Committee and TfNSW, ARTC (incl. ARTC Structures Specialist)</td><td>Within one week</td><td>MSEC</td></tr>
<tr><td>RMG meet and consider whether any additional management measures are required, which may include:
- undertake additional structural inspections
- install and measure changes to additional crack gauges
- increase frequency of surveys and inspections and reporting
- install roller steel reinforcement straps to the underside of the concrete arch;
- install mesh to underside of the arch;
- install temporary support structure within the road pavement to provide temporary support to arch;
- provide additional support to parapet walls; and/or
- repair cracked brickwork
- consider whether to recommend to TC senior management to reduce vehicle loads if impact to rail operations is unacceptable to TfNSW or ARTC
- consider whether to recommend to TC senior management to amend start position of future longwalls further away from Overbridge based on analysis of monitoring data</td><td>As required</td><td>RMG</td></tr>
<tr><td>Report trigger exceedence and RMG decisions to TfNSW, ARTC, MSI, ONRSR and SA NSW</td><td>Within 24 hours</td><td>Tahmoor Coal</td></tr>
</table>

APPENDIX B. Drawings

Drawings

Drawing No.	*Description*	*Revision*
MSEC1193-19-01	General Layout	01
MSEC1193-19-02	Wellers Road Overbridge Monitoring	01
MSEC1193-01-01	Subsidence Monitoring Plan	C

msec mine subsidence ENGINEERING CONSULTANTS
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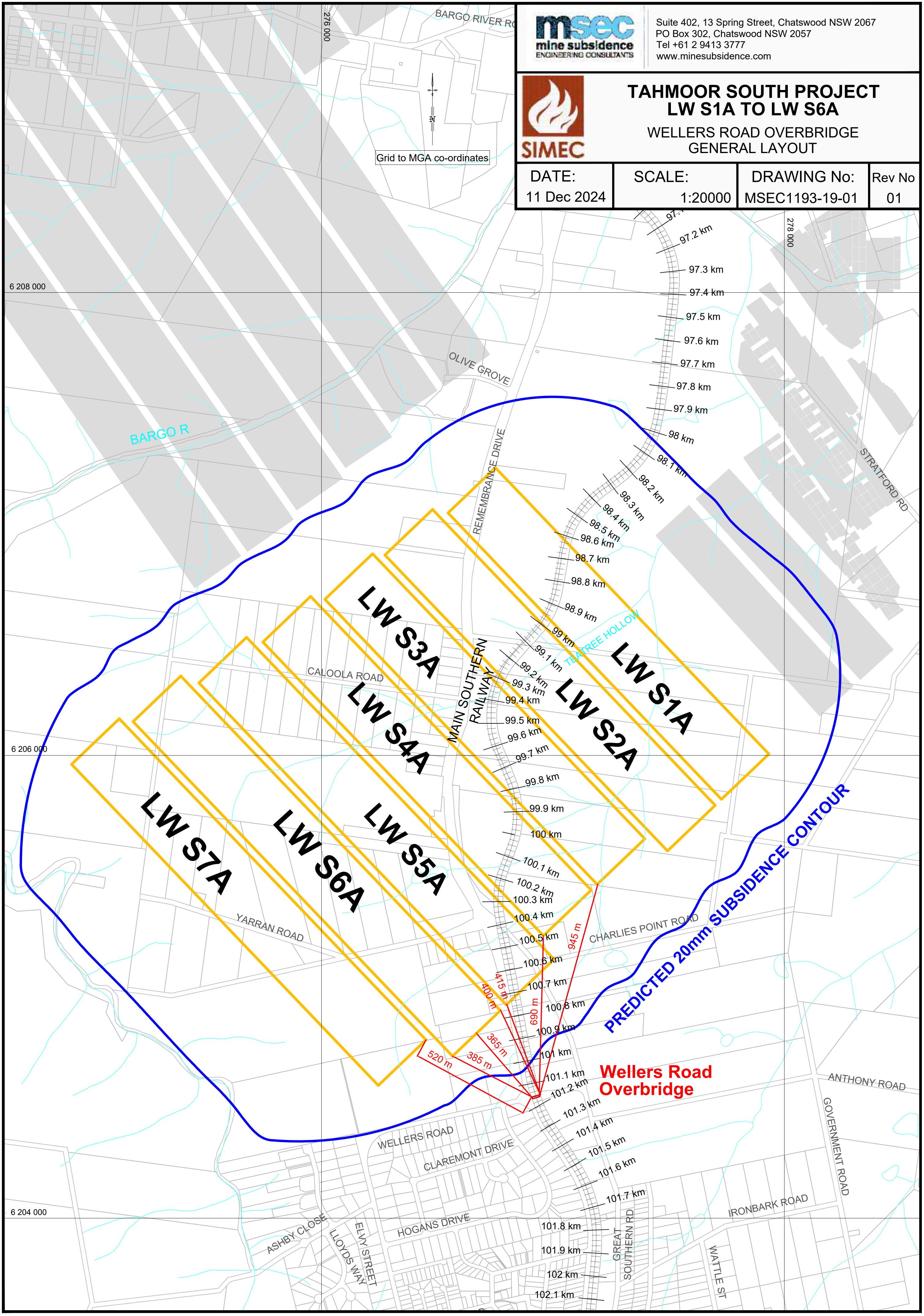
SIMEC

TAHMOOR SOUTH PROJECT
LW S1A TO LW S6A

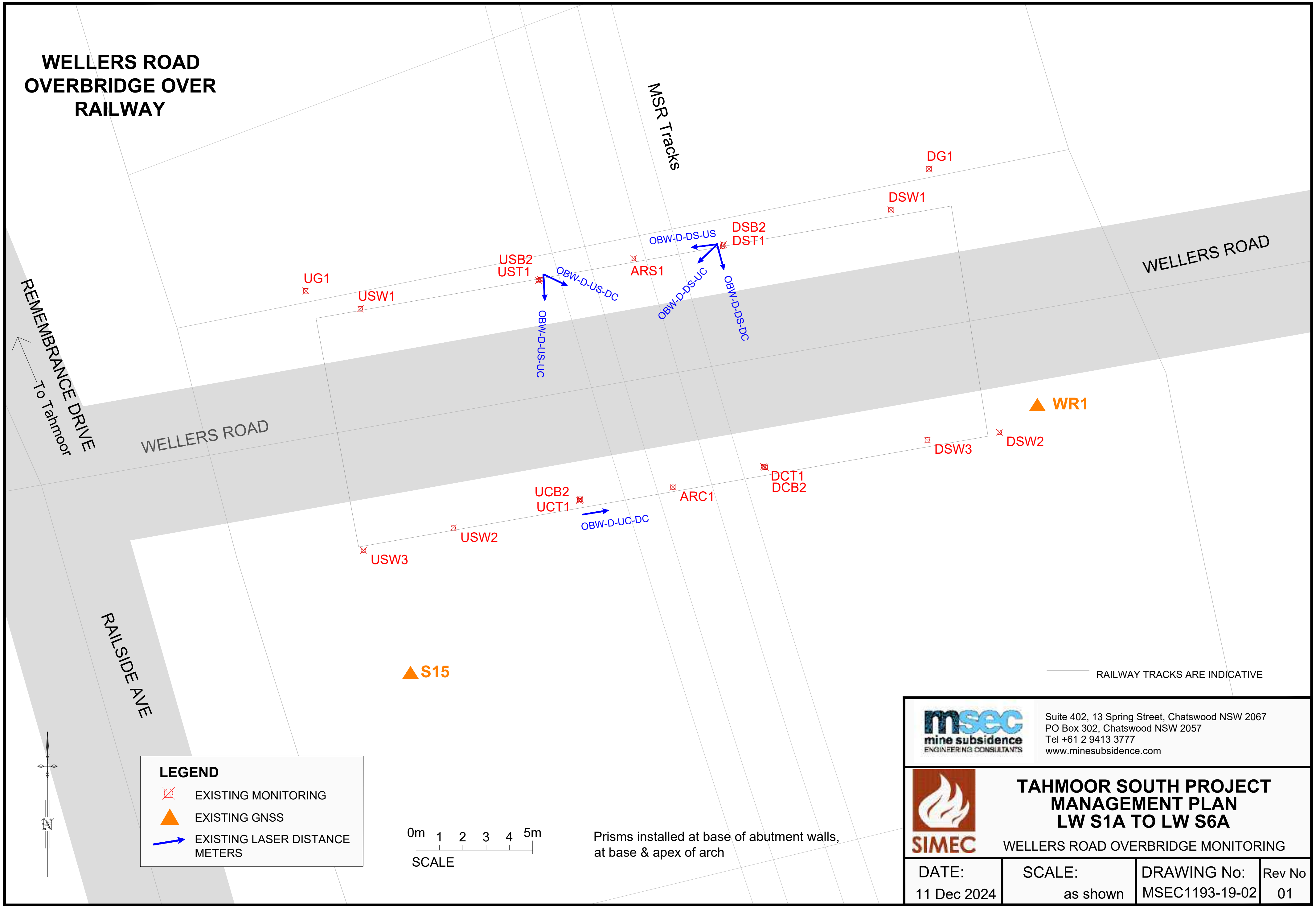
WELLERS ROAD OVERBRIDGE
GENERAL LAYOUT

DATE:	SCALE:	DRAWING No:	Rev No
11 Dec 2024	1:20000	MSEC1193-19-01	01



I:\Projects\Tahmoor South\MSEC1193 - LW S1A-S6A Management Plans\MSEC1193-19 Wellers Rd Overbridge\AcadData\MSEC1193-19-02 Wellers Rd Overbridge.dwg

WELLERS ROAD OVERBRIDGE OVER RAILWAY



RAILWAY TRACKS ARE INDICATIVE

LEGEND

- ☒ EXISTING MONITORING
- ▲ EXISTING GNSS
- → EXISTING LASER DISTANCE METERS

Prisms installed at base of abutment walls, at base & apex of arch

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TAHMOOR SOUTH PROJECT MANAGEMENT PLAN LW S1A TO LW S6A

WELLERS ROAD OVERBRIDGE MONITORING

DATE:	SCALE:	DRAWING No:	Rev No
11 Dec 2024	as shown	MSEC1193-19-02	01

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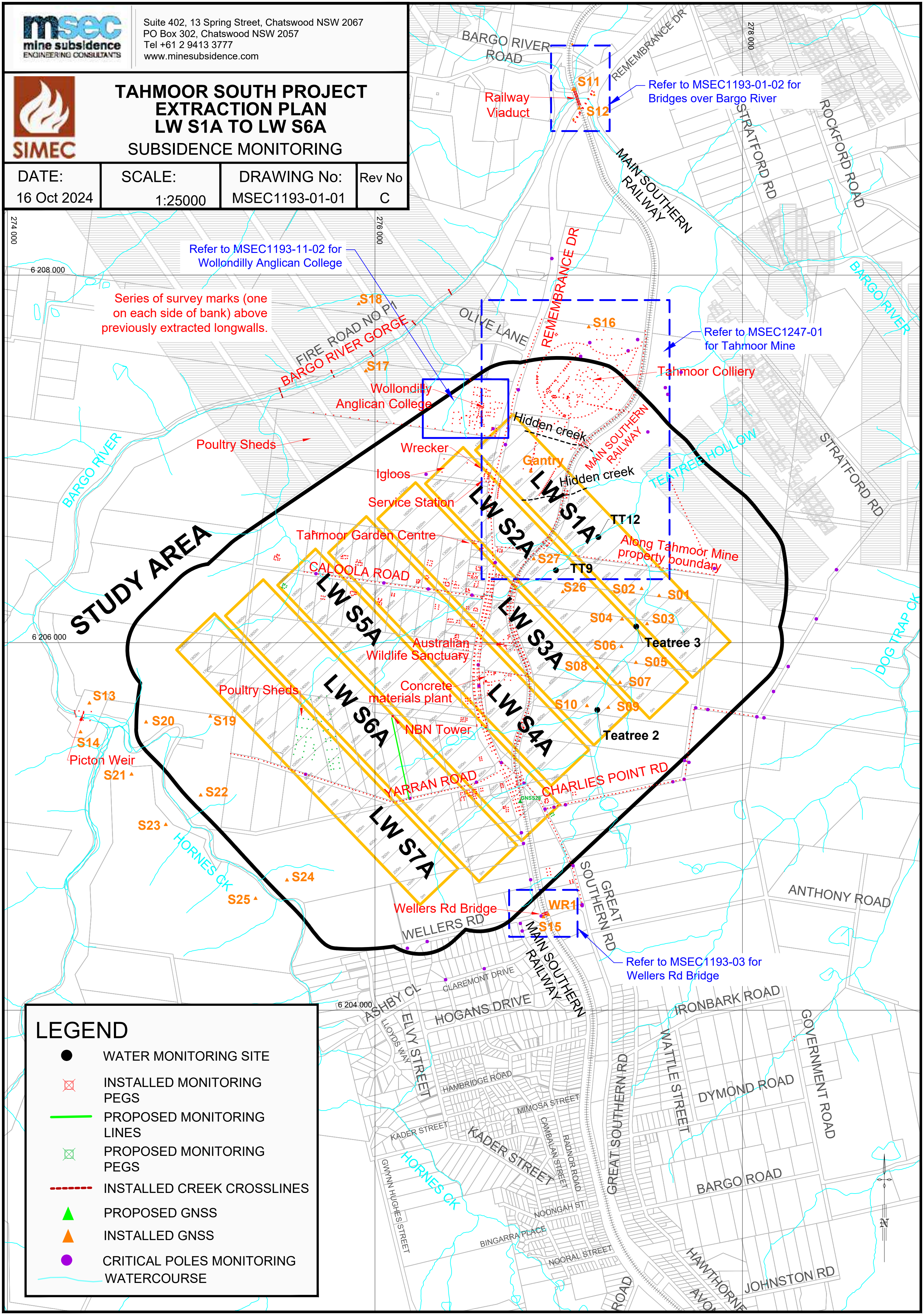
SIMEC

TAHMOOR SOUTH PROJECT EXTRACTION PLAN LW S1A TO LW S6A

SUBSIDENCE MONITORING

DATE:	SCALE:	DRAWING No:	Rev No
16 Oct 2024	1:25000	MSEC1193-01-01	C



LEGEND

- ● WATER MONITORING SITE
- ☒ INSTALLED MONITORING PEGS
- ━ PROPOSED MONITORING LINES
- ☒ PROPOSED MONITORING PEGS
- - - - INSTALLED CREEK CROSSLINES
- ▲ PROPOSED GNSS
- ▲ INSTALLED GNSS
- ● CRITICAL POLES MONITORING
- ～ WATERCOURSE

APPENDIX C. Supporting Documentation

Supporting Documentation

HMS, (2021).	*Tahmoor South Longwalls LW1A – LW6A Potential Impacts on the ARTC's Main Southern Railway Line Risk Assessment*. Report No. HMS1479, Final Report, HMS Consultants, September 2021.
JMA (2024)	*Structure Investigation Report – Impact of Far Field Movement - Wellers Road Overbridge, Bargo*, JMA Solutions, Report No. R0806-R3, January 2024.
Newcastle Geotech (2022)	*Simec Mining – Tahmoor South – Longwalls S1A to S6A – Main Southern Rail – Embankment and Cutting Geotechnical Assessment*, Newcastle Geotech, Report No. 493-8, October 2022.

SIMEC

Tahmoor Coking Coal Operations

Tahmoor South Longwalls LW1A - LW6A Potential Impacts on the ARTC's Main Southern Railway Line Risk Assessment

Final Report
September 2021
HMS 1479

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SIMEC

Tahmoor Coking Coal Operations

Tahmoor South Longwalls LW1A - LW6A Potential Impacts on the ARTC's Main Southern Railway Line Risk Assessment

Final Report

September 2021

HMS 1479

Client:
Mr Ross Barber, Project Manager, Tahmoor

Author:
Mr David Swan, MD, HMS Consultants Pty Ltd

This Report was prepared on the basis of information recorded by HMS Consultants Australia Pty Ltd during August 2021, being the group consensus opinion of the impacts of Tahmoor South Project longwalls on the Main Southern Railway Line.

File	Report	Prepared By	Client Review	Date
20220828 HMS1474 ARTC – Tahmoor South LW1A – 6A Draft Report – V1	Draft	D Swan	Workshop members	Aug 2021
20220828 HMS1474 ARTC – Tahmoor South LW1A – 6A Subsidence Final Report	Final	D Swan	Project Manager	Sep 2021

TABLE OF CONTENTS

Note; An appendix showing impacts on rail infrastructure in risk order has not been included, as all risk were ranked as low risks.

1 EXECUTIVE SUMMARY

HMS Consultants Australia Pty Ltd (HMS) facilitated a risk assessment for Tahmoor Coking Coal Operations (Tahmoor) via MSTeams, on the potential impacts of Tahmoor's South Project extraction of longwalls LW1A - LW6A beneath the Australian Rail Track Corporation (ARTC) managed - Main Southern Railway (MSR), situated in the Bargo NSW region.

This risk assessment also considers the potential subsidence impacts on the Tahmoor balloon rail loop and associated infrastructure.

The indicative longwall schedule has extraction commencing in October 2022.

It is important to note Tahmoor has successfully conducted longwall operations beneath the MSR corridor in the western domain longwalls as well as longwalls 25 - 32 over the past decade. This risk assessment has utilised information where applicable from the previous longwall risk assessments, as well as information extracted from Mine Subsidence Engineering Consultants Pty Ltd (MSEC) Subsidence Management Plans, to consider the potential subsidence impacts of Tahmoor's South Project longwalls LW1A – LW6A on the rail line and associated infrastructure.

This report details the methods used and the recommendations resulting from the risk assessment conducted during August 2021.

The overriding objective of this risk assessment is the development of mitigation strategies, where necessary, to prevent disruptions to railway operations and reduce the level of risk So Far As Is Reasonably Practicable (SFAIRP) for the safety and health of persons travelling on the rail line.

In accordance with the scope, risks relating to the impacts on the railway line and associated infrastructure were identified, considered and recorded by the risk assessment team. The reader should refer to Section 3 of this report for details regarding the objectives, scope, assumptions and limitations of this risk assessment.

In total, the risk assessment team identified thirteen (14) separate risks all of which were considered credible and were subsequently assessed by the workshop team.

All risk items were ranked as **'Low'** risk with the existing "proven over time" risk controls in place.

In relation to NSW WHS legislation and the Planning Approval – Key Performance Measures (see Section 3.4 Objectives), the risk assessment determined that risk items were of a '**Low**' risk ranking, with the identified inherent and mitigation controls implemented.

Additional controls/ actions identified in the risk assessment are listed in the Action Plan in Appendix B.

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

2 INTRODUCTION

HMS Consultants Australia Pty Ltd (HMS) facilitated a risk assessment via MSTeams due to the NSW COVID19 restrictions, on the potential impacts of SIMEC - Tahmoor Mine’s proposed extraction of Longwalls LW1A - LW6A beneath the Australian Rail Track Corporation (ARTC) - Main Southern Railway Line near Bargo, NSW.

This report details the methods used and the recommendations resulting from the risk assessment conducted in August 2021.

3 CONTEXT

3.1 Background

Tahmoor is situated approximately 80 kilometres south-west of Sydney in the Southern Coalfields of New South Wales, within the Wollondilly Shire Council. Recently, Tahmoor received approval for the Tahmoor South Project, an extension of underground mining at Tahmoor, to the south of existing surface facilities. The project seeks to extend the life of mining at the Tahmoor until approximately 2032, extending employment for close to 400 people for a further 10 years.

Coal extraction of up to 4 million tonnes of Run of Mine (ROM) coal per annum is proposed with up to 33 million tonnes of ROM coal proposed over the Life of the Project through longwall mining. This technique for coal extraction has been used by Tahmoor for over 30 years.

The current mining schedule is such that LW1A - LW6A will commence to impact on the MSR Line and associated infrastructure in October 2022. In order to manage mine subsidence induced rail stress in this area, and to maintain the integrity and continued safe operation of the railway the Track Expansion System (TES) will be utilised if required. The TES comprises a combination of Expansion Switches, Anchor Points, Zero Toe Load (ZTL) clips and remote monitoring systems to manage the section of track affected by the mining. The TES has been approved by ARTC Standards for use in managing track influenced by longwall mining in the NSW Southern Highlands. The expansion switches are designed to allow relative movement of adjoining rails to prevent the unacceptable changes in rail stress which could affect the integrity of the tracks and safe operation of the MSR line.

The expansion switches are of a type that has been used successfully in other sections of the MSR Line where longwall mining has taken place, specifically at Tahmoor (LW25-32) and also at Appin Mine (LW702-707 and 901) since January 2009. Prior to this, trials were conducted at Mt Owen, in the NSW Hunter Valley and at Tahmoor, and a TES was developed and implemented. The management of the TES incorporates inspections, monitoring, maintenance and adjustment of the switches based upon an on-going review process. Critical rail parameters are monitored and maintained using a staged process during the time the longwall is being extracted in accordance with a Subsidence Management Plan approved by all stakeholders.

3.2 Purpose

The key purpose of this risk assessment is to evaluate the risks associated with the continued safe and serviceable operation of the MSR line during the mining of Tahmoor Mine's LW1A - LW6A, and to ensure risks will be managed in accordance with the Subsidence Management Plan.

3.3 Scope

The risk assessment evaluated risks to the safety and serviceability of the MSR Line and associated infrastructure primarily within the predicted 20mm subsidence contour associated with extraction of the longwall panels. This also included impacts on associated culverts, embankments and other rail infrastructure.

In addition, the risk assessment also evaluated risks to several far-field structures as well as the Tahmoor balloon loop line and several structures.

Assessment of the risks considered the three (3) stages of subsidence as detailed in the Management Plan and described below (see Section 3.6 Assumptions). A detailed scope is provided in Section 5.5 of this Report.

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:

- Protecting the health and safety of all users of the Main Southern Rail Corridor,
- In accordance with applicable legislation, including NSW Work Health and Safety Act 2011 and Regulation 2011,
- Involving key stakeholders and subject specialists,
- Planning Approval - Key Performance Measures:
  - The project does not cause any exceedances of the performance measures to the satisfaction of the stakeholders
  - The MSR, as a key public infrastructure, is always safe and serviceable
  - Damage that does not affect safety or serviceability must be fully repaired at the completion of the project(s)
  - Serviceability should be maintained to all railway infrastructure in accordance with the requirements of the ARTC Works Deed which is the legal instrument between ARTC and Tahmoor Coal that enables works to be carried out within the rail corridor.

The risk assessment was undertaken in accordance with AS/NZ ISO 31000:2018 – Risk Management, and the requirements of MDG 1010 - Risk Management Handbook for the Mining Industry, as well as the revised ARTC Risk Management Procedure, dated 26th May 2016.

The risk assessment process engaged key stakeholders and subject specialists and was facilitated by an external person, having qualifications and experience in mining and the application of risk management to mining projects.

3.5 Limitations

Limitations of the risk assessment include:

- The risk assessment did not consider direct commercial risks to ARTC.
- Risks to external services (other third party services – non ARTC services) where identified, will be assessed separately.

3.6 Assumptions

The following assumptions were made during the risk assessment:

- LW1A - LW6A extraction timeline, follows:
  - LW1A: October 2022 to April 2023 (6 months)
  - LW2A: May 2023 to January 2024 (8 months)
  - LW3A: February 2024 to September 2024 (7 months)
  - LW4A: October 2024 to June 2025 (8 months)
  - LW5A: July 2025 to February 2026 (7 months)
  - LW6A: March 2026 to November 2026 (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.

3.7 Exclusions

Some far-field structures were not considered in this risk assessment, those structures are described following:

- Bargo River Road Bridge 96.05km
- Bargo Railway Station & Pedestrian Footbridge 102.873km
- Avon Dam Road Bridge 103.780km

The Bargo Railway Station & Pedestrian Footbridge and the Avon Dam Road Bridge will be assessed prior to mining the ‘B series’ longwalls.

Diagram 1 following, depicts the Tahmoor South Project ‘A series’ longwalls and infrastructure along the MSR line.

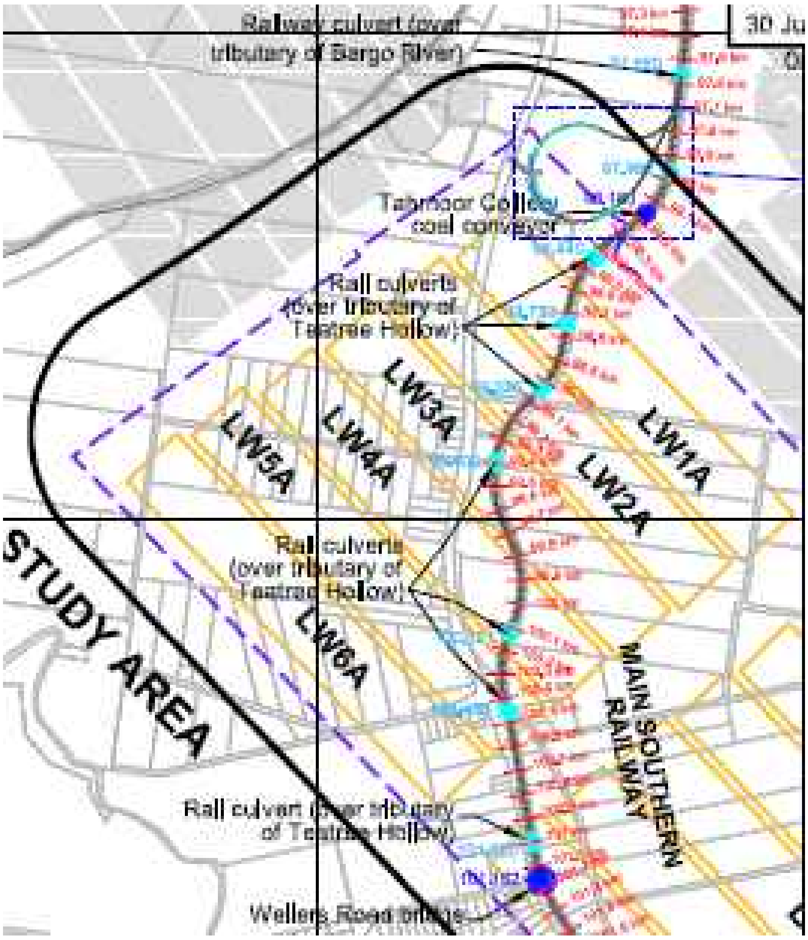


Diagram 1 – Tahmoor South Project ‘A series’ longwalls and infrastructure along the MSR line.

4 DEFINITIONS

Risk

The chance of something happening or circumstances arising or changing that will have an impact upon ARTC and 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 ARTC Risk 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 workshop involved a group of people representing ARTC, Tahmoor Coal and ONRSR as well as subject specialists having involvement with the design and management of the Project. The workshop was facilitated via MSTeams due to NSW COVID 19 restrictions, by an independent facilitator having qualifications and experience in mining and the application of risk management to mining and construction projects.

5.1 Participants

The workshop participants are listed in *Table 1 – Workshop Participants* following.

Name	Position	Organisation	Years in Field of Expertise
Michael Irons	Property Manager	ARTC	11
Steve Chance	Line Manager	ARTC	26
Chris Bloor	Director	Bloor Rail	+40
Kyle Coffee	Project Manager – Monitoring Systems	Globetech	
David Swan	Director (Facilitator)	HMS Consultants	45
John Matheson	Structural Engineer	JMA	35
Daryl Kay	Subsidence Engineer	MSEC	18
Mark Delaney	Geotechnical Engineer	Newcastle Geotechnical	35
Ian Cochran	Structures Specialist	ONRSR	+40
David Cooper	Track Specialist	ONRSR	+40
Allan Pidgeon	Rail Engineer	PCE	+50
Graeme Robinson	RMG Chairman – Management Committee	Robinson Rail	+50
Ross Barber	Project Manager	Tahmoor Coal	40
David Talbert	Project Support	Tahmoor Coal	30
Kevin Golledge	Project Manager	Tahmoor Coal	55

Table 1 – Workshop Participants

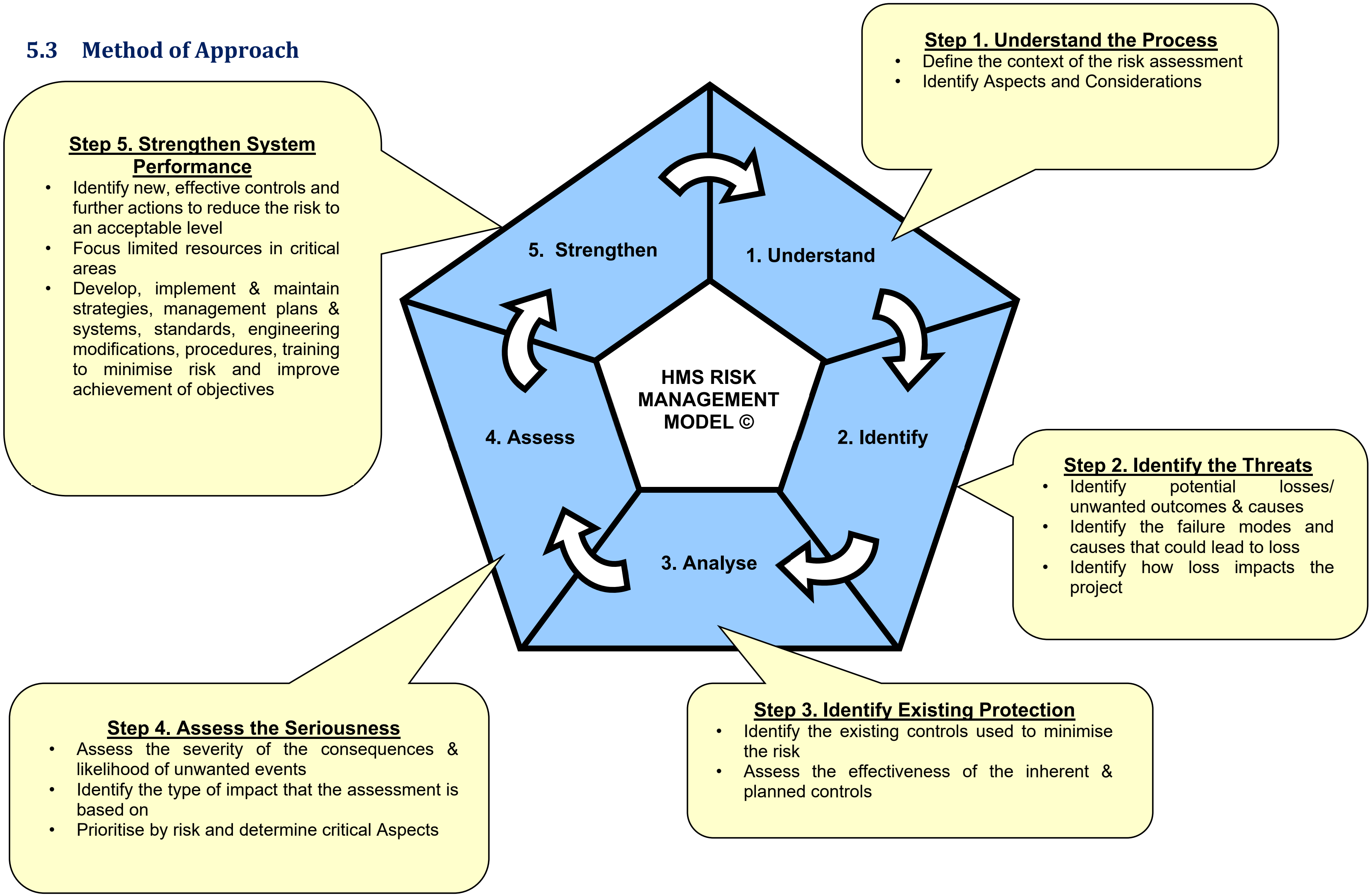
5.2 Presentation of Information & Subsidence Data

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 via the MSTeams shared file function.

A summary of the presenters and their speciality, follows:

- Ross Barber – Mining overview and timeline
- Daryl Kay – Mine subsidence predictions and potential impacts to assets
- Mark Delaney – Geotechnical analysis and potential impacts to culvert, cuttings and embankments
- John Matheson – Potential impacts to structures

5.3 Method of Approach



Step 1. Understand the Process
- Define the context of the risk assessment
- Identify Aspects and Considerations

Step 2. Identify the Threats
- Identify potential losses/ unwanted outcomes & causes
- Identify the failure modes and causes that could lead to loss
- Identify how loss impacts the project

Step 3. Identify Existing Protection
- Identify the existing controls used to minimise the risk
- Assess the effectiveness of the inherent & planned controls

Step 4. Assess the Seriousness
- Assess the severity of the consequences & likelihood of unwanted events
- Identify the type of impact that the assessment is based on
- Prioritise by risk and determine critical Aspects

Step 5. Strengthen System Performance
- Identify new, effective controls and further actions to reduce the risk to an acceptable level
- Focus limited resources in critical areas
- Develop, implement & maintain strategies, management plans & systems, standards, engineering modifications, procedures, training to minimise risk and improve achievement of objectives

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 via MSTeams. The name, position title and experience of each team member were recorded.
- Presentations on Tahmoor's longwall mining impacts on the MSR Line and Tahmoor loop line 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.

#	Description
1	Changes to MSR track geometry
2	Changes to MSR rail stress
3	Changes to MSR track centres
4	Changes to Tahmoor Colliery railway loop line
5	Tahmoor Coal Conveyor (over rail)
6	Tahmoor Coal rail balloon loop road bridge over MSR
7	Culverts
8	Embankments
9	Cuttings
10	Wellers Road Bridge (101.162km) Constructed C1918
11	Optical fibre cable
12	Signalling and communications
13	Far Field – Railway Viaduct over Bargo River (96.265km)
14	Far Field – Remembrance Drive Bridge (over rail) (96.400)

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 railway line and/or associated infrastructure were evaluated. 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

Note that the risks identified in previous risk assessments for Tahmoor's earlier longwall panels were used as the basis for this risk assessment and were reviewed for applicability for LW1A - LW6A. Where the risk was identified as being applicable, it was re-evaluated. The team also considered any new or emerging risks and evaluated them appropriately.

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 – ARTC Risk Matrix, Definitions and Criteria.

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 ARTC Risk 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 ARTC Risk Management Procedure.

In the final stage of the risk reduction strategy, SIMEC and the Rail Management Group are to formally accept these further risk controls and assign people, resources and time frames for the effective implementation. Before LW1A - LW6A commences to impact on the railway line 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 fourteen (14) separate risks, 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.	%
Very High	0	0
High	0	0
Medium	0	0
Low	14	100
TOTAL	**14**	**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	0	0
Major	1	7
Moderate	0	0
Minor	2	14
Not Significant	11	79
TOTAL	**14**	**100**

Table 4 – Risk Distribution by Consequence

One (1) risk was rated as having a worst case impact that may result in a consequence involving a fatality **(‘Major’** safety consequence). This risk concerned the potential damage of a signalling cable, resulting in a signal failure. Experience in the management of signalling cables in response to subsidence has been gained over the past 15 years. During this period there has been nil damage of cables resulting in signal failure events.

6.4 Action Plan

An Action Plan has been prepared (see Appendix B), listing potential additional controls / further actions from the risk assessment.

The reader should note that the TES, incorporating rail expansion switches and associated monitoring, maintenance equipment and procedures, have been developed and refined for over a decade. Substantial experience has been gained from its successful use on other sections of the MSR Line in association with previous longwall mining at Tahmoor Mine (LW25-32) and also at Appin Mine (LW702-707 and 901). In addition, growing levels of experience and data gained from ground surveys, ATS surveys and other measuring apparatus such as extensometers, inclinometers and piezometers has been used to refine these existing controls.

Before LW1A - LW6A commences to impact on the railway line, an audit or review of the existing, planned and additional controls identified should be conducted under the auspices of the Tahmoor Coal's Rail Management Group governance to ensure the controls have been effectively implemented to manage the identified risk to SFAIRP levels.

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 Graeme Robinson

Position: Project Manager, Robinson Rail

Signature: **Date:** August 2021

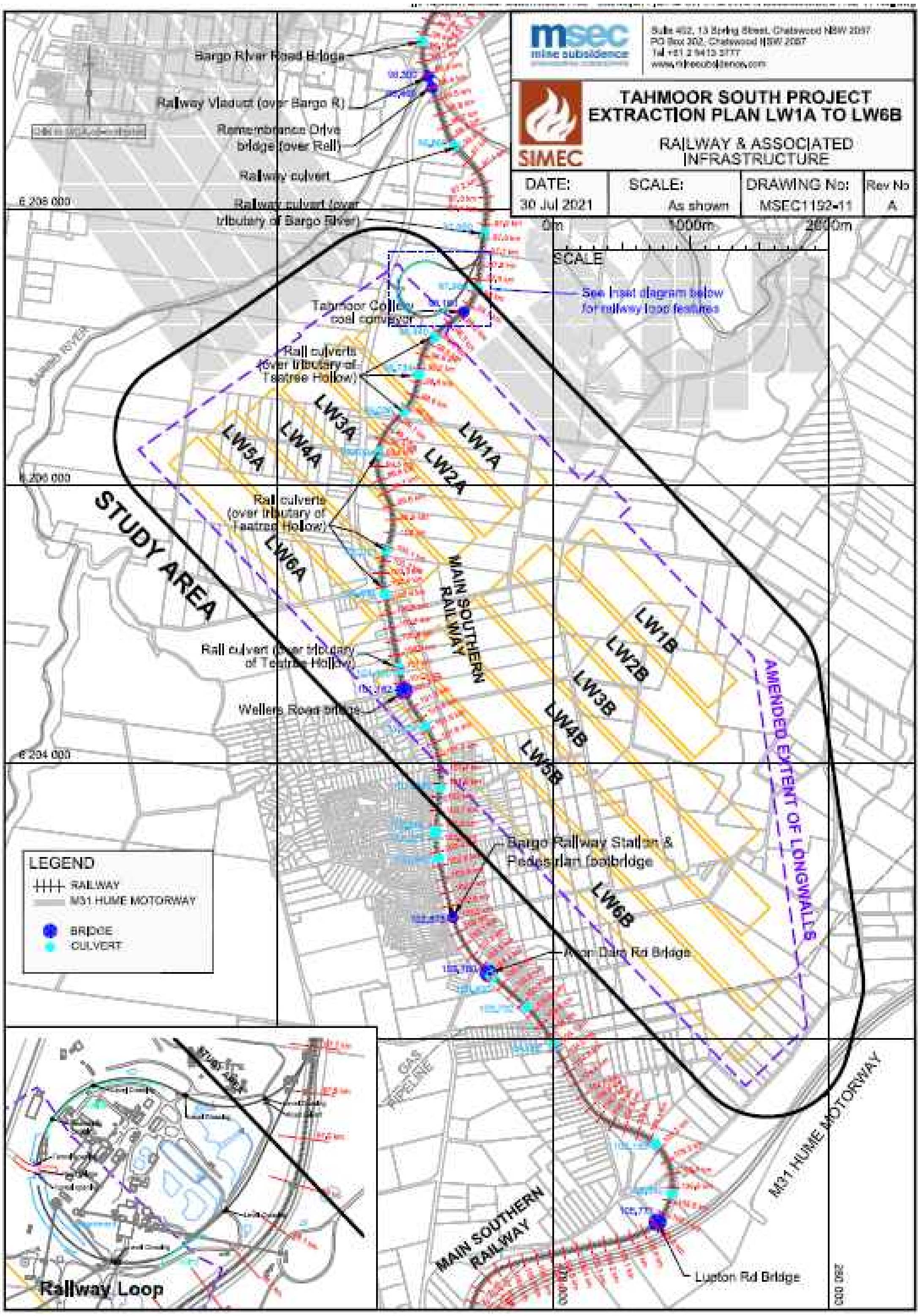
Appendix A

SIMEC Pty Ltd

Tahmoor Mine

Longwall Mining in Relation to Main Southern Railway Line

Location Plan



Location Plan

Appendix B

SIMEC Pty Ltd

Tahmoor Mine

LW1A - LW6A Impacts on Main Southern Railway Line

Action Plan

#	Risk/ Asset Description	Action Description	Who
1	Changes to MSR track geometry (vertical and horizontal misalignment, changes in track cant, track twist)	1. Assess pre-mining track condition and adjust to ARTC Standard where applicable. Identify potential sites of non-conventional movement 2. Install Track Monitoring System on affected track 3. Regularly review and assess monitoring data 4. Conduct additional visual inspections 5. Adjust the track in response to monitoring results during mining if required 6. Geotechnical mapping of cuttings to identify any fault structures and review of Tahmoor Coal structural geology database	RMG
2	Changes to MSR rail stress	1. Conduct investigation into baseline stress regime on the track that will remain in CWR. 2. Install Track Monitoring System 3. Assess pre-mining track condition and adjust to ARTC Standard where applicable 4. Identify potential sites of non-conventional movement 5. Regularly review and assess monitoring data 6. Conduct additional visual inspections 7. Adjust the track in response to monitoring results during mining if required	RMG
3	Changes to MSR track centres, clearances between track and clearances to structures (vertical and horizontal misalignment, changes in track cant, track twist)	1. Assess pre-mining track condition, including detailed clearance survey, and adjust to ARTC Standard where applicable Identify potential sites of non-conventional movement 2. Install Track Monitoring System on affected track 3. Regularly review and assess monitoring data 4. Conduct additional visual inspections 5. Realign / resurface the track in response to monitoring results during mining if required 6. Geotechnical mapping of cuttings to identify any fault structures. 7. Review the application of the current ARTC Section 7 which includes updated requirements	RMG
4	Changes to Tahmoor Colliery railway loop line	1. Loop line owned by Tahmoor Coal, with interface agreement with LOR for maintenance purposes. Establish subsidence communication process with LOR 2. Conduct investigation into baseline stress regime on the railway loop	RMG
5	Tahmoor Coal Conveyor (over rail)	1. Understand current condition of Conveyor gantry and supports. 2. Management measures include; - Assess pre-mining condition of the conveyor gantry structure - Consider mitigation measures if recommended by a structural engineer - Install / maintain existing monitoring systems - Regularly review and assess the monitoring data - Conduct additional visual inspections - Conduct repairs as required	RMG
6	Tahmoor Coal rail balloon loop road bridge over track	1. Understand current condition of Armco structure. 2. Management measures include; - Assess pre-mining condition of the Armco structure - Consider mitigation measures if recommended by a structural engineer - Install / maintain existing monitoring systems - Regularly review and assess the monitoring data - Conduct additional visual inspections	RMG

		- Conduct repairs as required	
7	Culverts	1. Install a baulk above culverts which are positioned directly above longwall panels. 2. Re-set 99.035km culvert extension due to piping issue 3. Management measures include: - Assess pre-mining condition of the culvert, (Dilapidation Report) - Consider mitigation measures if recommended by a structural engineer - Install / maintain existing monitoring systems - Regularly review and assess the monitoring data - Conduct additional visual inspections - Conduct repairs as required Grout interface between brick headwalls and concrete RCP extensions 4. Grout all pipe interfaces 5. Repair any recommendations observed from detail culvert inspection	RMG
8	Embankments	1. Geotechnical assessment of embankment ground conditions and stability analysis to establish baseline conditions. 2. Install extensometers as determined by assessment	RMG
10	Wellers Road Bridge (101.162km) Constructed C1918	1. Conduct assessment for longwall panels from 101A through to 106B 2. Install monitoring regime from commencement of longwall operations 3. Implementation of planned triggered responses: - Detailed inspection by structural engineer - Repair cracked brickwork/ spalled concrete - Install mesh to underside of the arch - Provide additional support to the arch/ walls - Seal cracks in pavement - Apply a load limit or stop vehicle traffic as appropriate 4.. Crack gauges on parapet wall	RMG
11	Optical fibre cable	1. Fibre optic cable is monitored remotely and can be exposed and re-stressed if required during the course of mining	RMG
12	Signalling and communications	1. Cable will be exposed and tested if required during the course of mine subsidence	RMG
13	Far Field – Railway Viaduct over Bargo River (96.265km)	1. Conduct a dilapidation report 2. Source historical structural design and as built reports	RMG
14	Far Field – Remembrance Drive Bridge (over rail) (96.400)	1. Conduct a dilapidation report 2. Source historical structural design and as built reports	RMG

Appendix C

SIMEC Pty Ltd

Tahmoor Mine

LW1A - LW6A Impacts on Main Southern Railway Line

Risk Register – Assessment Order

August 2021

Risk Description					Assessment of Current Residual Risk					Risk Reduction Strategies		
#	**Consideration/ Aspect**	**Risk Issue**	**Failure Mode and Causes**	**Potential Impacts**	**Existing / Planned Controls**	**Type**	**Consequence**	**Likelihood**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**Historical Knowledge/ SFAIRP Comments**	**Yes SFAIRP**
1	Changes to MSR track geometry (vertical and horizontal misalignment, changes in track cant, track twist)	Impacts on track serviceability	**Failure Mode:** Subsidence adversely impacting on track geometry **Causes:** 1. Mining subsidence adversely affects track geometry 2. Condition of track deteriorates further from non-mining causes 3. Step displacement across a fault structure in rock formation	Unplanned intervention on track **Worst Credible:** Track closure less than 6 hrs	**Inherent Control:** 1. Mine Design – avoiding major geological structures 2. Location of turnouts relative to subsidence **Mitigating Controls:** 3. Subsidence Management Plan 4. Track remote monitoring system 5. Maintenance Plans 6. Track resurfacing as required **Monitoring Controls:** 7. Driver reports 8. Ground surveys 9. Electronic monitoring 10. Non-destructive testing of rail (Ultrasonic) 11. Enhanced Track Examination System 12. Visual inspections by track certifier daily during active subsidence and as required, weekly front of train inspection 13. Track geometry survey (KRAB trolley / AK Car) 14. Detail track survey **Triggered Responses:** 14. Track maintenance - Track examination system - Track recording surveys (KRAB trolley / AK Car) - ARTC Track and Civil Code of Practice S.5.0 15. Mandatory Responses (ARTC defect responses) 16. Temporary speed restrictions 17. Triggered alarms (Stage 2 only) and maintenance response 18. Proactive management initiates maintenance response prior to reaching trigger levels (Target is to maintain "Green" Status) 19. Increase monitoring and reporting frequencies as required based on actual monitoring data at specific identified locations 20. Review monitoring data by RMG and ARTC in governance meetings prior to changes in management or monitoring measures 22. Other actions at the direction of the RMG	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Assess pre-mining track condition and adjust to ARTC Standard where applicable Identify potential sites of non-conventional movement 2. Install Track Monitoring System on affected track 3. Regularly review and assess monitoring data 4. Conduct additional visual inspections 5. Adjust the track in response to monitoring results during mining if required 6. Geotechnical mapping of cuttings to identify any fault structures and review of Tahmoor Coal structural geology database	1. Assessment and mapping of geological structures in subsidence area undertaken by Tahmoor Coal 2. Tahmoor Coal and ARTC have developed and implemented engineering and administrative measures to successfully manage potential impacts on track serviceability over 15 years	Yes

Risk Description					Assessment of Current Residual Risk					Risk Reduction Strategies		
#	**Consideration/ Aspect**	**Risk Issue**	**Failure Mode and Causes**	**Potential Impacts**	**Existing / Planned Controls**	**Type**	**Consequence**	**Likelihood**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**Historical Knowledge/ SFAIRP Comments**	**Yes SFAIRP**
2	Changes to MSR rail stress	Impacts on track serviceability	**Failure Mode:** Rail stress leading to broken rail or buckle **Causes:** 1. Mining subsidence causes excessive compressive or tensile stress 2. Poor track stability (lateral constraint)	Unplanned intervention on track **Worst Credible:** Track closure less than 6 hrs	**Inherent Control:** 1. Mine Design – avoiding major geological structures **Mitigating Controls**: 2. Subsidence Management Plan 3. Track remote monitoring system 4. Maintenance Plans 5. Track Expansion System 6. Track resurfacing as required **Monitoring Controls:** 7. Driver reports 8. Ground surveys including across cuttings 9. Electronic monitoring 10. Non-destructive testing of rail (Ultrasonic) 11. Track Examination System 12. Visual inspections by track certifier daily during active subsidence and as required, weekly front of train inspection 13. Track geometry survey (KRAB trolley / AK Car) **Triggered Responses:** 14. Track maintenance - Track examination system - Track recording surveys (KRAB trolley / AK Car) - ARTC Track and Civil Code of Practice S.5.0 15. Mandatory Responses (ARTC defect responses) 16. Temporary speed restrictions 17. Triggered alarms (Stage 2 only) and maintenance response 18. Proactive management initiates maintenance response prior to reaching trigger levels (Target is to maintain "Green" Status) 19. Increase monitoring and reporting frequencies as required based on actual monitoring data at specific identified locations 20. Review monitoring data by RMG and ARTC in governance meetings prior to changes in management or monitoring measures 21. Other actions at the direction of the RMG	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Conduct investigation into baseline stress regime on the track that will remain in CWR. 2. Install Track Monitoring System 3. Assess pre-mining track condition and adjust to ARTC Standard where applicable 4. Identify potential sites of non-conventional movement 5. Regularly review and assess monitoring data 6. Conduct additional visual inspections 7. Adjust the track in response to monitoring results during mining if required	1. Assessment and mapping of geological structures in subsidence area undertaken by Tahmoor Coal 2. Tahmoor Coal and ARTC have developed and implemented engineering and administrative measures to successfully manage potential impacts on track serviceability over 15 years	**Yes**

Risk Description					Assessment of Current Residual Risk					Risk Reduction Strategies		
#	**Consideration/ Aspect**	**Risk Issue**	**Failure Mode and Causes**	**Potential Impacts**	**Existing / Planned Controls**	**Type**	**Consequence**	**Likelihood**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**Historical Knowledge/ SFAIRP Comments**	**Yes SFAIRP**
3	Changes to MSR track centres, clearances between track and clearances to structures (vertical and horizontal misalignment, changes in track cant, track twist)	Impacts on track serviceability	**Failure Mode:** Subsidence adversely impacting on track geometry, including track centres **Causes:** 1. Mining subsidence adversely affects track geometry, in particular Cant, and Track Alignment 2. Condition of track deteriorates further from non-mining causes 3. Step displacement across a fault structure in rock formation	Unplanned intervention on track **Worst Credible:** Track closure less than 6 hrs	**Inherent Control:** 1. Mine Design – avoiding major geological structures **Mitigating Controls:** 2. Subsidence Management Plan 3. Track remote monitoring system 4. Maintenance Plans 5. Track resurfacing as required **Monitoring Controls:** 6. Driver reports 7. Ground surveys 8. Electronic monitoring 9. ARTC Register of Clearance Infringements 10. Enhanced Track Examination System 11. Visual inspections by track certifier daily during active subsidence and as required, weekly front of train inspection 12. Track geometry survey (KRAB trolley / AK Car) **Triggered Responses:** 13. Track maintenance - Track examination system - Track recording surveys (KRAB trolley / AK Car) - ARTC Track and Civil Code of Practice S.7 14. Mandatory Responses (ARTC defect responses) 15. Temporary speed restrictions 16. Triggered alarms (Stage 2 only) and maintenance response 17. Proactive management initiates maintenance response prior to reaching trigger levels (Target is to maintain "Green" Status) 18. Increase monitoring and reporting frequencies as required based on actual monitoring data at specific identified locations 19. Review monitoring data by RMG and ARTC in governance meetings prior to changes in management or monitoring measures 20. Other actions at the direction of the RMG	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Assess pre-mining track condition, including detailed clearance survey, and adjust to ARTC Standard where applicable Identify potential sites of non-conventional movement 2. Install Track Monitoring System on affected track 3. Regularly review and assess monitoring data 4. Conduct additional visual inspections 5. Realign / resurface the track in response to monitoring results during mining if required 6. Geotechnical mapping of cuttings to identify any fault structures. 7. Review the application of the current ARTC Section 7 which includes updated requirements	1. Assessment and mapping of geological structures in subsidence area undertaken by Tahmoor Coal 2. Tahmoor Coal and ARTC have developed and implemented engineering and administrative measures to successfully manage potential impacts on track serviceability over 15 years	Yes

Risk Description					Assessment of Current Residual Risk					Risk Reduction Strategies		
#	**Consideration/ Aspect**	**Risk Issue**	**Failure Mode and Causes**	**Potential Impacts**	**Existing / Planned Controls**	**Type**	**Consequence**	**Likelihood**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**Historical Knowledge/ SFAIRP Comments**	**Yes SFAIRP**
4	Changes to Tahmoor Colliery railway loop line	Impacts on track serviceability	**Failure Mode:** Rail stress leading to broken rail or buckle **Causes:** 1. Mining subsidence causes excessive compressive or tensile stress 2. Poor track stability (lateral constraint) Unplanned intervention on track	Unplanned intervention on track **Worst Credible:** Track closure less than 6 hrs	**Inherent Control:** 1. Track function is for slow moving trains to access the Tahmoor mine train loadout Facility 2. Minimum subsidence impact – within the 20mm – 80mm zone **Mitigating Controls:** 3. Subsidence Management Plan 4. Engagement with Laing O'Rourke Maintenance (LOR) 5. Ground and Track survey monitoring 6. Good initial track geometry, track structure and rail stress regime 7. Track resurfacing as required **Monitoring Controls:** 8. Driver reports 9. Visual inspections by track certifier daily during active subsidence and as required, weekly front of train inspection 10. Track geometry survey (KRAB trolley) **Triggered Responses:** 11. Track maintenance - Track recording surveys (KRAB trolley) - Tahmoor Coal Siding Interface Agreement with LOR 12. Increase monitoring and reporting frequencies as required based on actual monitoring data at specific identified locations 13. Review monitoring data by RMG during weekly meetings prior to changes in management or monitoring measures 14. Other actions at the direction of the RMG	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Loop line owned by Tahmoor Coal, with interface agreement with LOR for maintenance purposes. Establish subsidence communication process with LOR 2. Conduct investigation into baseline stress regime on the railway loop	1. The predicted changes due to conventional subsidence movements are expected to be negligible	**Yes**

Risk Description					Assessment of Current Residual Risk					Risk Reduction Strategies		
#	**Consideration/ Aspect**	**Risk Issue**	**Failure Mode and Causes**	**Potential Impacts**	**Existing / Planned Controls**	**Type**	**Consequence**	**Likelihood**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**Historical Knowledge/ SFAIRP Comments**	**Yes SFAIRP**
5	Tahmoor Coal Conveyor (over rail) 	Impacts of conveyor gantry serviceability	**Failure Mode:** Loss of integrity of conveyor gantry structure **Causes:** 1. Mining induced ground movements.	1. Unplanned intervention on rail **Worst Credible:** Track closure less than 1 day	**Inherent Control:** 1. Capacity to undertake footing vertical and horizontal adjustments 2. The potential impact on the track is minimal as pier supports set back from track with capacity to undertake maintenance with operational track 3. Tahmoor maintenance and alarm system **Mitigating Controls:** 4. Subsidence Management Plan **Monitoring Controls:** 5. Absolute and local 3D surveys 6. Survey marks on conveyor gantry 7. Visual Inspections 8. Tilt gauges 9. Baseline measurement across gantry **Triggered Response:** 10. Inspection, Evaluation and Respond to damage	A	2	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Understand current condition of Conveyor gantry and supports. 2. Management measures include; - Assess pre-mining condition of the conveyor gantry structure - Consider mitigation measures if recommended by a structural engineer - Install / maintain existing monitoring systems - Regularly review and assess the monitoring data - Conduct additional visual inspections - Conduct repairs as required	1. Owned by Tahmoor Coal with life of asset maintenance system in place 2. WHS (Mines and Petroleum Sites) Regulation 2014 [NSW] Part 2 Managing risks Division 3(4) Mechanical Engineering Control Plan……..The Operator of a mine or petroleum site at which there is a risk to health and safety associated with the mechanical aspects of plant and structures at the mine 3. Aurecon Structural Audit – Aug 2019	**Yes**
6	Tahmoor Coal rail balloon loop road bridge over track 	Impacts on bridge serviceability	**Failure Mode:** Loss of integrity of Armco tunnel structure **Causes:** 1. Mining induced ground movements	1. Unplanned intervention on rail **Worst Credible**: Track closure less than 1 day	**Inherent Control:** 1. Ductile structure **Mitigating Controls:** 2. Subsidence Management Plan **Monitoring Controls:** **3.** Absolute and local 3D surveys 4. Survey marks on conveyor gantry 5. Visual Inspections 6. Baseline measurement of opening **Triggered Response:** 7. Inspection, Evaluation and Respond to damage	A	2	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Understand current condition of Armco structure. 2. Management measures include; - Assess pre-mining condition of the Armco structure - Consider mitigation measures if recommended by a structural engineer - Install / maintain existing monitoring systems - Regularly review and assess the monitoring data - Conduct additional visual inspections - Conduct repairs as required	1. Owned by Tahmoor Coal with life of asset maintenance system in place 2. WHS (Mines and Petroleum Sites) Regulation 2014 [NSW] Part 2 Managing risks Division 3(4) Mechanical Engineering Control Plan……..*The Operator of a mine or petroleum site at which there is a risk to health and safety associated with the mechanical aspects of plant and structures at the mine*	**Yes**

Risk Description					Assessment of Current Residual Risk					Risk Reduction Strategies		
#	Consideration/ Aspect	Risk Issue	Failure Mode and Causes	Potential Impacts	Existing / Planned Controls	Type	Consequence	Likelihood	Risk Level	Additional Controls/ Further Actions (SAFERR)	Historical Knowledge/ SFAIRP Comments	Yes SFAIRP
7	Culverts: 98.445 km 900mm 98.739 km 900mm 99.035 km 1200mm 99.384 km 1500mm 100.130 km 1500mm 100.425 km 1500mm 101.000 km 1500mm 101.470 km 1200mm 101.920 km 1200mm	Impacts on culvert serviceability	**Failure Mode:** Loss of integrity of culvert - cracking or shearing leading to unplanned intervention of culvert **Causes:** 1. Mining induced ground movements. 2. Potential valley closure. 3. Piping failure along access road at interface between brick headwall and RCP pipe extension.	1. Changes to track geometry leading to; - Operating restrictions - Track closure. 2. Blockage of water way increasing flooding level and potential instability of embankment 3. Developing of a sinkhole and undermining of the track 4. Potential erosion 5. Damage to culvert 6. Loss of Heritage value **Worst Credible:** Track Closure less than 6hrs	**Maintenance:** 1. Culvert maintenance 2. ARTC Structures Standards and Inspections 3. SMP / Maintenance Plan **Train Operations:** 4. Driver reports **Subsidence Management Plan, including:** **Mitigation Controls (prior to undermining):** 5. Studies and assessments (geotechnical, structural) **Monitoring Controls:** 6. Ground survey 7. Track monitoring 8. Visual inspections (track certifier) 9. Geotechnical inspections 10. Wet weather inspection 11. Survey internal culvert dimensions **Triggered responses:** 12. Additional inspections in event of prolonged or high intensity rainfall 13. Repairing/ reinforce cracks in brickwork 14. Repair culvert	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Install a baulk above culverts which are positioned directly above longwall panels. 2. Re-set 99.035km culvert extension due to piping issue 3. Management measures include: - Assess pre-mining condition of the culvert, (Dilapidation Report) - Consider mitigation measures if recommended by a structural engineer - Install / maintain existing monitoring systems - Regularly review and assess the monitoring data - Conduct additional visual inspections - Conduct repairs as required Grout interface between brick headwalls and concrete RCP extensions 4. Grout all pipe interfaces 5. Repair any recommendations observed from detail culvert inspection	1. Tahmoor Coal and ARTC have developed and implemented measures to successfully manage potential impacts on culverts over 15 years 2. ARTC Geotechnical Risk Site Database 3. Hydrology studies completed by HEC February 2020 4. Heritage studies completed by EMM Consulting February 2020	**Yes**
8	Embankments 98.380 – 98.500 98.700 – 98.770 99.000 – 99.050 99.250 – 99.400 100.020 – 100.220 100.400 – 100.500	Impacts on embankment serviceability	**Failure Mode:** Displacement leading to loss of track support **Causes:** 1. Mining induced ground movements. 2. Potential valley closure 3. Leakage from cracked culvert 4. Significant rain event / flooding	1. Changes to track geometry leading to; - Operating restrictions - Track closure. 2 Potential erosion **Worst Credible:** Track Closure less than 6hrs	**Inherent Control:** 1. Access roads along most embankment sides act as stabilising berms. 2. Relatively low embankment height 3. Embankment core expected to be constructed with rocky sandstone fill materials **Maintenance:** 3. Embankment maintenance 4. ARTC Standards and Inspections 5. SMP / Maintenance Plan **Train Operations:** 6. Driver reports 7. Subsidence Management Plan, including: - Mitigation Controls (prior to undermining): Studies and assessments (geotechnical, structural) **Monitoring Controls:** 8. Ground survey 9. Track monitoring 10. Visual Inspection (track certifier) 11. Geotechnical inspections 12. Wet weather inspection 13. Embankment crest extensometers	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Geotechnical assessment of embankment ground conditions and stability analysis to establish baseline conditions. 2. Install extensometers as determined by assessment	1. Tahmoor Coal and ARTC have developed and implemented measures to successfully manage potential impacts on embankments over 15 years 2. Experience from detailed embankment monitoring and inspection notes they are able to tolerate considerable mining-induced ground deformations without experiencing impacts, are generally not prone to development of tension cracks and are not prone to exhibit “steps or humps” in spite of changes in vertical alignment and high strain levels measured. 3. ARTC Geotechnical Risk Site Database	**Yes**

Risk Description					Assessment of Current Residual Risk					Risk Reduction Strategies		
#	**Consideration/ Aspect**	**Risk Issue**	**Failure Mode and Causes**	**Potential Impacts**	**Existing / Planned Controls**	**Type**	**Consequence**	**Likelihood**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**Historical Knowledge/ SFAIRP Comments**	**Yes SFAIRP**
9	Cuttings: 98.000 – 98.250 98.530 – 98.650 98.800 – 98.950 99.150 99.550 – 99.850 100.250 – 100.350 100.500 – 100.850	Blockage of cess drainage	**Failure Mode:** Debris falling into cess **Causes:** 1. Mining induced ground movement 2. Natural weathering and erosion 3. Significant rain event	Unplanned intervention **Worst credible:** Track Closure less than 6hrs	**Inherent Control:** 1. Shallow competent rock favourable to stability. and wide cess drains. **Maintenance** 2. Track examination system 3. ARTC Track Standards 4. Clear cess drains and loose material at crest 5. Check shoulder ballast profile **Operations** 6. Driver reports 7. TSR's if required **Subsidence Management Plan** 8. Ground surveys 9. Visual Inspection (track certifier) 10. Geotechnical inspections 11. Maintenance Plans 12. Wet weather inspection **Triggered Response** 13. Clean and reinstate drains	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Nil additional identified	1. Tahmoor Coal and ARTC have successfully maintained cess drainage systems during longwall mining for over 15years 2. No subsidence related batter instability incidents recorded for cuttings over 15 years with occasional batter erosion associated with significant rainfall events. 3. ARTC Geotechnical Risk Site Database	**Yes**
10	Wellers Road Bridge (101.162km) Constructed C1918 	Impacts on bridge serviceability	**Cause:** 1. Mining induced ground movements	1. Speed restrictions during bridge repairs 2. Traffic control for road users 3. Unplanned intervention **Worst credible**: Track Closure less than 6hrs	**Inherent Control:** 1. Performance can be progressively monitored as longwall extraction moves gradually towards the bridge. 2. Bridge located 500m from LW106A **Mitigating Controls:** 3. Subsidence Management Plan 4. Numerical analysis of the bridge structure **Monitoring Controls:** 5. Absolute and local 3D surveys 6. Survey pegs on bridge 7. Visual Inspections 8. Baseline measurement across abutments **Triggered Response:** 9. Inspection, Evaluation and Respond to movement	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Conduct assessment for longwall panels from 101A through to 106B 2. Install monitoring regime from commencement of longwall operations 3. Implementation of planned triggered responses: - Detailed inspection by structural engineer - Repair cracked brickwork/ spalled concrete - Install mesh to underside of the arch - Provide additional support to the arch/ walls - Seal cracks in pavement - Apply a load limit or stop vehicle traffic as appropriate 4.. Crack gauges on parapet wall	1. Tahmoor Coal and ARTC have successfully maintained bridge structures during longwall mining for over 10 years 2. TfNSW Structural Assessment Risk Site Database 3. JMA Structural Assessment Report R0237, May 2014 4. Original bridge design drawings and dimensions	**Yes**

Risk Description					Assessment of Current Residual Risk					Risk Reduction Strategies		
#	**Consideration/ Aspect**	**Risk Issue**	**Failure Mode and Causes**	**Potential Impacts**	**Existing / Planned Controls**	**Type**	**Consequence**	**Likelihood**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**Historical Knowledge/ SFAIRP Comments**	**Yes SFAIRP**
11	Optical fibre cable	Damaged cable	**Failure Mode:** Extreme differential movement **Causes:** Mining induced ground movement	1. Loss of security monitoring 2. Lack of train information service 3. Lack of other commercial use **Worst credible:** Loss of communication	**Mitigating Controls** 1. Cable is installed in conduit **Monitoring Controls** 2. Automated monitoring of signal 3. Inspections and repair capability	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, no additional controls were identified 1. Fibre optic cable is monitored remotely and can be exposed and re-stressed if required during the course of mining.	1. Experience in the management of optical fibre issues in response to subsidence has been gained over 15 years from previous mining of Tahmoor and Appin longwalls.	**Yes**
12	Signalling and communications	Damage to direct buried cables	**Failure Mode:** Extreme differential movement **Causes:** 1. Mining induced ground movement resulting in crossed wires	1. Signal Failure **Worst Credible:** Train collision	**Monitoring Controls** 1. Inspections and repair capability 2. Visual inspections along cable route 3. Baseline impedance test of the copper cable **Triggered Response** 4. Triggered response based on ground strain - expose cable to relieve stress	S	4	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, no additional controls were identified 1. Cable will be exposed and tested if required during the course of mine subsidence.	1. Experience in the management of copper cable issues in response to subsidence has been gained over 15 years from previous mining of Tahmoor and Appin longwalls. 2. 2015 review conducted by independent specialist signalling engineer with regard to potential for wrong side signal failure in this mode.	**Yes**
13	Far Field – Railway Viaduct over Bargo River (96.265km)	Impacts on railway viaduct serviceability	**Cause:** 1. Mining induced ground movements 2. Far-Field effects from mining	1. Speed restrictions during bridge repairs **Worst Credible:** 2. Unplanned intervention on rail	**Inherent Control:** 1. >1.7km from active subsidence 2. Destressed area due to surrounding longwall mining **Mitigating Controls:** 3. Subsidence Management Plan **Monitoring Controls:** 4. Absolute and local 3D surveys 5. Survey pegs on bridge 6. Visual Inspections 7. Baseline measurement across abutments **Triggered Response:** 8. Inspection, Evaluation and Respond to movement	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Conduct a dilapidation report 2. Source historical structural design and as built reports	1. Knowledge gained from Picton Viaduct structural assessment 2. Previous LW mining which has occurred in and around the structure has not resulted in any known material impact	**Yes**

Risk Description					Assessment of Current Residual Risk					Risk Reduction Strategies		
#	**Consideration/ Aspect**	**Risk Issue**	**Failure Mode and Causes**	**Potential Impacts**	**Existing / Planned Controls**	**Type**	**Consequence**	**Likelihood**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**Historical Knowledge/ SFAIRP Comments**	**Yes SFAIRP**
14	Far Field – Remembrance Drive Bridge (over rail) (96.400)	Impacts on bridge serviceability	**Cause:** 1. Mining induced ground movements 2. Far-Field effects from mining	1. Speed restrictions during bridge repairs **Worst Credible:** Unplanned intervention on rail	**Inherent Control:** 1. >1.5km from active subsidence **Mitigating Controls:** 2. Subsidence Management Plan **Monitoring Controls:** 3. Absolute and local 3D surveys 4. Survey pegs on bridge 5. Visual Inspections 6. Baseline measurement across abutments **Triggered Response:** 7. Inspection, Evaluation and Respond to movement	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Conduct a dilapidation report 2. Source historical structural design and as built reports	1. Subsidence impact knowledge gained from far field impact monitoring	**Yes**

Appendix D

SIMEC Pty Ltd

Tahmoor Mine

LW1A - LW6A Impacts on Main Southern Railway Line

Risk Register – Consequence Order

August 2021

Risk Description					**Assessment of Current Residual Risk**					**Risk Reduction Strategies**		
#	**Consideration/ Aspect**	**Risk Issue**	**Failure Mode and Causes**	**Potential Impacts**	**Existing / Planned Controls**	**Type**	**Consequence**	**Likelihood**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**Historical Knowledge/ SFAIRP Comments**	**Yes SFAIRP**
12	Signalling and communications	Damage to direct buried cables	**Failure Mode:** Extreme differential movement **Causes:** 1. Mining induced ground movement resulting in crossed wires	1. Signal Failure **Worst Credible:** Train collision	**Monitoring Controls** 1. Inspections and repair capability 2. Visual inspections along cable route 3. Baseline impedance test of the copper cable **Triggered Response** 4. Triggered response based on ground strain - expose cable to relieve stress	S	4	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, no additional controls were identified 1. Cable will be exposed and tested if required during the course of mine subsidence.	1. Experience in the management of copper cable issues in response to subsidence has been gained over 15 years from previous mining of Tahmoor and Appin longwalls. 2. 2015 review conducted by independent specialist signalling engineer with regard to potential for wrong side signal failure in this mode.	**Yes**
5	Tahmoor Coal Conveyor (over rail) 	Impacts of conveyor gantry serviceability	**Failure Mode:** Loss of integrity of conveyor gantry structure **Causes:** 1. Mining induced ground movements.	1. Unplanned intervention on rail **Worst Credible:** Track closure less than 1 day	**Inherent Control:** 1. Capacity to undertake footing vertical and horizontal adjustments 2. The potential impact on the track is minimal as pier supports set back from track with capacity to undertake maintenance with operational track 3. Tahmoor maintenance and alarm system **Mitigating Controls:** 4. Subsidence Management Plan **Monitoring Controls:** 5. Absolute and local 3D surveys 6. Survey marks on conveyor gantry 7. Visual Inspections 8. Tilt gauges 9. Baseline measurement across gantry **Triggered Response:** 10. Inspection, Evaluation and Respond to damage	A	2	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Understand current condition of Conveyor gantry and supports. 2. Management measures include; - Assess pre-mining condition of the conveyor gantry structure - Consider mitigation measures if recommended by a structural engineer - Install / maintain existing monitoring systems - Regularly review and assess the monitoring data - Conduct additional visual inspections - Conduct repairs as required	1. Owned by Tahmoor Coal with life of asset maintenance system in place 2. WHS (Mines and Petroleum Sites) Regulation 2014 [NSW] Part 2 Managing risks Division 3(4) Mechanical Engineering Control Plan……..The Operator of a mine or petroleum site at which there is a risk to health and safety associated with the mechanical aspects of plant and structures at the mine 3. Aurecon Structural Audit – Aug 2019	**Yes**
6	Tahmoor Coal rail balloon loop road bridge over track 	Impacts on bridge serviceability	**Failure Mode:** Loss of integrity of Armco tunnel structure **Causes:** 1. Mining induced ground movements	1. Unplanned intervention on rail **Worst Credible**: Track closure less than 1 day	**Inherent Control:** 1. Ductile structure **Mitigating Controls:** 2. Subsidence Management Plan **Monitoring Controls:** **3.** Absolute and local 3D surveys 4. Survey marks on conveyor gantry 5. Visual Inspections 6. Baseline measurement of opening **Triggered Response:** 7. Inspection, Evaluation and Respond to damage	A	2	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Understand current condition of Armco structure. 2. Management measures include; - Assess pre-mining condition of the Armco structure - Consider mitigation measures if recommended by a structural engineer - Install / maintain existing monitoring systems - Regularly review and assess the monitoring data - Conduct additional visual inspections - Conduct repairs as required	1. Owned by Tahmoor Coal with life of asset maintenance system in place 2. WHS (Mines and Petroleum Sites) Regulation 2014 [NSW] Part 2 Managing risks Division 3(4) Mechanical Engineering Control Plan……..*The Operator of a mine or petroleum site at which there is a risk to health and safety associated with the mechanical aspects of plant and structures at the mine*	**Yes**

Risk Description					Assessment of Current Residual Risk					Risk Reduction Strategies		
#	**Consideration/ Aspect**	**Risk Issue**	**Failure Mode and Causes**	**Potential Impacts**	**Existing / Planned Controls**	**Type**	**Consequence**	**Likelihood**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**Historical Knowledge/ SFAIRP Comments**	**Yes SFAIRP**
1	Changes to MSR track geometry (vertical and horizontal misalignment, changes in track cant, track twist)	Impacts on track serviceability	**Failure Mode:** Subsidence adversely impacting on track geometry **Causes:** 1. Mining subsidence adversely affects track geometry 2. Condition of track deteriorates further from non-mining causes 3. Step displacement across a fault structure in rock formation	Unplanned intervention on track **Worst Credible:** Track closure less than 6 hrs	**Inherent Control:** 1. Mine Design – avoiding major geological structures 2. Location of turnouts relative to subsidence **Mitigating Controls:** 3. Subsidence Management Plan 4. Track remote monitoring system 5. Maintenance Plans 6. Track resurfacing as required **Monitoring Controls:** 7. Driver reports 8. Ground surveys 9. Electronic monitoring 10. Non-destructive testing of rail (Ultrasonic) 11. Enhanced Track Examination System 12. Visual inspections by track certifier daily during active subsidence and as required, weekly front of train inspection 13. Track geometry survey (KRAB trolley / AK Car) 14. Detail track survey **Triggered Responses:** 14. Track maintenance - Track examination system - Track recording surveys (KRAB trolley / AK Car) - ARTC Track and Civil Code of Practice S.5.0 15. Mandatory Responses (ARTC defect responses) 16. Temporary speed restrictions 17. Triggered alarms (Stage 2 only) and maintenance response 18. Proactive management initiates maintenance response prior to reaching trigger levels (Target is to maintain "Green" Status) 19. Increase monitoring and reporting frequencies as required based on actual monitoring data at specific identified locations 20. Review monitoring data by RMG and ARTC in governance meetings prior to changes in management or monitoring measures 22. Other actions at the direction of the RMG	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Assess pre-mining track condition and adjust to ARTC Standard where applicable Identify potential sites of non-conventional movement 2. Install Track Monitoring System on affected track 3. Regularly review and assess monitoring data 4. Conduct additional visual inspections 5. Adjust the track in response to monitoring results during mining if required 6. Geotechnical mapping of cuttings to identify any fault structures and review of Tahmoor Coal structural geology database	1. Assessment and mapping of geological structures in subsidence area undertaken by Tahmoor Coal 2. Tahmoor Coal and ARTC have developed and implemented engineering and administrative measures to successfully manage potential impacts on track serviceability over 15 years	Yes

Risk Description					Assessment of Current Residual Risk					Risk Reduction Strategies		
#	**Consideration/ Aspect**	**Risk Issue**	**Failure Mode and Causes**	**Potential Impacts**	**Existing / Planned Controls**	**Type**	**Consequence**	**Likelihood**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**Historical Knowledge/ SFAIRP Comments**	**Yes SFAIRP**
2	Changes to MSR rail stress	Impacts on track serviceability	**Failure Mode:** Rail stress leading to broken rail or buckle **Causes:** 1. Mining subsidence causes excessive compressive or tensile stress 2. Poor track stability (lateral constraint)	Unplanned intervention on track **Worst Credible:** Track closure less than 6 hrs	**Inherent Control:** 1. Mine Design – avoiding major geological structures **Mitigating Controls**: 2. Subsidence Management Plan 3. Track remote monitoring system 4. Maintenance Plans 5. Track Expansion System 6. Track resurfacing as required **Monitoring Controls:** 7. Driver reports 8. Ground surveys including across cuttings 9. Electronic monitoring 10. Non-destructive testing of rail (Ultrasonic) 11. Track Examination System 12. Visual inspections by track certifier daily during active subsidence and as required, weekly front of train inspection 13. Track geometry survey (KRAB trolley / AK Car) **Triggered Responses:** 14. Track maintenance - Track examination system - Track recording surveys (KRAB trolley / AK Car) - ARTC Track and Civil Code of Practice S.5.0 15. Mandatory Responses (ARTC defect responses) 16. Temporary speed restrictions 17. Triggered alarms (Stage 2 only) and maintenance response 18. Proactive management initiates maintenance response prior to reaching trigger levels (Target is to maintain "Green" Status) 19. Increase monitoring and reporting frequencies as required based on actual monitoring data at specific identified locations 20. Review monitoring data by RMG and ARTC in governance meetings prior to changes in management or monitoring measures 21. Other actions at the direction of the RMG	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Conduct investigation into baseline stress regime on the track that will remain in CWR. 2. Install Track Monitoring System 3. Assess pre-mining track condition and adjust to ARTC Standard where applicable 4. Identify potential sites of non-conventional movement 5. Regularly review and assess monitoring data 6. Conduct additional visual inspections 7. Adjust the track in response to monitoring results during mining if required	1. Assessment and mapping of geological structures in subsidence area undertaken by Tahmoor Coal 2. Tahmoor Coal and ARTC have developed and implemented engineering and administrative measures to successfully manage potential impacts on track serviceability over 15 years	**Yes**

Risk Description					Assessment of Current Residual Risk					Risk Reduction Strategies		
#	**Consideration/ Aspect**	**Risk Issue**	**Failure Mode and Causes**	**Potential Impacts**	**Existing / Planned Controls**	**Type**	**Consequence**	**Likelihood**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**Historical Knowledge/ SFAIRP Comments**	**Yes SFAIRP**
3	Changes to MSR track centres, clearances between track and clearances to structures (vertical and horizontal misalignment, changes in track cant, track twist)	Impacts on track serviceability	**Failure Mode:** Subsidence adversely impacting on track geometry, including track centres **Causes:** 1. Mining subsidence adversely affects track geometry, in particular Cant, and Track Alignment 2. Condition of track deteriorates further from non-mining causes 3. Step displacement across a fault structure in rock formation	Unplanned intervention on track **Worst Credible:** Track closure less than 6 hrs	**Inherent Control:** 1. Mine Design – avoiding major geological structures **Mitigating Controls:** 2. Subsidence Management Plan 3. Track remote monitoring system 4. Maintenance Plans 5. Track resurfacing as required **Monitoring Controls:** 6. Driver reports 7. Ground surveys 8. Electronic monitoring 9. ARTC Register of Clearance Infringements 10. Enhanced Track Examination System 11. Visual inspections by track certifier daily during active subsidence and as required, weekly front of train inspection 12. Track geometry survey (KRAB trolley / AK Car) **Triggered Responses:** 13. Track maintenance - Track examination system - Track recording surveys (KRAB trolley / AK Car) - ARTC Track and Civil Code of Practice S.7 14. Mandatory Responses (ARTC defect responses) 15. Temporary speed restrictions 16. Triggered alarms (Stage 2 only) and maintenance response 17. Proactive management initiates maintenance response prior to reaching trigger levels (Target is to maintain "Green" Status) 18. Increase monitoring and reporting frequencies as required based on actual monitoring data at specific identified locations 19. Review monitoring data by RMG and ARTC in governance meetings prior to changes in management or monitoring measures 20. Other actions at the direction of the RMG	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Assess pre-mining track condition, including detailed clearance survey, and adjust to ARTC Standard where applicable Identify potential sites of non-conventional movement 2. Install Track Monitoring System on affected track 3. Regularly review and assess monitoring data 4. Conduct additional visual inspections 5. Realign / resurface the track in response to monitoring results during mining if required 6. Geotechnical mapping of cuttings to identify any fault structures. 7. Review the application of the current ARTC Section 7 which includes updated requirements	1. Assessment and mapping of geological structures in subsidence area undertaken by Tahmoor Coal 2. Tahmoor Coal and ARTC have developed and implemented engineering and administrative measures to successfully manage potential impacts on track serviceability over 15 years	Yes

Risk Description					Assessment of Current Residual Risk					Risk Reduction Strategies		
#	**Consideration/ Aspect**	**Risk Issue**	**Failure Mode and Causes**	**Potential Impacts**	**Existing / Planned Controls**	**Type**	**Consequence**	**Likelihood**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**Historical Knowledge/ SFAIRP Comments**	**Yes SFAIRP**
4	Changes to Tahmoor Colliery railway loop line	Impacts on track serviceability	**Failure Mode:** Rail stress leading to broken rail or buckle **Causes:** 1. Mining subsidence causes excessive compressive or tensile stress 2. Poor track stability (lateral constraint) Unplanned intervention on track	Unplanned intervention on track **Worst Credible:** Track closure less than 6 hrs	**Inherent Control:** 1. Track function is for slow moving trains to access the Tahmoor mine train loadout Facility 2. Minimum subsidence impact – within the 20mm – 80mm zone **Mitigating Controls:** 3. Subsidence Management Plan 4. Engagement with Laing O'Rourke Maintenance (LOR) 5. Ground and Track survey monitoring 6. Good initial track geometry, track structure and rail stress regime 7. Track resurfacing as required **Monitoring Controls:** 8. Driver reports 9. Visual inspections by track certifier daily during active subsidence and as required, weekly front of train inspection 10. Track geometry survey (KRAB trolley**)** **Triggered Responses:** 11. Track maintenance - Track recording surveys (KRAB trolley) - Tahmoor Coal Siding Interface Agreement with LOR 12. Increase monitoring and reporting frequencies as required based on actual monitoring data at specific identified locations 13. Review monitoring data by RMG during weekly meetings prior to changes in management or monitoring measures 14. Other actions at the direction of the RMG	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Loop line owned by Tahmoor Coal, with interface agreement with LOR for maintenance purposes. Establish subsidence communication process with LOR 2. Conduct investigation into baseline stress regime on the railway loop	1. The predicted changes due to conventional subsidence movements are expected to be negligible	**Yes**

Risk Description					Assessment of Current Residual Risk					Risk Reduction Strategies		
#	Consideration/ Aspect	Risk Issue	Failure Mode and Causes	Potential Impacts	Existing / Planned Controls	Type	Consequence	Likelihood	Risk Level	Additional Controls/ Further Actions (SAFERR)	Historical Knowledge/ SFAIRP Comments	Yes SFAIRP
7	Culverts: 98.445 km 900mm 98.739 km 900mm 99.035 km 1200mm 99.384 km 1500mm 100.130 km 1500mm 100.425 km 1500mm 101.000 km 1500mm 101.470 km 1200mm 101.920 km 1200mm	Impacts on culvert serviceability	**Failure Mode:** Loss of integrity of culvert - cracking or shearing leading to unplanned intervention of culvert **Causes:** 1. Mining induced ground movements. 2. Potential valley closure. 3. Piping failure along access road at interface between brick headwall and RCP pipe extension.	1. Changes to track geometry leading to; - Operating restrictions - Track closure. 2. Blockage of water way increasing flooding level and potential instability of embankment 3. Developing of a sinkhole and undermining of the track 4. Potential erosion 5. Damage to culvert 6. Loss of Heritage value **Worst Credible:** Track Closure less than 6hrs	**Maintenance:** 1. Culvert maintenance 2. ARTC Structures Standards and Inspections 3. SMP / Maintenance Plan **Train Operations:** 4. Driver reports **Subsidence Management Plan, including: Mitigation Controls (prior to undermining):** 5. Studies and assessments (geotechnical, structural) **Monitoring Controls:** 6. Ground survey 7. Track monitoring 8. Visual inspections (track certifier) 9. Geotechnical inspections 10. Wet weather inspection 11. Survey internal culvert dimensions **Triggered responses:** 12. Additional inspections in event of prolonged or high intensity rainfall 13. Repairing/ reinforce cracks in brickwork 14. Repair culvert	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Install a baulk above culverts which are positioned directly above longwall panels. 2. Re-set 99.035km culvert extension due to piping issue 3. Management measures include: - Assess pre-mining condition of the culvert, (Dilapidation Report) - Consider mitigation measures if recommended by a structural engineer - Install / maintain existing monitoring systems - Regularly review and assess the monitoring data - Conduct additional visual inspections - Conduct repairs as required Grout interface between brick headwalls and concrete RCP extensions 4. Grout all pipe interfaces 5. Repair any recommendations observed from detail culvert inspection	1. Tahmoor Coal and ARTC have developed and implemented measures to successfully manage potential impacts on culverts over 15 years 2. ARTC Geotechnical Risk Site Database 3. Hydrology studies completed by HEC February 2020 4. Heritage studies completed by EMM Consulting February 2020	**Yes**
8	Embankments 98.380 – 98.500 98.700 – 98.770 99.000 – 99.050 99.250 – 99.400 100.020 – 100.220 100.400 – 100.500	Impacts on embankment serviceability	**Failure Mode:** Displacement leading to loss of track support **Causes:** 1. Mining induced ground movements. 2. Potential valley closure 3. Leakage from cracked culvert 4. Significant rain event / flooding	1. Changes to track geometry leading to; - Operating restrictions - Track closure. 2 Potential erosion **Worst Credible:** Track Closure less than 6hrs	**Inherent Control:** 1. Access roads along most embankment sides act as stabilising berms. 2. Relatively low embankment height 3. Embankment core expected to be constructed with rocky sandstone fill materials **Maintenance:** 3. Embankment maintenance 4. ARTC Standards and Inspections 5. SMP / Maintenance Plan **Train Operations:** 6. Driver reports 7. Subsidence Management Plan, including: - Mitigation Controls (prior to undermining): Studies and assessments (geotechnical, structural) **Monitoring Controls:** 8. Ground survey 9. Track monitoring 10. Visual Inspection (track certifier) 11. Geotechnical inspections 12. Wet weather inspection 13. Embankment crest extensometers	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Geotechnical assessment of embankment ground conditions and stability analysis to establish baseline conditions. 2. Install extensometers as determined by assessment	1. Tahmoor Coal and ARTC have developed and implemented measures to successfully manage potential impacts on embankments over 15 years 2. Experience from detailed embankment monitoring and inspection notes they are able to tolerate considerable mining-induced ground deformations without experiencing impacts, are generally not prone to development of tension cracks and are not prone to exhibit “steps or humps” in spite of changes in vertical alignment and high strain levels measured. 3. ARTC Geotechnical Risk Site Database	**Yes**

Risk Description					Assessment of Current Residual Risk					Risk Reduction Strategies		
#	**Consideration/ Aspect**	**Risk Issue**	**Failure Mode and Causes**	**Potential Impacts**	**Existing / Planned Controls**	**Type**	**Consequence**	**Likelihood**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**Historical Knowledge/ SFAIRP Comments**	**Yes SFAIRP**
9	Cuttings: 98.000 – 98.250 98.530 – 98.650 98.800 – 98.950 99.150 99.550 – 99.850 100.250 – 100.350 100.500 – 100.850	Blockage of cess drainage	**Failure Mode:** Debris falling into cess **Causes:** 1. Mining induced ground movement 2. Natural weathering and erosion 3. Significant rain event	Unplanned intervention **Worst credible:** Track Closure less than 6hrs	**Inherent Control:** 1. Shallow competent rock favourable to stability. and wide cess drains. **Maintenance** 2. Track examination system 3. ARTC Track Standards 4. Clear cess drains and loose material at crest 5. Check shoulder ballast profile **Operations** 6. Driver reports 7. TSR's if required **Subsidence Management Plan** 8. Ground surveys 9. Visual Inspection (track certifier) 10. Geotechnical inspections 11. Maintenance Plans 12. Wet weather inspection **Triggered Response** 13. Clean and reinstate drains	A	1	E	🟩 L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Nil additional identified	1. Tahmoor Coal and ARTC have successfully maintained cess drainage systems during longwall mining for over 15years 2. No subsidence related batter instability incidents recorded for cuttings over 15 years with occasional batter erosion associated with significant rainfall events. 3. ARTC Geotechnical Risk Site Database	**Yes**
10	Wellers Road Bridge (101.162km) Constructed C1918 	Impacts on bridge serviceability	**Cause:** 1. Mining induced ground movements	1. Speed restrictions during bridge repairs 2. Traffic control for road users 3. Unplanned intervention **Worst credible**: Track Closure less than 6hrs	**Inherent Control:** 1. Performance can be progressively monitored as longwall extraction moves gradually towards the bridge. 2. Bridge located 500m from LW106A **Mitigating Controls:** 3. Subsidence Management Plan 4. Numerical analysis of the bridge structure **Monitoring Controls:** 5. Absolute and local 3D surveys 6. Survey pegs on bridge 7. Visual Inspections 8. Baseline measurement across abutments **Triggered Response:** 9. Inspection, Evaluation and Respond to movement	A	1	E	🟩 L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Conduct assessment for longwall panels from 101A through to 106B 2. Install monitoring regime from commencement of longwall operations 3. Implementation of planned triggered responses: - Detailed inspection by structural engineer - Repair cracked brickwork/ spalled concrete - Install mesh to underside of the arch - Provide additional support to the arch/ walls - Seal cracks in pavement - Apply a load limit or stop vehicle traffic as appropriate 4.. Crack gauges on parapet wall	1. Tahmoor Coal and ARTC have successfully maintained bridge structures during longwall mining for over 10 years 2. TfNSW Structural Assessment Risk Site Database 3. JMA Structural Assessment Report R0237, May 2014 4. Original bridge design drawings and dimensions	**Yes**

Risk Description					Assessment of Current Residual Risk					Risk Reduction Strategies		
#	**Consideration/ Aspect**	**Risk Issue**	**Failure Mode and Causes**	**Potential Impacts**	**Existing / Planned Controls**	**Type**	**Consequence**	**Likelihood**	**Risk Level**	**Additional Controls/ Further Actions (SAFERR)**	**Historical Knowledge/ SFAIRP Comments**	**Yes SFAIRP**
11	Optical fibre cable	Damaged cable	**Failure Mode:** Extreme differential movement **Causes:** Mining induced ground movement	1. Loss of security monitoring 2. Lack of train information service 3. Lack of other commercial use **Worst credible:** Loss of communication	**Mitigating Controls** 1. Cable is installed in conduit **Monitoring Controls** 2. Automated monitoring of signal 3. Inspections and repair capability	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, no additional controls were identified 1. Fibre optic cable is monitored remotely and can be exposed and re-stressed if required during the course of mining.	1. Experience in the management of optical fibre issues in response to subsidence has been gained over 15 years from previous mining of Tahmoor and Appin longwalls.	**Yes**
13	Far Field – Railway Viaduct over Bargo River (96.265km)	Impacts on railway viaduct serviceability	**Cause:** 1. Mining induced ground movements 2. Far-Field effects from mining	1. Speed restrictions during bridge repairs **Worst Credible:** 2. Unplanned intervention on rail	**Inherent Control:** 1. >1.7km from active subsidence 2. Destressed area due to surrounding longwall mining **Mitigating Controls:** 3. Subsidence Management Plan **Monitoring Controls:** 4. Absolute and local 3D surveys 5. Survey pegs on bridge 6. Visual Inspections 7. Baseline measurement across abutments **Triggered Response:** 8. Inspection, Evaluation and Respond to movement	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Conduct a dilapidation report 2. Source historical structural design and as built reports	1. Knowledge gained from Picton Viaduct structural assessment 2. Previous LW mining which has occurred in and around the structure has not resulted in any known material impact	**Yes**
14	Far Field – Remembrance Drive Bridge (over rail) (96.400)	Impacts on bridge serviceability	**Cause:** 1. Mining induced ground movements 2. Far-Field effects from mining	1. Speed restrictions during bridge repairs **Worst Credible:** Unplanned intervention on rail	**Inherent Control:** 1. >1.5km from active subsidence **Mitigating Controls:** 2. Subsidence Management Plan **Monitoring Controls:** 3. Absolute and local 3D surveys 4. Survey pegs on bridge 5. Visual Inspections 6. Baseline measurement across abutments **Triggered Response:** 7. Inspection, Evaluation and Respond to movement	A	1	E	L	Consideration of; safety, asset, financial, environmental, regulatory and reputation (SAFERR) impacts, identified the additional control/s; 1. Conduct a dilapidation report 2. Source historical structural design and as built reports	1. Subsidence impact knowledge gained from far field impact monitoring	**Yes**

Appendix E

ARTC Risk Matrix

	Risk Category	Consequence				
Safety category is focussed on Impact to People	**S: Safety**	No Medical Treatment Required	Lost Time Injury Results (LTI) OR	Serious Injury Occurs	Single Fatality Occurs	Multiple but Localised Fatalities Occur
Asset category is focussed on Operations Impact, Track, Systems (Hardware & Software)	**A: Assets**	<6hrs Track Closure	>6hrs but <24hrs Track Closure	>24hrs but <48hrs Track Closure	>48hrs but <5 Days Track Closure	>5 Days Track Closure
Focussed on Financial Impact Cash flow, liquidity, Capital, Asset Value, Procurement & Contracts	**F: Financial**	<$250K	>$250K but <$2M	> $2M but <$10M	>$10M but <$50M	>$50M
Focussed on Environment Impact Heritage, Flora & Fauna, Archaeology & Indigenous, Pollution and Amenity (Public)	**E: Environment**	Contained Environmental Damage - fully recoverable (no	Isolated Environmental Damage - minimal ARTC	Localised/Clustered Environmental Damage - requiring remediation	Considerable Environmental damage - requiring remediation	Widespread long term or permanent damage to the environment -
Focussed on Regulatory/Legislation Exposure Non-compliance & Our Licence to Operate	**R: Regulatory**	Minimal or no Regulatory involvement	Notice to Produce Information	Improvement Notice or Threatened Action	Prohibition Notice or Fine/s	Prosecution of the company and/or its office holders
Focussed on Reputational Exposure Customer Dissatisfaction, Shareholder Support, Service Quality & Reliability, Public Image	**R: Reputation**	Isolated event able to be resolved [<7Days]	Management intervention required [>7days but	Tactical (Business Unit / Divisional) intervention required [>3 months but	Strategic intervention required [>18mths but	Corporate Loss of Shareholder and/or Customer support (tangible business
	Descriptor	***Not Significant***	***Minor***	***Moderate***	***Major***	***Extreme***

Likelihood		***Descriptor***	**Level**	**1**	**2**	**3**	**4**	**5**
Description	**Frequency of**							
Is expected to occur in most	Once per month	***Almost***	**A**	**MED - 1A**	**MED - 2A**	**HIGH - 3A**	**V HIGH - 4A**	**V HIGH - 5A**
Will probably occur in most	Between once a month and once a	***Likely***	**B**	**LOW - 1B**	**MED - 2B**	**HIGH - 3B**	**V HIGH - 4B**	**V HIGH - 5B**
Might occur at some time	Between once a year and once in	***Possi***	**C**	**LOW - 1C**	**LOW - 2C**	**MED - 3C**	**HIGH - 4C**	**HIGH - 5C**
Could occur at some time	Between once in 5 years and once in	***Unlike***	**D**	**LOW - 1D**	**LOW - 2D**	**LOW - 3D**	**MED - 4D**	**MED - 5D**
May occur in exceptional circumstances	Once in more than 20 years	***Rare***	**E**	**LOW - 1E**	**LOW - 2E**	**LOW - 3E**	**LOW - 4E**	**MED - 5E**

Structure Investigation Report

Reference: R0806-R3

Impact of Far Field Movement

Wellers Road Overbridge, Bargo

DOCUMENT HISTORY			
Revision	Date	Amendments	Author
	4.11.2022	Draft report issued to RMG	JM
R1	9.11.2022	Amendments recommended by RMG	JM
R2	11.11.2022	Amended to incorporate peer review comments	JM
R3	10.01.2024	Report updated to include longwall panel LW 7A	JM

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This investigation does not include the assessment of any building services such as electrical, gas, plumbing, drainage or stormwater or the presence of pest infestation. Similarly, it does not include the assessment of wall and roof framing or sub floor construction, which was inaccessible unless it is specifically referred to in the above report.

The observations and comments contained within this should not be construed as relieving the design engineer, builder, certifying authorities and customer of their relevant statutory obligations in relation to the relevant structures.

EXECUTIVE SUMMARY

Wellers Road Overbridge (WROB) at 101.152km on the Main Southern Railway is located beyond the predicted 20mm subsidence contour and outside the zone of active subsidence. The structure of Wellers Road Overbridge has been investigated, specifically targeting the possible impact of far field movement caused by longwall mining at Tahmoor South. Predictions of differential vertical and horizontal movement at 350m from the end of the nearest longwall panel (LW S6A) are comparatively small compared with what has occurred at other bridges and culvert structures that have been subsided in Tahmoor and Picton.

The investigation indicates that in the absence of any previous far field movement at this site, valley opening, and closure is not an insurmountable problem for the concrete arch structure at Wellers Road Overbridge, which is reinforced with widely spaced steel rails. However, since concrete is not necessarily homogeneous, the impact of valley closure could be more uncertain than it is for other far field movements.

Pre-existing cracking has been observed on the parapet and spandrel walls, which has most likely been caused by lateral earth pressure acting against the spandrel walls, arch rocking due to transient live load, seasonal temperature change and possible reactive soil movement beneath the remote ends of the spandrel walls. The damage is not structurally significant and does not currently impact the serviceability of the structure, nor is it expected to adversely impact the structure if the predicted amount of valley opening, or closure occurs.

Pre-existing cracking has also been observed on the arch intrados most likely caused by the impact of transient live load and seasonal temperature change. Whilst a transverse or lateral crack of width w=0.45mm (monitorable in accordance with ARTC EXE-09-01) has developed across approximately two-thirds of the width of the bridge near midspan, there was no evidence that the arch had spread outwards over the top of the abutment walls. It was concluded, therefore, that the crack had most likely been caused by transient live load. Longitudinal cracks were observed at several locations, which at a maximum width of 1.0mm, are less than the 3mm trigger that requires monitoring under ARTC EXE-09-01. The longitudinal cracks tended to correlate with the location of the widely spaced reinforcement rails and the longitudinal cracking could have been caused by the corrosion occurring on the flange of the embedded rails.

Transverse shear (racking) displacement could occur between the abutment walls supporting the concrete arch, which has been described as a horizontal mid-ordinate displacement by MSEC. If such movement is not relieved by a plan rotation between the underside of the concrete arch and the bearing surface on top of the abutment walls, transverse shear (racking) displacement could impact the concrete arch. The transverse shear capacity of the concrete arch has been calculated for a range of opening and closure displacements. The corresponding elastic displacement of the uncracked arch was calculated, which describes the Blue Trigger Monitoring Review Points for Valley Opening, Closure, and Transverse Shear Displacement and the concrete arch structure is expected to remain serviceable and track safety is not expected to be impacted, adversely.

As a control, it is recommended that a 5mm early warning trigger should be adopted as an intermediate monitoring review point to determine the likelihood of far-field movements or damage could exceed predictions. If it appears likely that the 5mm trigger will be exceeded or if structure damage exceeds expectations, then the Rail Management Group (RMG) should consider whether additional response measures are required. JMA has recommended that crack gauges should be installed on the parapet and spandrel walls, abutment wall and arch intrados cracks to monitor for the impact of far field movement during LW S1A-S7A, see **Figure 4 & Figures 60-62** and **Figures 61 & 62**. Furthermore, JMA has recommended that laser distometers should be installed to monitor abutment opening, closure and transverse displacement, see **Figure 63**.

BACKGROUND

Far-field horizontal ground movement can occur around longwall mining areas with the ground surface moving horizontally in the general direction of progressive longwall panel extraction. Survey data recorded at Thirlmere Way Underbridge (TWUB), Connellan Crescent Overbridge (CCOB) and Argyle Street Underbridge (ASUB) in Picton during mining of LW-W3 and W4 in the Western Domain, indicates that small amounts of opening and closure movement were measured between the survey marks and laser distometers (TWUB and ASUB) located on the opposing abutment walls at each bridge location. It is noted that TWUB was located at a similar offset distance to W4 in the Western Domain to WROB to LW S6A in Tahmoor South.

Wellers Road Overbridge is a concrete arch bridge with widely spaced reinforcement rails supported by brick masonry abutments with brick masonry spandrel and parapet walls, spanning across the Main Southern Railway at Bargo, see **Figures 1 & 3**. The terrain undulates gently around the site of the Overbridge, noting that the railway is situated in a comparatively shallow cutting and the road grades sharply upward for the intersection with Remembrance Driveway to enable the bridge structure to clear the rail traffic.

The bridge is located approximately 350m from longwall panel LW-S6A at Tahmoor South and 500m from the corner of LW S7A, see **Figure 2**. Previous epochs of Longwall and Wongawilli Method coal mining have been conducted in the area, with the closest area of second workings being located approximately 3km away, see **Figure 2**.

Figure 1 Location of Wellers Road Overbridge (yellow loupe) over the MSR, image courtesy of Google Earth.

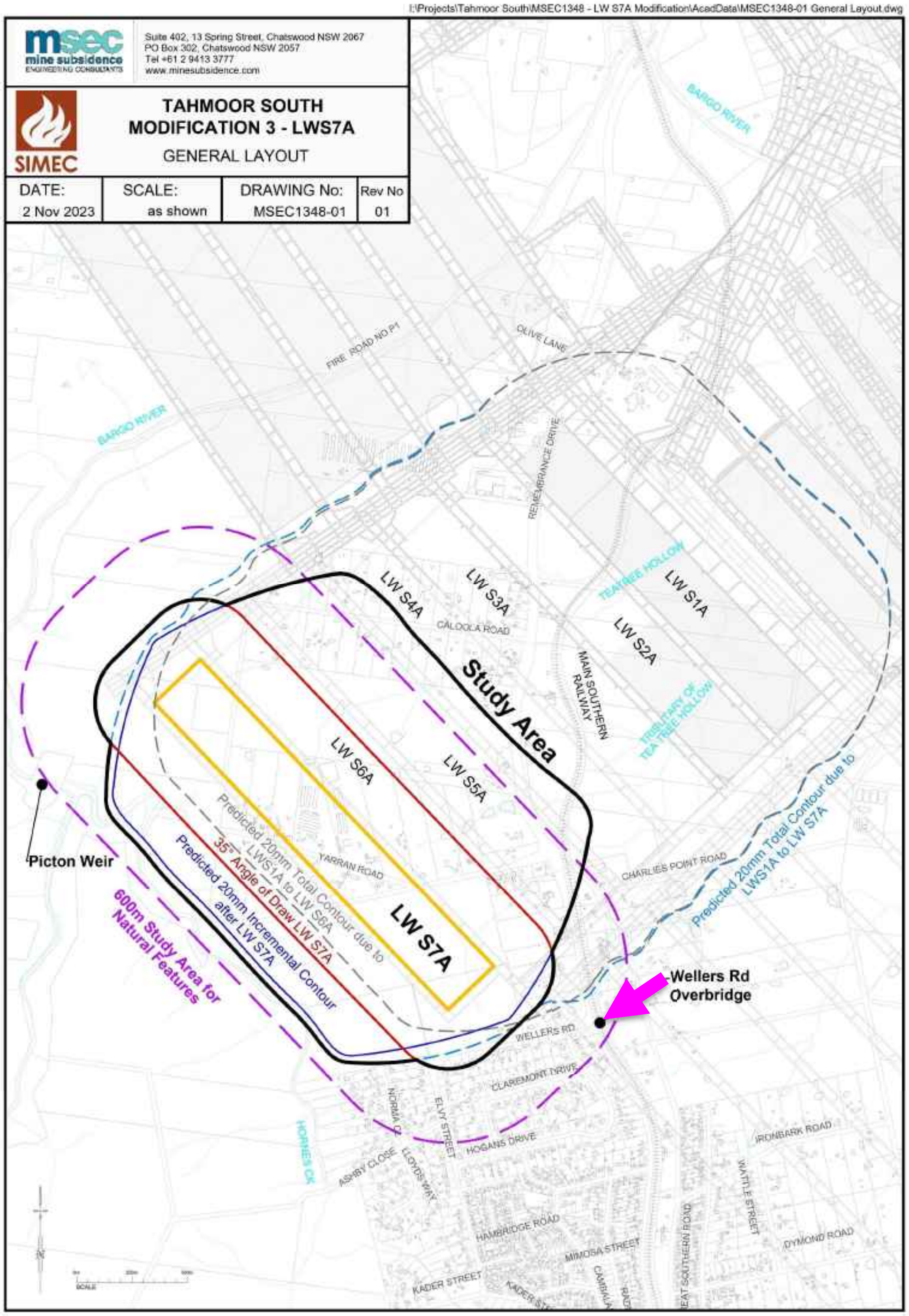


Figure 2 Wellers Road Overbridge as indicated by the magenta-coloured arrow is located 350mm from the end of LW S6A and 500m from the corner of LW- S7A

STRUCTURE GEOMETRY

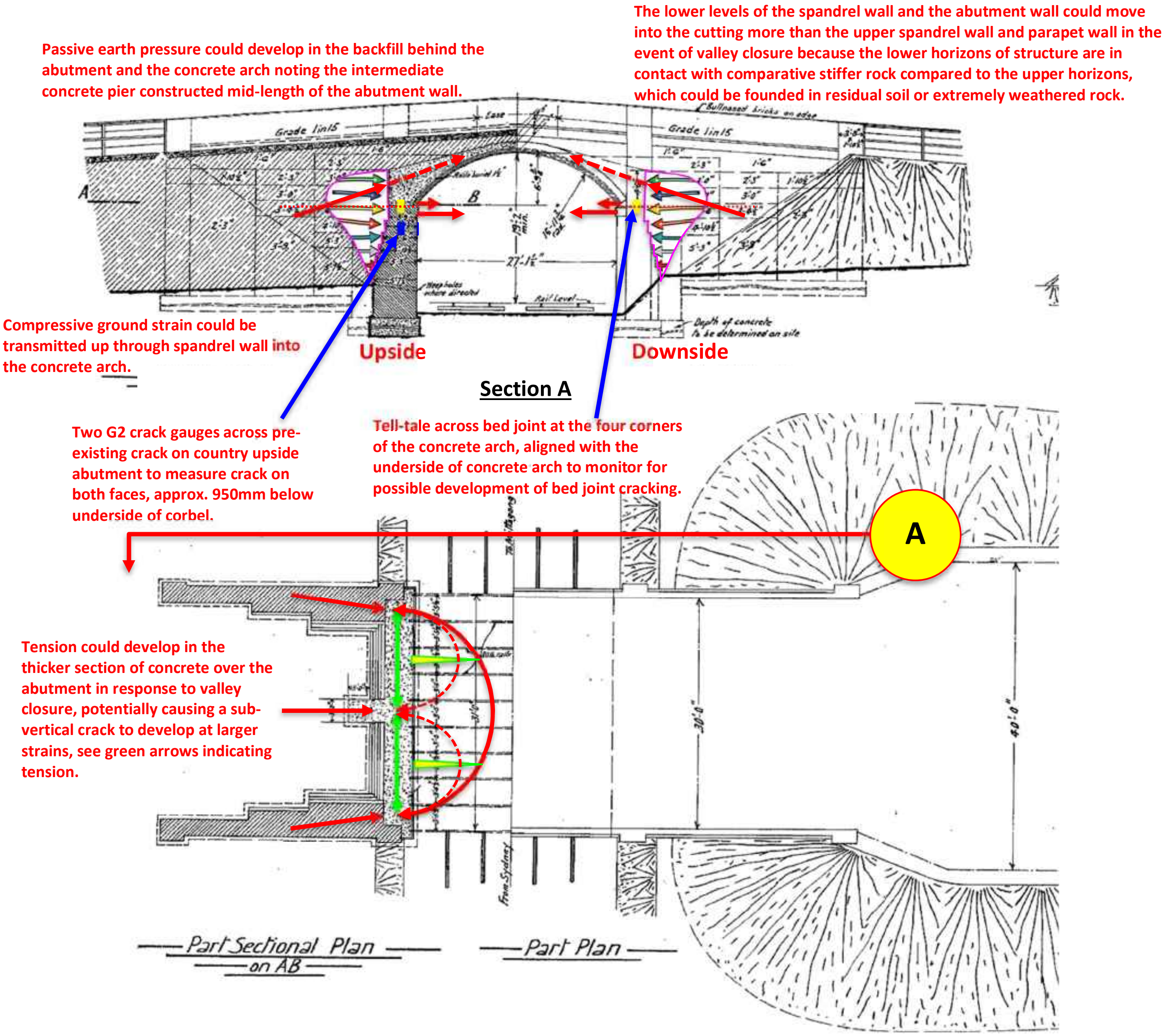
The Wellers Road Overbridge, 101.152km from Sydney, is located between Tahmoor and Bargo. The bridge was built circa 1917 as part of a deviation of the Main Southern Railway between Picton and Mittagong.

The drawings for Wellers Road Overbridge indicate that the 456mm thick concrete arch spans around 8.27m with a rise of 2.067m for a ratio of 4:1. The concrete arch has an engaged backing, increasing in thickness from 456mm at the tangent point to around 1370mm at the rear face of the concrete masonry abutment wall, see **Figure 3**. Furthermore, the drawings show that an intermediate mass concrete buttress was constructed behind the brick abutment. The drawings show that the concrete arch was reinforced with 80lb rails, however, the rails have not been exposed to verify that they exist. Therefore, the bridge was assessed as though it was unreinforced.

The cutting slopes outwards at around 45° from the cess. Whilst the cutting surface is not clearly visible, the rock is assumed to be shale interbedded with sandstone noting the reddish-brown coloured soil that is visible in some of the photographs. The elevational section shows concrete footings supporting the spandrel walls away from the abutments, see top frame in **Figure 3**. The end of the thickened concrete arch bears against an inwards projection of the spandrel wall on the sides and a central (intermediate) concrete buttress, which along with backfill placed against the rear of the abutment walls, resists arch spreading, see bottom frame **Figure 3**.

The spandrel wall is supported by a 456mm thick edge projection of the concrete arch above the tracks. Horizontal cracks were observed in the spandrel walls during the site inspections that have been conducted (2014 & 2022), which had not appeared to change in width, significantly, between the dates of the inspections. The horizontal cracks have most likely developed in response to transient vehicle loads causing the edge of the arch to deflect downwards then upwards in a longitudinal rocking motion as vehicles transit the bridge. This "rocking" action forces the overlying concrete spandrel walls to bridge across the downwards displacing portion of the arch causing the upper and lower horizons of the spandrel wall to separate and vertical cracking to develop in the parapet walls. The development of vertical cracking could have been exacerbated by shrink-swell behaviour of clay soil upon which the more remote ends of the spandrel/parapet walls could have been founded although it is noted that the soils above the Hawkesbury Sandstone tend towards being slightly reactive.

The spandrel walls beyond the abutment step in thickness with depth below finished ground level consistent with NSWGR drawings of the time. Weepholes are clearly visible on the downside abutment wall and appear to be partly concealed by ballast on the upside.



Passive earth pressure could develop in the backfill behind the abutment and the concrete arch noting the intermediate concrete pier constructed mid-length of the abutment wall.

The lower levels of the spandrel wall and the abutment wall could move into the cutting more than the upper spandrel wall and parapet wall in the event of valley closure because the lower horizons of structure are in contact with comparative stiffer rock compared to the upper horizons, which could be founded in residual soil or extremely weathered rock.

Compressive ground strain could be transmitted up through spandrel wall into the concrete arch.

Two G2 crack gauges across pre-existing crack on country upside abutment to measure crack on both faces, approx. 950mm below underside of corbel.

Tell-tale across bed joint at the four corners of the concrete arch, aligned with the underside of concrete arch to monitor for possible development of bed joint cracking.

Tension could develop in the thicker section of concrete over the abutment in response to valley closure, potentially causing a sub-vertical crack to develop at larger strains, see green arrows indicating tension.

Figure 3 Actions in the bridge structure caused by valley closure shown diagrammatically, superimposed on a sectional bridge elevation (Section A) viewed from the countryside and plan of Wellers Road Overbridge. Note, for crack gauge type, refer to Appendix B.

STRUCTURE CONDITION

The structure of Wellers Road Overbridge was inspected on 22 February 2014 from track level and on 14 May 2022 from a "Hi-rail" elevated work platform. The defects that were observed in May 2014 and subsequently inspected from an EWP in September 2022 are recorded in **Table 4, Appendix G**.

Vertical cracking was observed on the Sydney parapet wall at three locations, two of which were not visible from the EWP, which could have been caused by reactive soil movement at the ends of the spandrel walls (remote from the main span and abutments spandrel) superimposed on the effect of transient live load and seasonal temperature change, see Figure 4. Horizontal bed joint cracks were observed along the parapet walls on the Sydney and Country spandrel wall on the upside, which could be related to transient live load and earth pressure acting against the spandrel walls. Other minor cracking was observed, which has been recorded in the Appendices for records purposes.

During the September 2022 inspection, the intrados of the concrete arch was tested by hammer sounding from the elevated work platform. This was carried out in eight transverse passes across the width of the bridge moving the hammer from upside to downside to cover a strip approximately 1.2metres wide as the Hi-rail moved back and forth along the tracks. The intrados was struck every 2-3 seconds with blows spaced approximately 0.2m-0.3m apart. The pattern of the hammer blows, therefore, followed a roughly sinusoidal path across the width of the bridge. A crisp sound report was heard from around 300-400 hammer blows, indicating a low-level of likelihood of concrete spalling. In addition to the general sweep of hammer blows, the intrados was struck along the edge of some cracks, noting that a crisp report was also registered from these areas. The intrados surface was generally in serviceable condition noting areas of the intrados where the sand and cement matrix was abraded around the near-surface aggregate by steam and diesel exhaust, which have been marked by white aerosol paint cross-hatching, see **Figures 23, 24 & 60.**

Cracking was observed at four locations on the parapet walls, which could have been caused by the impact of traffic loading that has been superimposed on seasonal temperature effects, see **Figure 3**.

Figure 4 Parapet wall (Sydney top) cracking showing recommended locations for Type G2 crack gauges.

Whilst the bridge is in serviceable condition, the RMG has installed crack monitoring gauges like those shown in **Figure 4** and **Appendix F**, and tell-tale marks at spring points at the four corners of the arch for monitoring, see **Figures 60-62**.

CHARACTERISTIC STRENGTH OF THE CONCRETE ARCH

Concrete core samples measuring approximately 50mm in diameter and 130mm in length were recovered from the concrete footings that support the abutment walls of Thirlmere Way Overbridge in Tahmoor during 2006. Testing was conducted by GHD-Geotechnics, to determine the unconfined compression strength and dry density of the core samples, from which the modulus of elasticity and equivalent cylinder strength has been determined for each sample, see **Table 1**.

Table 1 Thirlmere Way Overbridge UCS test results, note cylinder strength has been inferred from core UCS testing in accordance with ACI Guide 214.4R-10.

Specimen	Depth (m)	Core Diameter (mm)	Core Length (mm)	Height/ Diameter	UCS MPa	F'$_c$ (MPa) ACI Guide 214.4R-10 (MPa)	E$_c$ (MPa) inferred	$\gamma_{dry\ kg/m3}$
BH1	7.49 to 7.53	51.7	140.3	2.71	19.3	19.4	17137	2016
BH1	8.35 to 8.5	50.3	139.6	2.78	16.4	16.2	16258	2065
BH1	9.38 to 9.51	50.5	137.2	2.72	10.6	10.6	12379	1984
BH1	10.47 to 10.6	50.8	144.0	2.84	16.8	16.4	17122	2131
BH1	11.0 to 11.13	50.0	131.2	2.62	9.7	9.9	12144	2005
BH2	7.3 to 7.44	51.8	139.0	2.69	14.2	14.3	14121	1960
BH2	8.5 to 8.63	51.4	137.1	2.67	11.6	11.7	14174	2100
BH2	9.47 to 9.51	51.6	142.1	2.76	15.1	15.0	15917	2090
BH2	10.43 to 10.56	51.6	137.2	2.60	13.2	13.4	14279	2020

The concrete recovered from the footings at Thirlmere Way Overbridge (TWOB) may best be described as a shard or cyclopean concrete noting the comparatively low dry densities that were recorded, from which, relatively low values of modulus of elasticity were calculated in accordance with AS5100. By way of contrast, hammer sounding and drilling of the now demolished concrete arch overbridge on Bridge Street in Picton, which was of similar construction to Wellers Road Overbridge, indicated a relatively hard concrete with rounded basalt (or similar) aggregate being exposed on the intrados. From the aggregate alone, the dry density of the concrete at Bridge Street and Wellers Road is likely to be significantly greater than the “shard” or “cyclopean” concrete used at Thirlmere Way Overbridge.

Using the compressive strength testing conducted on TWOB specimens as an indicator of compressive strength, which on the face of the hammer sounding could be overly conservative, the following material properties have been used to assess the concrete arch at Wellers Road:

- F'_c = 11MPa, which is the characteristic compressive strength of the Thirlmere Way Overbridge specimens with a 3% exceedance probability based on UCS testing of 9 specimens.
- Concrete density 2450kg/m3
- E_c = 17,300 MPa
- ν= 0.2-0.3
- Cohesive (shear) strength of concrete 1.50MPa (Mohr-Coulomb)
- Friction angle of concrete 55°(Mohr-Coulomb) Tan 55° = 1.43
- Residual friction angle of concrete 40° (Mohr-Coulomb) Tan 40°=0.84

It is noted that clause A1.4 of AS5100.7: 2017 recommends a compressive strength of 21MPa for use in a bridge assessment when material test data is not available. A compressive strength of this magnitude is possible if the concrete was produced in the proportions of 1 part cement, 2 parts sand and 3 parts coarse aggregate and a water: cement ratio, w:c = 0.6. This concrete could achieve a modulus of elasticity of 23,900 MPa, which is 38% higher than that used in the modelling.

In a strain-driven environment like valley opening or closure, structure reactions are expected to develop in proportion to the product of structure stiffness and displacement, according to Hooke's Law. If structure geometry is held constant and the concrete modulus of elasticity increases by 38%, structure stiffness and, therefore, structure reaction to ground displacement increases by 38%. However, it is noted that whilst the concrete modulus of elasticity increases by 38%, concrete compressive strength increases by 91% (11MPa increases to 21MPa). Therefore, as stiffness increases, the ability of the structure to resist the strain-driven impacts increases at a greater rate. Therefore, the use of lower strength concrete in the assessment should be conservative for the assessment of valley opening and closure.

For the calculation of the design shear force acting on sections of un-cracked concrete work, in any direction, is calculated by the equation: $\tau_d = \phi(C + \sigma_n \times \text{Tan } \psi)$, where ϕ is a capacity reduction factor (ϕ=0.6), C is the cohesive shear strength of concrete acting across the compression area of the arch σ_n is the compression stress normal to a shear surface in the compression zone of an arch noting that the depth of the compression zone varies, depending on how the structure is loaded and where the hinges develop.

Where the concrete arch was modelled in isolation (spandrel walls assumed not to interact with the arch), the concrete arch is generally uncracked under structure self-weight, earth fill and pavement loads. When a T44 truck load is applied asymmetrically to the arch, the load is predominantly resisted by arch compression with tension being generated on the intrados and extrados at various locations, which the analysis indicates, should cause cracking to develop.

Where tenson and, therefore, cracking develops near the intrados or extrados under transient loads and compressive stress is not subsequently re-established after the vehicle has moved across the bridge, these areas are treated has having no residual cohesive shear strength and friction cannot be mobilized because the cracks have not closed. However, if compression is re-established after transient loading, even though the section might have been cracked in tension and cohesive strength is lost, the now closed crack interface is assumed to have post-critical shear strength determined by compressive stress normal to the cracked surface and the post-critical residual friction angle, assumed to be 40°.

Vertical load is typically supported by arch compression and radial shear stress (due to vertical loading) across the compression area of the arch. Radial shear stress is comparatively small in comparison with arch compressive stress. If total shear stress (the vector resolution of vertical and horizontal shear stress) caused (primarily) by transverse shear displacement exceeds the shear capacity across the compression areas of the arch, then diagonal tension cracking could occur across the arch or diagonal tension could increase the width of pre-existing cracks. It is recommended, therefore, that Type 2 crack gauges (see **Figures 58 & 59** in **Appendix F**) should be installed across pre-existing cracks, see **Figure 60** in **Appendix G**.

ANTICIPATED FAR FIELD MOVEMENT

Far field movement could occur at the bridge location some 350m from the end of longwall panel LW-S6A noting that the corner of LW S7A is located approximately 500m from the bridge. Typically, far field horizontal movement tends to occur as a bodily movement of the ground surface towards the extracted goaf area of greater magnitude than vertical ground surface movement with comparatively low levels of strain. However, where structures have been constructed across surface incisions, higher levels of localised movement could occur.

A statistical analysis of potential differential far field horizontal movements is provided in MSEC1193-02-Rev A. In reference to this data, around +17mm of valley opening and -14mm of valley closure could occur across the railway cutting at Wellers Road Overbridge, due to far field movement, with a 1% Exceedance Probability. Furthermore, horizontal mid-ordinate deviation of up to 14mm could occur, with a 1% Exceedance Probability.

Table 2 Probabilities of exceedance for incremental differential horizontal movements for survey bays located from the nearest goaf edge in the Southern Coalfield at offset distances equivalent to Remembrance Drive Bridge over the Bargo River, reproduced courtesy of MSEC.

Offset distance from LW	Probability of Exceedance	Incremental differential horizontal movements for pegs spaced between 10 and 30m (mm)		
		Opening (mm)	Closure (mm)	Horizontal mid-ordinate deviation (mm)
350 m (Wellers Road Overbridge)	1 in 20 (0.05)	9	8	9
	1 in 100 (0.01)	17	14	14

The structural assessment of the Wellers Road Overbridge considers far field movement due to LW-S1A to S7A noting that Wellers Road Overbridge is more than 3km from the nearest areas of previous longwall mining.

EXTENT OF INVESTIGATION

A targeted investigation of the impact of valley opening, closure and transverse shear displacement, which could occur because of far field movement caused by longwall mining, has been conducted on the Wellers Road Overbridge.

The magnitude of ground displacements that have been simulated in the structure model are as follows:

i. The nodes at the end of the concrete arch were moved outwards and inwards by an amount of 20mm multiplied by a rating factor, to simulate the effect of valley closure on the abutments and spandrel walls, which are most likely to be founded on weathered rock.
ii. Transverse shear displacement could occur because of far field movement. The predicted capacity in transverse shear has been used to determine a corresponding value of displacement modelling flexural and shear stiffness of the bridge deck.

A displacement factor of 1.5 has been applied to mine subsidence movements as required by AS5100, at the Strength Limit State.

Dynamic Load Amplification

A dynamic load amplification factor α=0.4 has been applied to the T44 truck load, which is not assumed to reduce in magnitude down through the pavement and fill to the concrete arch to model the dynamic effects of vehicles moving across the bridge.

Structure Modelling

A 2-D digital model of the Wellers Road Overbridge has been developed in Microstran, using cruciform radial elements to intersect with and connect the six (6) concentric rings of "concrete" that are 76mm in thickness, creating circumferential and radial elements of similar length. The ring and vertical backing elements are modelled as compression-only members with zero concrete tensile strength, noting that compression-only members are released in the non-linear analysis when decompression occurs. The radial elements that interconnect with the circumferential ring elements, are subjected to tension, compression in addition to bending and shear, as the elements transmit forces between the rings, which is required to achieve convergence of the model.

Horizontal supports (providing horizontal support-only) have been provided at the remote ends of the horizontal backing and skewback elements, see **Figure 5**. This assumes that the thickened potion of the arch over the abutment walls can sustain a tension tie-force as the horizontal reaction from the arch, is in turn, arched across the structure laterally, to the spandrel walls.

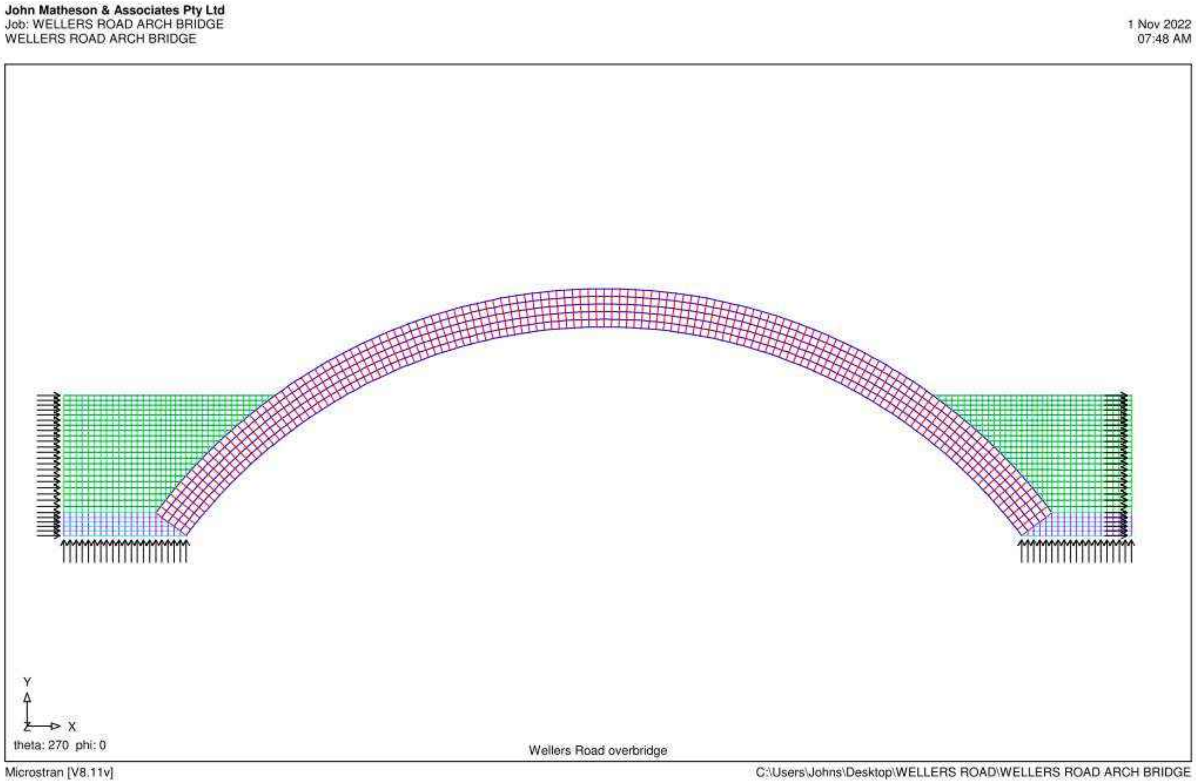


Figure 5 Elevation of the model of Wellers Road Overbridge showing circumferential and radial ring elements, and horizontal and vertical backing and skewback elements.

Vertical supports (providing vertical support-only) have been placed at the bottom of the vertical skewback elements, which are modelled as compression-only members to allow decompression to occur along the interface between the underside of the skewback and top of the brickwork abutment walls. This allows the structure to partially lift from the brick abutment walls and the vertical reaction to move towards front face of the abutment walls depending on relative stiffness and loading.

Unfactored T44 loads have been applied directly to the extrados elements as a distributed loading reflecting how the wheel loads distribute down through the pavement and earth fill to the extrados, both tin the lateral directions as well as the span direction. The load and displacement factors are applied as load combination cases, including dynamic load amplification.

Load Distribution

Depth of pavement and fill at various locations was estimated from the road profile drawing, see **Figure 3**. The surcharge loading was distributed down through the fill at a slope of 1 Horizontally to 2 Vertically (26.6°) according to AS5100, distributing uniformly across the extrados within the footprint area, see **Figure 5**.

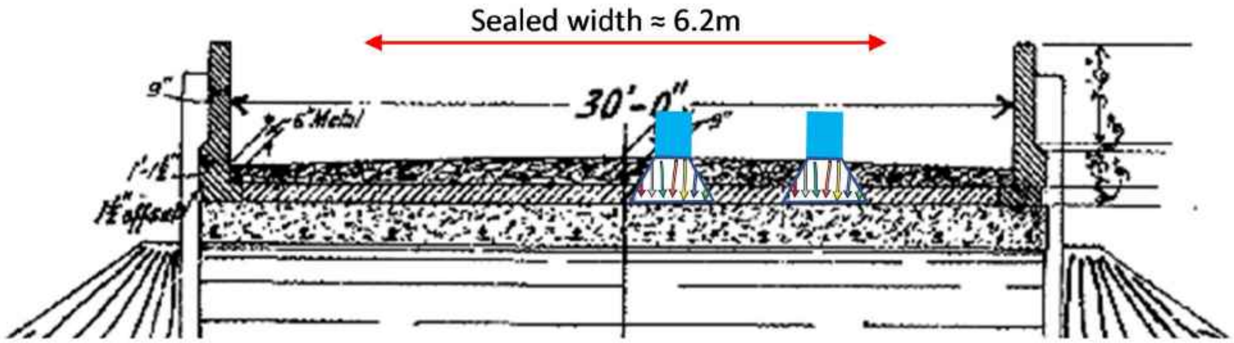
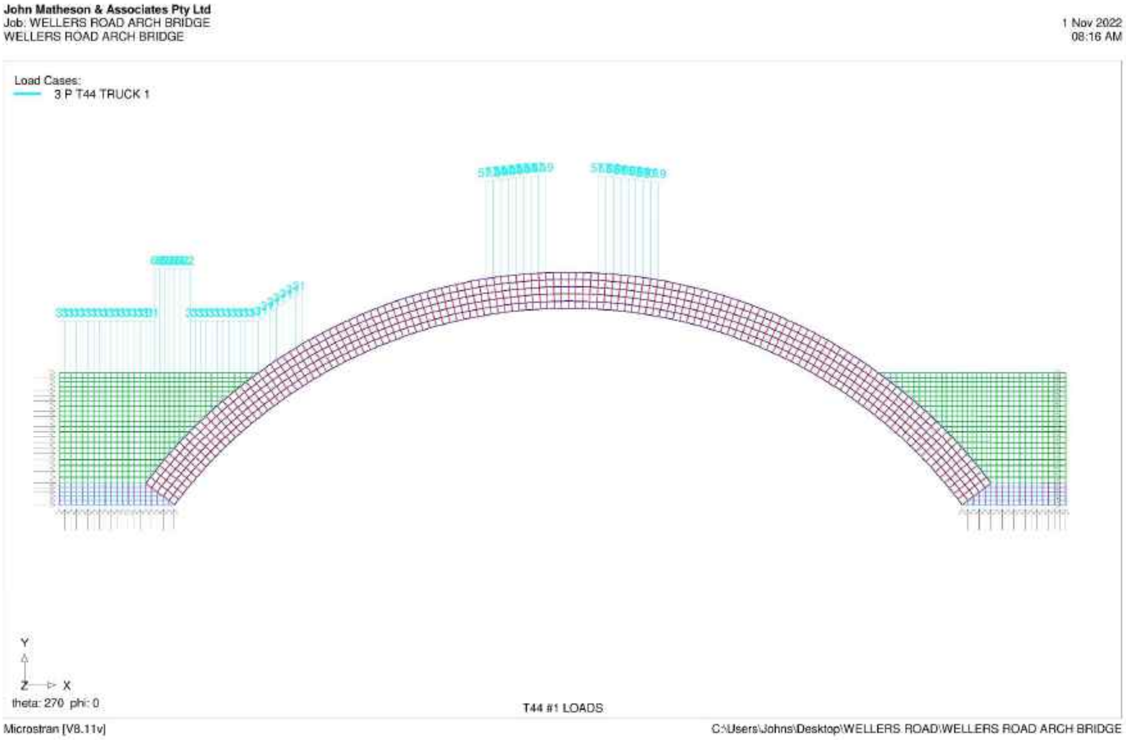


Figure 6 Load distributed down through the pavement and fill onto the extrados of the arch.

The same approach was applied to the distribution of wheel load in the longitudinal direction of the bridge, see Figures **7 & 8**.


John Matheson & Associates Pty Ltd
Job: WELLERS ROAD ARCH BRIDGE
WELLERS ROAD ARCH BRIDGE

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Load Cases:
3 P T44 TRUCK 1

T44 #1 LOADS

Microstran [V8.11v]

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Figure 7 Asymmetric T44 loading No 1 with axles centred about 1/4 span.

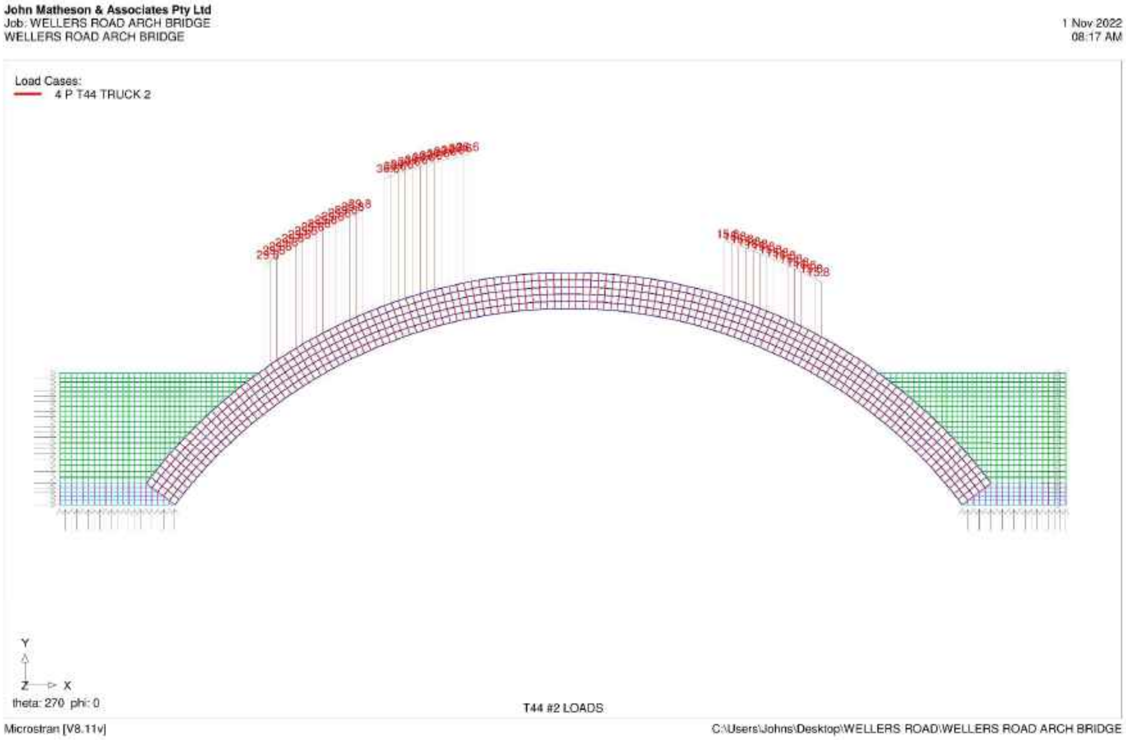


Figure 8 Asymmetric T44 loading No 2 with axles centred about 1/4 span.

Load Rating

Two T44 axle load cases were centred loads (#1 & #2) asymmetrically at ¼ span of the concrete arch, see **Figures 7 & 8**. When the truck moves onto the bridge and the axle loads are located as shown in **Figure 8**, the model predicts decompression to occur and cracking could develop in the two hinge locations, see **Figure 10**. The sagging hinge is located close to midspan, and it is likely that as the truck moves across the bridge, the hinge would also move towards the other side of the bridge passing through midspan. As the truck leaves the bridge in a manner like that shown in **Figure 7**, the model predicts that tension cracking should close as very slight compressive stress is re-established. A transverse crack measuring 0.45mm in width has developed across approximated two-thirds of the width of the arch, see **Figure 60** in **Appendix G**. The transverse crack extends up the Sydney side face of the arch to the extrados, measuring 0.45mm in width at two-thirds depth, see **Figure 43**. The tendency of the transverse crack towards the Sydney side of the arch indicates that seasonal temperature change could have contributed to crack development noting that the north-facing Sydney side has had greater temperature variation than the countryside causing the crack to extend up the side face of the arch. The extent to which this crack extends through the arch is not known and it is recommended, therefore, that a Type 2 crack gauge should be installed on both the side face of the arch and the intrados near the edge to monitor for change in crack width or differential shearing movement along the crack on the side face of the arch.

A two-dimensional model, whilst useful in determining the ULS capacity of an arch structure, does not model the effect of localised effect of wheel loading nor does it predict the magnitude of transverse bending stress. It is apparent from the longitudinal cracking observed on the intrados, that not only has decompression in the span direction caused a transverse crack across the width of the arch around midspan, but transverse bending could have contributed to the longitudinal cracking, which measure up to 1mm in width, see **Figure 14** in **Appendix A**.

The simulation predicts a maximum compressive stress of around 8.6MPa in the concrete arch at ULS with a rating factor of RF=1.0, see **Figure 11**. The analysis predicts that two hinges could develop at ULS, indicated by the red arrows, see **Figure 10**.

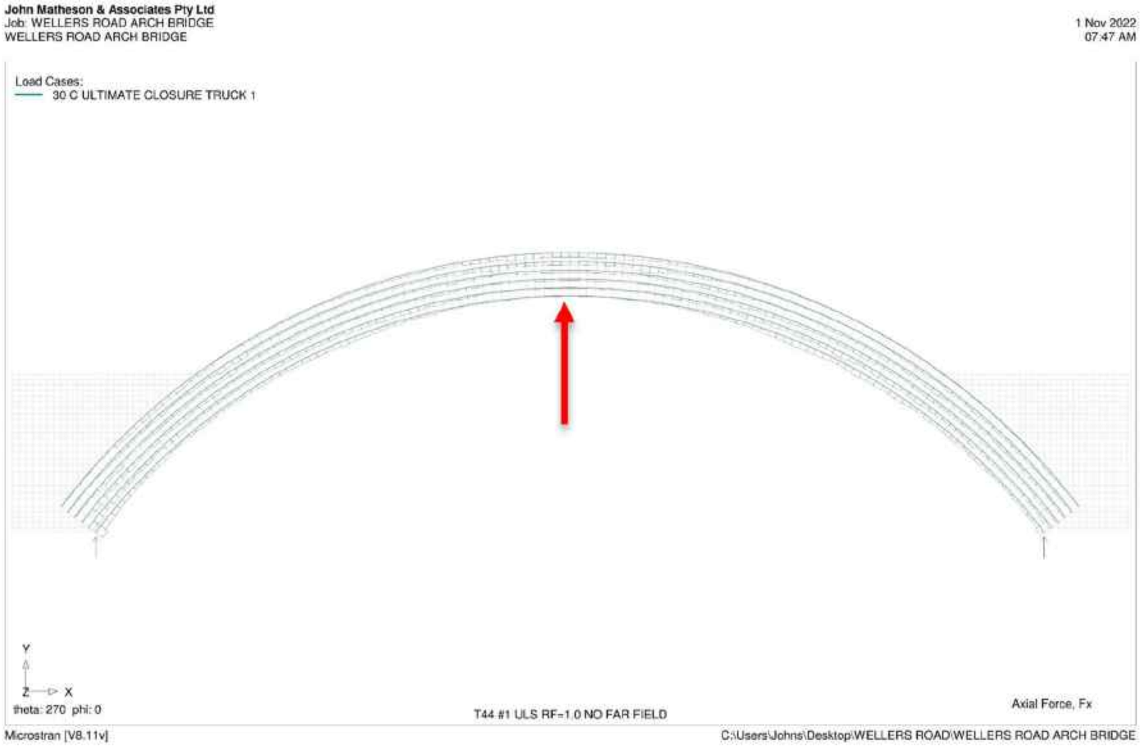


Figure 9 The intrados is very close to decompression around midspan under T44 loading #1 centred at ¼ span.

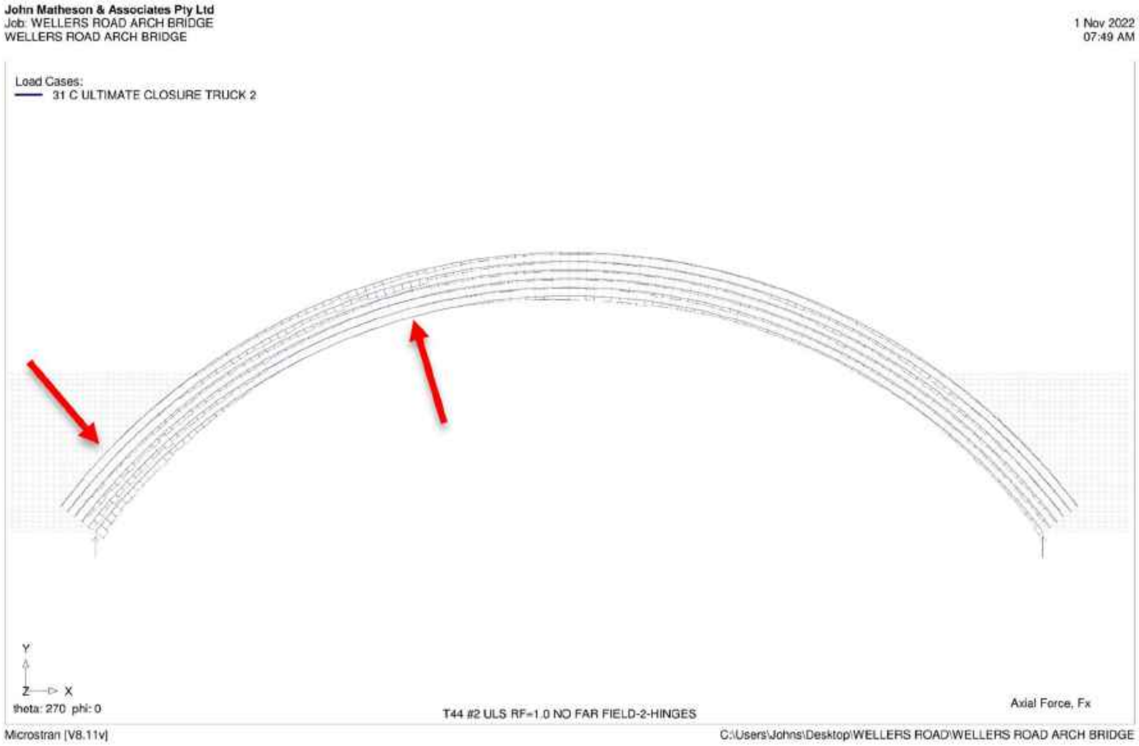


Figure 10 The numerical model predicts that two (2) hinges will develop for T44 #2 truck load (centred at ¼ span) at ULS with a rating factor RF=1, red arrows indicate the hinge locations.

Concerning the intrados cracking, the transverse or lateral crack does not fully extend across the width of the arch and may only extend through the arch on the Sydney side, which could be temperature related. Since this crack is sub-2mm in width and may not continue through most of the arch, the RMG could monitor the crack according to ARTC-EXE-09-01 and the RMG should install three Type B gauges across the crack for monitoring. The longitudinal cracking is less than the threshold value of 3mm that requires monitoring under ARTC-EXE-09-01. However, the RMG should install Type 2 gauges at 5 locations across these cracks for monitoring. The purpose for so doing is to monitor for a change in longitudinal crack width if transverse tension develops near the abutment in the event of valley closure (see green arrow in **Figure 3**), see the next section.

Valley Opening & Closure

Valley closure across the railway is expected to move the foundation supporting the abutment and spandrel walls toward one another. This movement is expected to be resisted by concrete arch, the spandrel wall that spans across the cutting, earth fill material and the road pavement. Because of structure geometry, inwards moving spandrel walls area expected to react against the four corners of the concrete arch causing the arch to displace upwards and likely causing tension forces to develop in the transverse direction over the abutment walls, between the reaction points, see **Figure 3**. While cracking was observed on the surface of the Sydney upside spandrel wall, see **Figures 45 & 47**, for which Type B crack gauges are recommended, valley closure should generate compressive stress in the spandrel wall. Since no horizontal bed joint cracking has been observed along the spandrel walls at the spring level (flat base of the arch), valley closure is expected to be transmitted into the arch and supported structure. As noted in the preceding section, the pre-existing longitudinal cracks should be gauged to monitor for any change in crack width that might signify that transverse tension is being generated by valley closure.

Valley opening across the railway is expected to do the reverse of valley closure with the foundation supporting the abutment and spandrel walls expected to move apart. This should cause the flat base of the concrete arch to follow the abutment wall. If the outwards movement of the flat base of the arch lags the abutment wall, it is expected that the outwards thrust of the concrete arch should, at some point, overcome interface friction (between the concrete and brick) allowing the base of the arch to move outwards and re-establish lateral longitudinal bearing against the brickwork that currently supports the arch. Survey and gauge monitoring in the event of opening (and closure) should enable informed decisions to be made concerning structure response during valley opening. However, it is recommended that telltale marks should be installed across the brick bed joint at spring level on all four corners of the bridge to detect the development of differential horizontal movement.

Under existing conditions with no valley opening or closure, a compressive stress of around 3.6MPa was calculated for a T44 truck assuming a rating factor of RF=1.0, which is much less than the characteristic compressive strength of the concrete (Thirlmere Way) of 8.2MPa and 8.85MPa, respectively, at the 0.1% and 0.2% exceedance probabilities. Therefore, the actual rating factor for this bridge is considerably higher than RF=1.0. For valley opening and closure displacement, a baseline value of 20mm was assumed. The bridge was then assessed for factored amounts of the assumed baseline valley opening and closure displacements, holding the rating factor for the T44 truck load constant at RF=1.0. Valley closure has the greatest impact on the development of compressive stress in the arch, with compressive stress more than doubling from 3.6MPa to 7.4MPa at 10mm of closure, see **Figure 11**. Compressive stress appears to asymptote reaching a maximum value of 8.6MPa, after a 3rd hinge develops, see the Magenta trace in **Figure 11**. It is noted with the development of a third hinge, that the arch has become statically determinate and is generally unaffected by differential settlement, temperature change or horizontal strain. However, it is recommended that opening or closure displacement should not exceed 25mm.

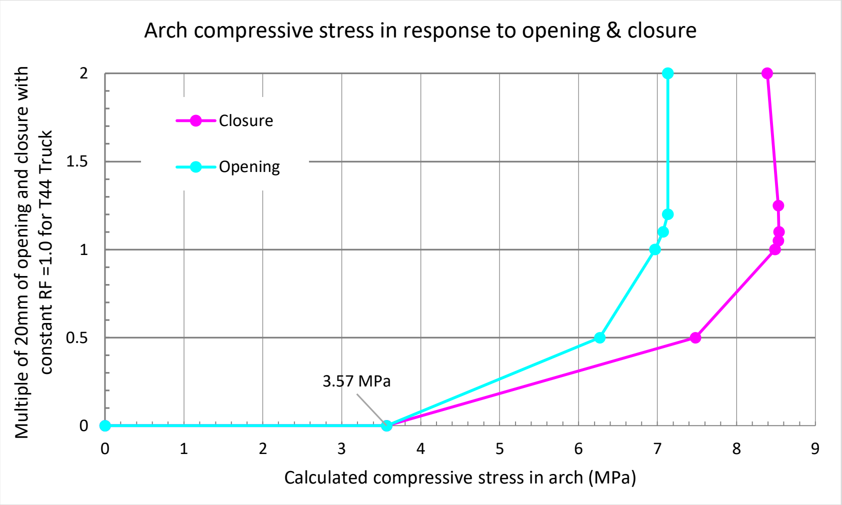


Figure 11 Variation in compressive stress calculated in the arch with increasing opening and closure movement.

Transverse Shear Displacement

It is possible that transverse shear displacement could occur independently of valley opening or closure. If so, the ability of an arch span to deform in shear can be calculated by elastic methods. The formula used to calculate transverse shear displacement considers gross (uncracked) flexural and shear stiffness of the arch as measured along the arch centreline between the spring points.

The transverse shear strength of the arch has been calculated at the strength limit state using maximum and minimum ULS load factors to calculate arch compression. It is noted that that some rings of the concrete arch can alternate between tension and then compression as the axle groups move across the arch span with calculations showing that as little as one or two of the assumed six rings of concrete being under constant compression. Under these conditions, the shear strength of the uncracked elements was determined according to Mohr-Coulomb, using a cohesion C=1.25MPa and a friction coefficient = 1.43 (Tan 55°). For elements where transient decompression can occur, the concrete has been assumed to lose cohesive strength but retain a post-critical friction coefficient of 0.84 (Tan 40°). Where the model shows decompression could occur and compression is unlikely to be re-established, the concrete has been assumed to lose cohesive strength and friction does not contribute to shear strength. The transverse shear strengths that are calculated are divided by the uncracked arch thickness and the transverse displacement is calculated using average stress, which should be conservative.

Using the material properties described earlier in the report, and the following equation for shear displacement:

$\delta = \frac{\tau A^{3}}{12EI} + \frac{\kappa \tau L}{G}$, an ultimate shear displacement of 6mm at Ultimate Limit State (ULS) and 4mm at Serviceability Limit State (SLS) working based on ULS/SLS=1.5.

Interaction of Valley Opening/Closure and Transverse Shear Displacement

The interaction between valley opening and closure, and transverse shear displacement has been calculated iteratively, applying pre-set opening and closure movement, and then calculating the transverse shear force at ULS. The locus of points so calculated can be used to form a Blue Trigger Monitoring review point for unfactored service loads and displacements, see **Figure 12**.

If transverse shear displacement (mid-ordinate deviation) exceeds predictions or damage occurs sooner than predicted, diagonal tension cracking could develop across the intrados, which could increase the width of pre-existing cracks or develop new cracks noting that such cracking is more likely to range from one corner to the diagonally opposite corner of the arch.

SERVICES

The impact of valley closure on any services has not been assessed in this report.

SUMMARY

The spandrel walls and concrete arch have developed pre-existing cracking, caused by lateral earth pressure acting against the spandrel walls, transient live load, and seasonal temperature change. Notwithstanding the observed cracking, the structure is in serviceable condition. However, since far field movement is possible at the site of this bridge, JMA recommends that the RMG should install crack gauges and tell-tale marks across cracks or bed joints where an increase in crack width or movement is possible, see **Figure 4** & **Figures 60-62.**

A targeted investigation of the Wellers Road Overbridge, as new, indicates that 25mm of valley opening or closure could occur in conjunction with a T44 loading without the Rating Factor of the bridge reducing below a value of RF=1.0. Furthermore, calculations indicate that the bridge could tolerate a range of transverse shear displacements depending upon the amount of opening or closure that has developed, see **Figure 12**.

From a subsidence management perspective, JMA recommends that the RMG should establish an early warning monitoring review point trigger of 5mm for valley opening or closure, like it has been for other bridge structures in Bargo, to enable a structure inspection to be conducted to determine whether any damage has occurred or whether it appears likely to occur with increasing valley closure or opening.

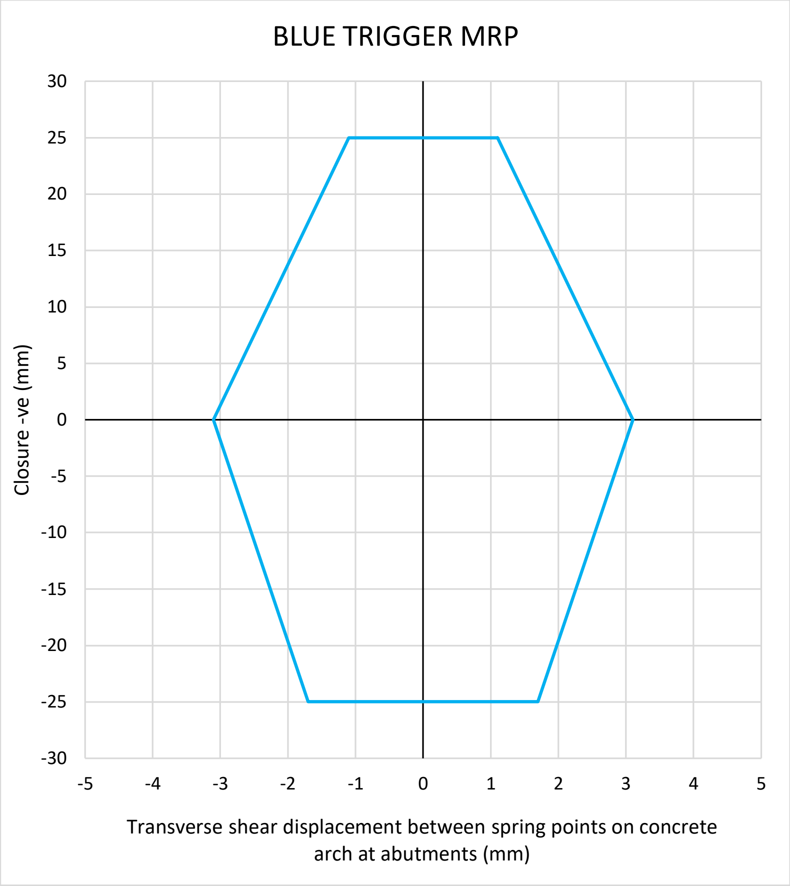


Figure 12 Blue monitoring review point for Bargo Bridge

RECOMMENDATIONS

Based on a targeted investigation of the impact of far field horizontal ground movement on the Wellers Road Overbridge and noting that the extraction of LW S2A is moving towards completion, JMA recommends the following actions:

i. Instal survey targets on the arch at midspan, abutment spring points and at the remote ends of the spandrel walls to monitor subsidence and horizontal ground movement.

ii. Instal laser distometers and targets to the vertical surface of the brick corbel immediately beneath the arch spring points to measure the perpendicular distance between the abutment walls at the country and Sydney ends of the up- and down-side abutment walls and the diagonal distance between the abutment walls, see **Figure 63** for the diagrammatic layout of distometers and targets. The laser distometers and targets, and the baseline distances and ambient temperature should be measured on site before the end of longwall panel LW S2A.

iii. Instal crack gauges over cracks as shown in **Figure 4 & Figures 60-62**. Install tell-tale marks at the spring points at the four corners of the arch, see **Figures 61 & 62**.

iv. If valley opening, closure or transverse step displacement appears likely to exceed 5mm as measured on the ground surface, the Rail Management Group (RMG) should conduct a site inspection of the bridge. Depending on the findings of the site inspection, consider whether increased monitoring and/or additional response measures are necessary. Additional response measures could include the following:
    a. Install and chemically anchor rolled steel reinforcement straps that have been rolled to a matching radius, to the underside of the concrete arch to improve structure ductility.
    b. Install a mesh to the underside of the arch to catch falling pieces of concrete if this appears likely.
    c. Install a temporary support structure in the depth of the road profile such as a grillage of steel girders or a reinforced concrete saddle and connect it to the arch to the support structure to span across the railway between the abutments.

Yours faithfully
John Matheson & Associates Pty Ltd

John Matheson BE (HON) MIE Aust CPEng
Director

Appendix A: Intrados Photographs

For crack gauge location, refer to **Figure 60** in **Appendix G**.

Figure 13: DSC_2866 Crack 1, gauge G1 upside

Figure 14: DSC_2868 Crack 1, gauge G1 upside

Figure 15: DSC_2869 Crack 1, gauge G1 upside

Figure 16: DSC_2870 Crack 2, gauge G2 upside

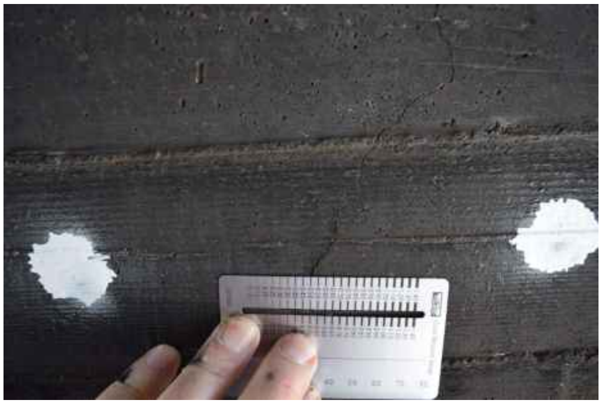


Figure 17: DSC_2871 Crack 2, gauge G2 upside

Figure 18: DSC_2872 Crack 3, gauge G3 upside

Figure 19: DSC_2873 Crack 4, gauge G4 midspan

Figure 20: DSC_2874 Crack 4, gauge G4 midspan

Figure 21: DSC_2875 Crack 5, gauge G5 midspan

Figure 22: DSC_2876 Crack 5, gauge G5 midspan

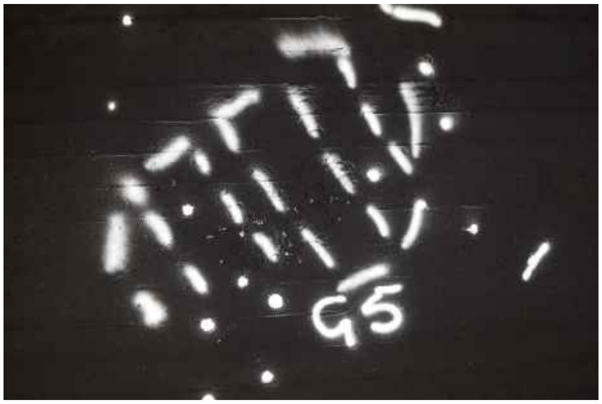


Figure 23: DSC_2877 Rounded aggregate exposed on surface

Figure 24: DSC_2878 Rounded aggregate exposed on surface

Appendix B: Country Spandrel Wall Photographs

Figure 25: DSC_2827

Figure 26: DSC_2830

Figure 27: DSC_2832

Figure 28: DSC_2849

Figure 29: DSC_2850

Figure 30: DSC_2851

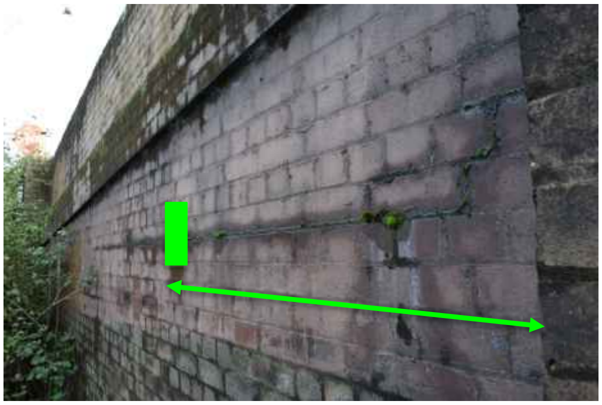


Figure 31: DSC_2854 Install gauge G1 2000mm from buttress

Figure 32: DSC_2855

Figure 33: DSC_2856

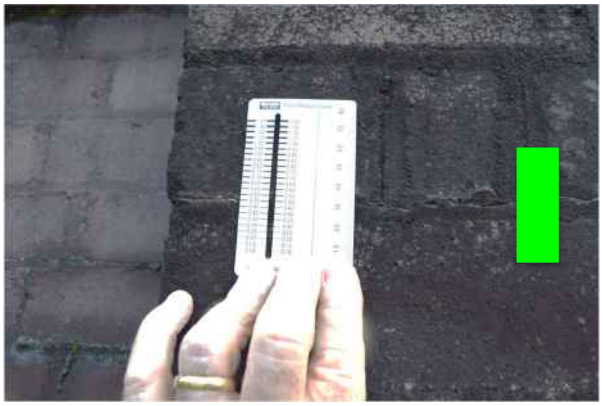


Figure 34: DSC_2857 Install gauge G1 mid buttress over crack

Figure 35: DSC_2858

Figure 36: DSC_2859

Appendix C: Sydney Spandrel Wall Photographs

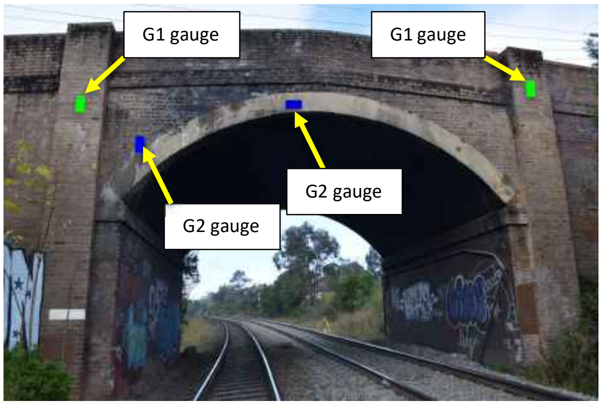


Figure 37: DSC_2841

Figure 38: DSC_2842

Figure 39: DSC_2845 Gauge G1 on upside see Figure 33

Figure 40: DSC_2847

Figure 41: DSC_2881

Figure 42: DSC_2882

Figure 43: DSC_2885 The transverse crack extends up the side face of the arch to the top

Figure 44: DSC_2889

Figure 45: DSC_2891 Gauge G1 on upside 1500mm off buttress

Figure 46: DSC_2892

Figure 47: DSC_2893 Gauge G1 on crack low down on upside

Figure 48: DSC_2894

Appendix D: Upside Abutment Wall Photographs

Figure 49: Bridge 101

Figure 50: DSC_2833

Figure 51: DSC_2834

Figure 52: DSC_2835 Install two Type 2 gauges

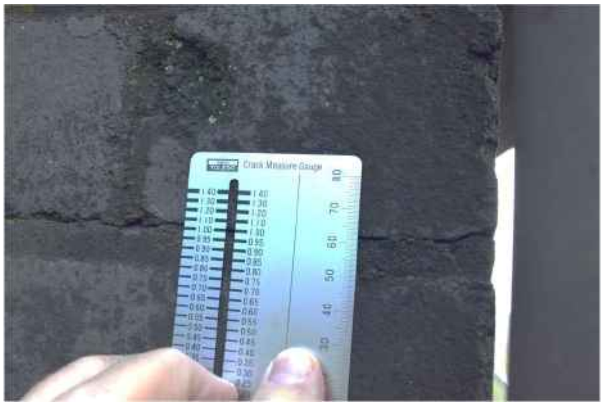


Figure 53: DSC_2837 Underlying crack width < 1mm

Figure 54: DSC_2838 Underlying crack width < 1mm

Figure 55: DSC_2839

Figure 56: DSC_2840 Bed joint crack vanishes ≈ 1100mm from corner

Appendix E: Downside Abutment Wall Photograph

Figure 57: Bridge 101 No noticeable cracking

Appendix F: Crack Gauges

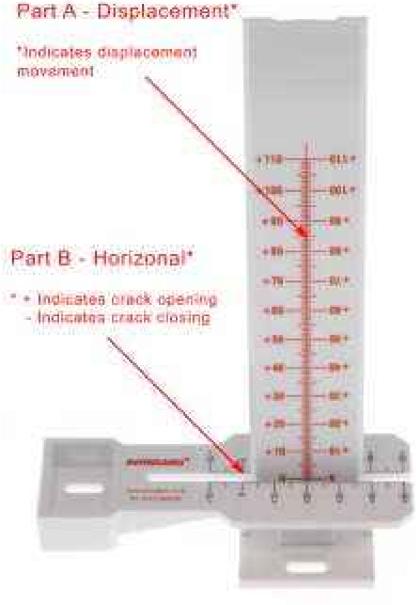


Figure 58 Crack gauge G1 where denoted 🟩

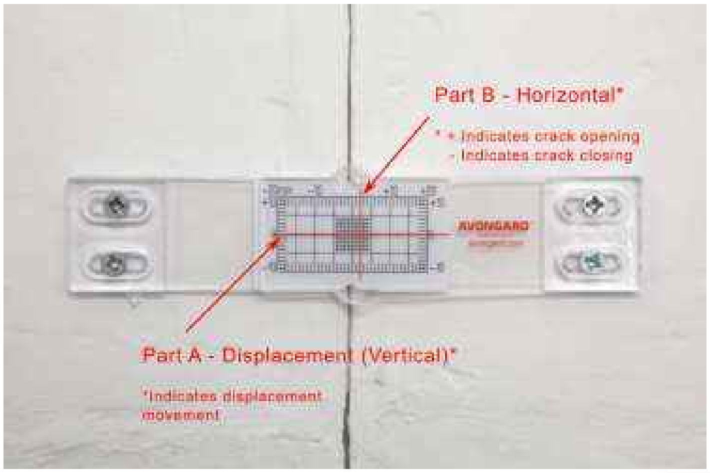


Figure 59 Crack gauge G2 where denoted 🟦

Appendix G: intrados cracking and crack gauges.

Table 3 Damage observed on 22 February 2014 and 14 May 2022

Wellers Road Overbridge at 101.152km						
Structure Element	**22 February 2014**			**14 May 2022**		
	Observed Damage	**Image**	**Damage Classification**	**Observed Damage**	**Image**	**Damage Classification**
External face of Sydney spandrel wall	i. Fine stepped cracking rising from the concrete arch in line with the vertical face of the downside abutment, stepping upwards before running horizontally eastward through the brick buttress approximately 5-courses below the spandrel corbel. Water staining is evident on the brick surface. ii. A fine stepped crack on the upside brick corbel where the concrete arch bears on the corbel. The crack extends horizontally across the nearby brick buttress. iii. A vertical crack on the upside end of the Sydney parapet beyond the upside abutment. iv. Bricks are missing from the parapet header-course.		Cracking generally up to Category 1 cracking (0.1mm<w<1.0mm) observed but could slightly exceed Category 1, reaching Category 2 in some locations.	i. Fine stepped cracking rising from the concrete arch in line with the vertical face of the downside abutment, stepping upwards before running horizontally eastward through the brick buttress 7-courses below the spandrel corbel. Water staining is evident on the brick surface. ii. A fine stepped crack in the upside brick corbel where the concrete arch bears on the corbel. The crack extends horizontally across the nearby brick buttress. iii. A vertical crack in the upside end of the Sydney parapet beyond the upside abutment. iv. Bricks are missing from the parapet header-course.	**Figures 37-48, 61**	Cracking generally up to Category 1 (0.1mm<w<1.0mm) observed but could slightly exceed Category 1, reaching Category 2 in some locations towards the cutting, which was not accessible.
Internal face of Sydney parapet wall	i. No meaningful damage observed other than a reflection of the vertical crack identified in iii) above.		Category 1 cracking (0.1mm<w<1.0mm)	i. No meaningful change in damage observed other than a reflection of the vertical crack identified in iii) above.		Category 1 cracking (0.1mm<w<1.0mm)
Downside abutment wall	i. No significant cracking observed.			i. No significant cracking observed.		
Upside abutment wall	i. No significant cracking observed.			i. A horizontal bed joint crack at the country corner of the upside abutment wall, 11-courses below corbel, see **Figures 70-77**. The crack on the abutment wall, was not previously observed because of poor light conditions and unauthorised aerosol painting of the wall prior to 2014 inspection.	**Figures 49-56, 62**	Category 1 crack (1.0mm)
Internal face of Country parapet wall	i. No significant cracking observed.			i. No significant cracking observed.		
External face of country spandrel wall	i. Horizontal cracking observed approximately 5brick courses below the spandrel corbel west of the upside abutment wall. ii. Cracking observed in spandrel above downside abutment wall highlighted by water staining.		Cracking was identified as Category 1 cracking (0.1mm<w<1.0mm) but could exceed 1mm, reaching Category 2 in places	i. No noticeable change in horizontal cracking observed 7-brick courses below the spandrel corbel west of the upside abutment wall. ii. No noticeable change in cracking observed in spandrel above downside abutment wall, highlighted by water staining.	Figures 25-36, 62	Category 1 (0.1mm<w<1.0mm) cracking observed noting 0.5mm crack width measured, see **Figures 31-35**.
Concrete arch intrados and edges				i. Category 1 (0.1mm<w<1.0mm) intrados cracking, mapped on intrados, see **Figure 60.** Crack widths measured at locations G1-G5, see **Figure 60**. ii. Cat 1 cracking (w=0.4mm) measured on the side face of the concrete arch on the Sydney side, see **Figure 43.**	**Figures 13-24, 60**	Category 1 cracking (0.1mm<w<1.0mm) measured on intrados of arch, see **Figure 14**.

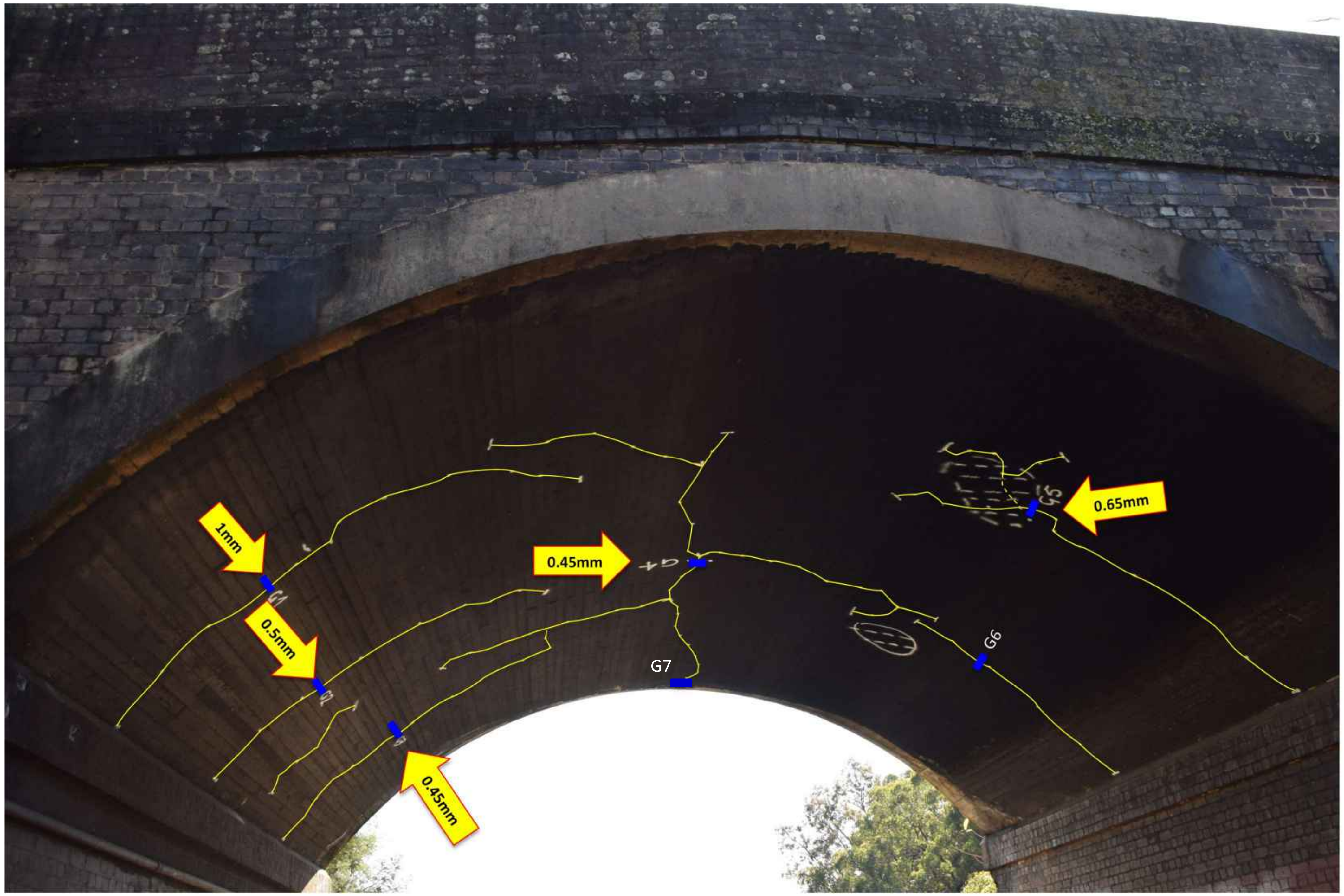


Figure 60 View from the countryside showing the location of seven (7) recommended intrados Type G2 crack gauge locations to monitor for change in width of pre-existing cracks noting that the longitudinal cracks around the circumference could corelate with the locations of 80lb rails, see Figure 3.

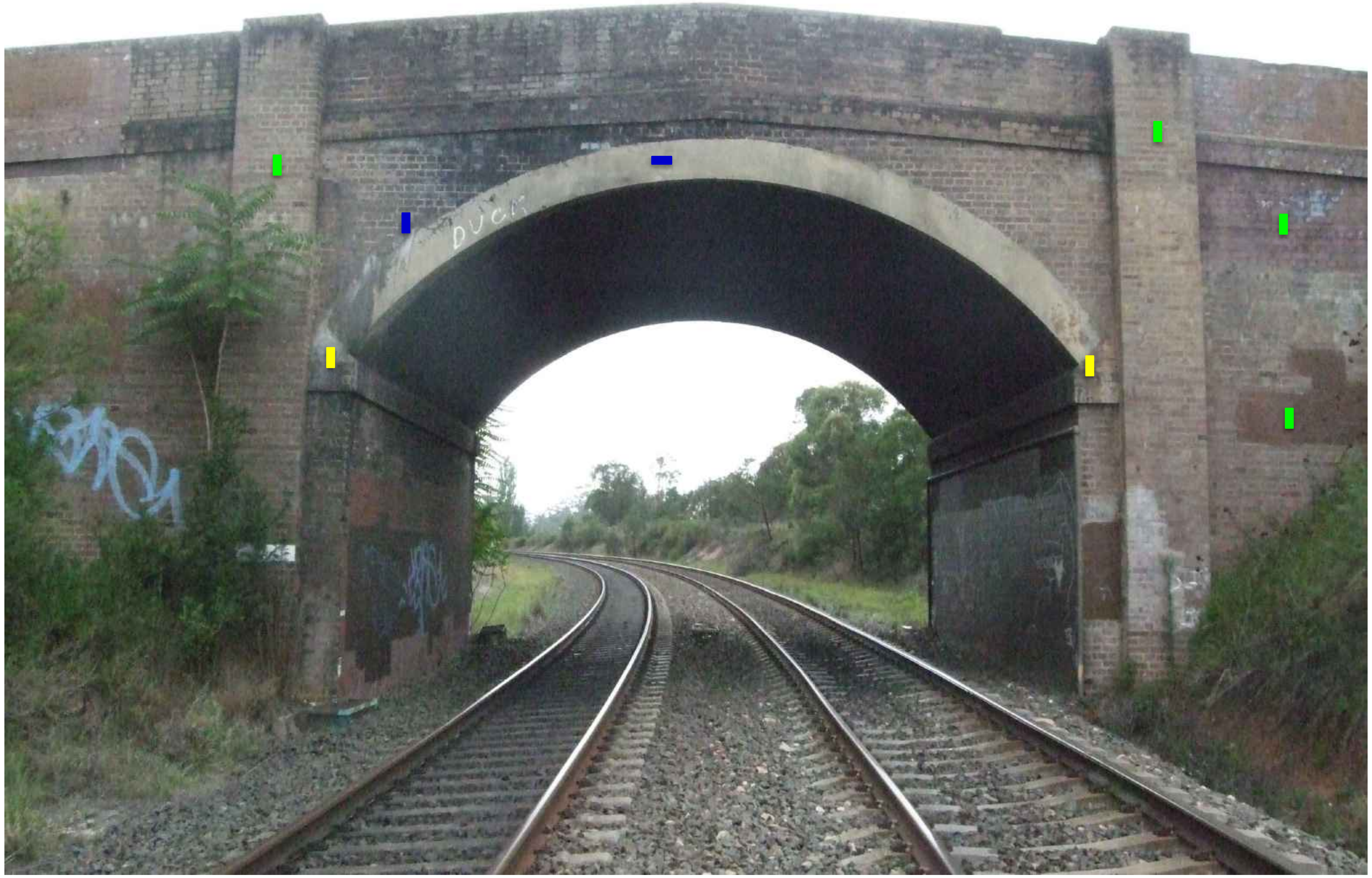
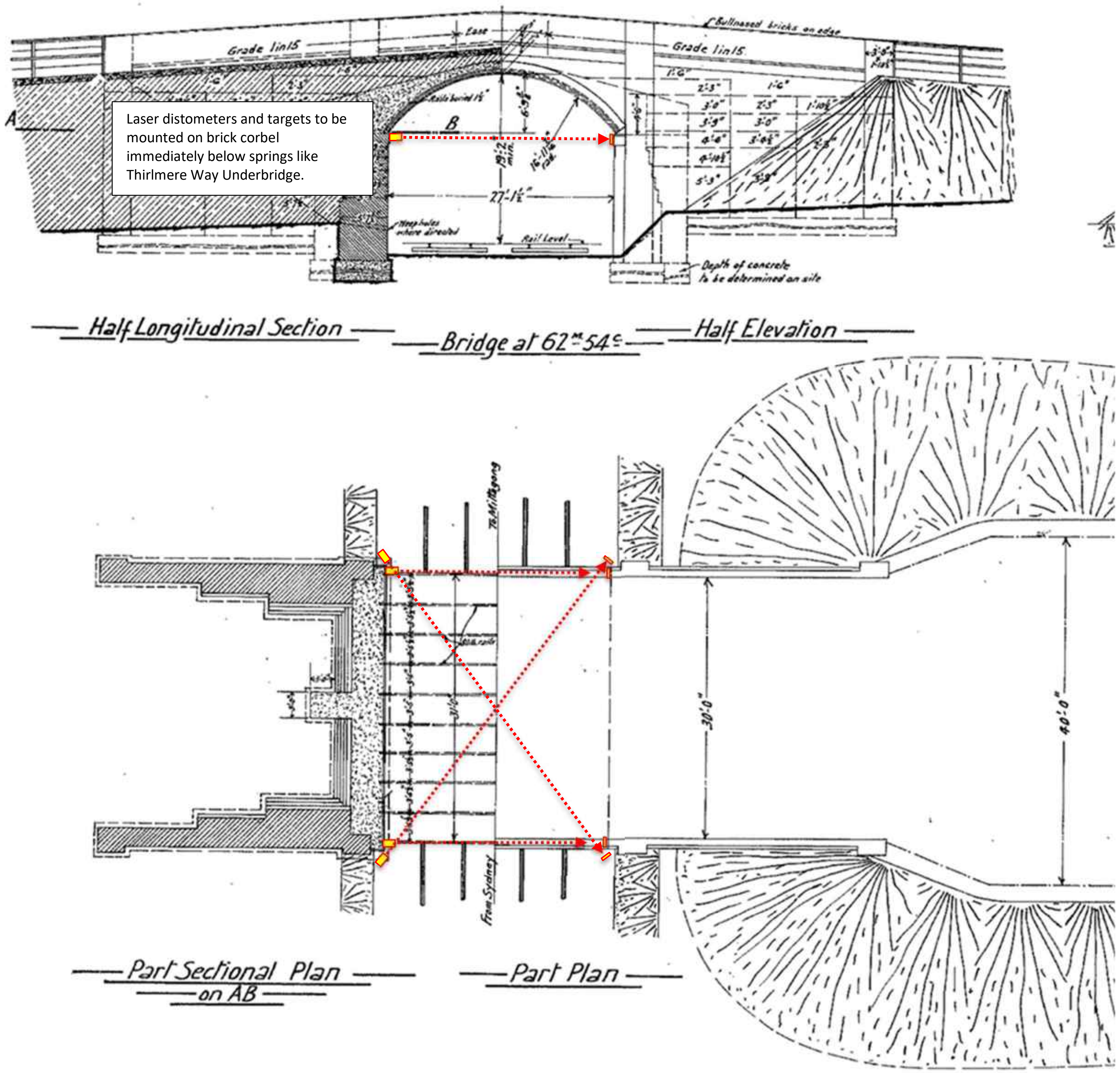


Figure 61 Sydney spandrel wall elevation showing location of 4# Type 1 (lime-green) & 2# Type 2 (dark blue) crack gauges and 2# tell-tale marks, yellow.

Figure 62 Country spandrel wall elevation showing location of 2# Type 1 (lime-green) & 2# Type 2 (dark blue) crack gauges and 2# tell-tale marks, yellow.



Laser distometers and targets to be mounted on brick corbel immediately below springs like Thirlmere Way Underbridge.

Figure 63 Proposed schematic layout of laser distometers and targets to be fastened to the face of the brick corbel immediately below the spring point. Telltales to be painted on concrete and brickwork at spring to monitor movement between arch and abutment.

Newcastle Geotech Pty Ltd

SIMEC MINING - TAHMOOR SOUTH - LONGWALLS S1A TO S6A

MAIN SOUTHERN RAIL

EMBANKMENT AND CUTTING GEOTECHNICAL ASSESSMENT

Simec Mining

Reference 493-8

October 2022

26/10/20229
Our ref 493-8

Simec Mining
Tahmoor Coking Coal Operations
Remembrance Driveway
Tahmoor NSW 2573

Attention: Ross Barber / Kevin Golledge

RE: SIMEC MINING - TAHMOOR SOUTH - LONGWALLS S1A TO S6A

MAIN SOUTHERN RAIL

EMBANKMENT AND CUTTING GEOTECHNICAL ASSESSMENT

Please find enclosed our Geotechnical Assessment Report along the Main Southern Rail between rail kilometres 97.0 and 101.0 that may be affected by potential impacts as a result of subsidence from the mining of Southern Domain Longwalls from S1A to S6A.

If you have any questions regarding this matter, please contact the undersigned.

For and on behalf of Newcastle Geotech Pty Ltd

Mark Delaney

Mark Delaney

Principal Engineering Geologist

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

This Report has been prepared by Newcastle Geotech on behalf of the Tahmoor Coal Rail Management Group. Newcastle Geotech acknowledges the following organisations that have made contributions to this report:

- Ross Barber - SIMEC
- Daryl Kay - Mine Subsidence Engineering Consultants (MSEC)
- Graeme Robinson – Robinson Rai
- John Rolles – Southern Rail Survey

DOCUMENT VERIFICATION

Reference number	493-8	
Title	Simec Mining - Tahmoor South - Longwalls S1a To S6a Main Southern Rail Embankment and Cutting Geotechnical Assessment	
Prepared by	Mark Delaney	Principal Engineering Geologist
Document status		
Version	**Date**	**Revision Description**
001	26/10/2022	First issue for review

1 INTRODUCTION

Newcastle Geotech Pty Ltd presents the results of a geotechnical assessment of the Main Southern Rail (MSR) at Tahmoor in the area of influence associated with Tahmoor South longwall mining panels S1A to S6A proposed for commencement by Tahmoor Coal in October 2022. the proposed longwalls are located between Tahmoor's surface facilities to the north and the township of Bargo to the south.

This report reviews the pre-condition of rail embankments and cuttings along the MSR between rail kilometres 97.0 and 101.0 that may be affected by potential impacts as a result of subsidence from the mining of the Southern Domain Longwalls from S1A to S6A under the current Deed with Australian Rail Track Corporation (ARTC). The report:

- Assesses geotechnical conditions in the cuttings and embankments based on inspection, subsurface investigation, laboratory testing and review of available data.
- Presents stability modelling of the fill embankments.
- Provides risk assessment of embankments and cuttings.
- Recommends monitoring and mitigation measures to ensure stability of embankments and cuttings are maintained during the mining process.

2 BACKGROUND

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 Western Domain (LW1 to LW4) adjacent to the Main Southern Railway.

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 to the south of the existing Tahmoor Mine. There are 6 short longwalls in the A block, proposed over a 4 to 5 year extraction program as shown in Figure 1, with longwall S1A to commence in October 2022.

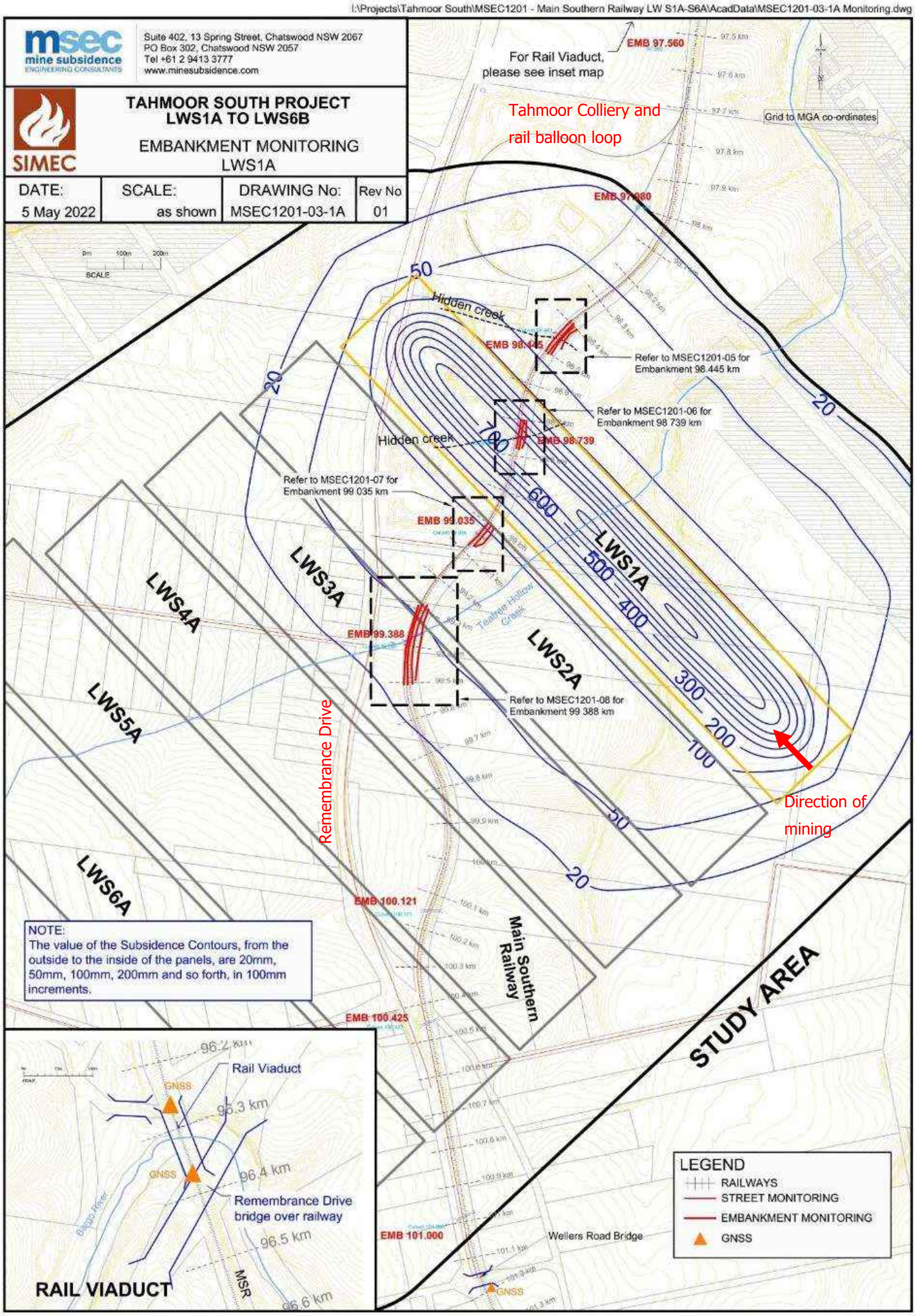
A Subsidence Management Plan is being prepared by Mine Subsidence Engineering Consultants Pty (MSEC) Ltd to ensure that the MSR remains safe and serviceable during the mining of Longwalls S1A to S6A. The subsidence management plan will identify and present controls in relation to geotechnical subsidence hazards including:

- Loss of track support due to instability of embankments.
- Debris on track due to instability of cuttings.
- Step displacements associated with faults.

Tahmoor Coal has extensive experience of mining beneath the main southern railway at similar depths of cover to that proposed for Tahmoor South with control measures successfully implemented to manage potential impacts on rail embankments, culverts and cuttings with performance extensively monitored by the Rail Management Group and documented by MSEC. This experience has indicated:

- In cuttings no impact has been recorded in relation to batter slope instability. At some locations non-conventional subsidence movements have been observed to develop within railway cuttings, resulting in impacts on track geometry but negligible impact on the cutting batters. The sides of some cuttings (but not all) have been observed to exhibit minor closure in response to mine subsidence.
- Fill embankments are able to tolerate considerable mining-induced ground deformations without experiencing impacts, are not prone to development of tension cracks and exhibit no "steps or humps" in spite of changes in vertical alignment and high strain levels measured.

Figure 1 – Site Location



3 RISK ASSESSMENT

A Risk Assessment (RA) was carried out by HMS Consultants Australia Pty Ltd (HMS) in August 2021 to review and evaluate risks to the safety and serviceability of the MSR Line and associated infrastructure primarily within the predicted 20mm subsidence contour associated with extraction of longwall panels S1A to S6A. This included impacts on associated culverts, embankments, cuttings and other rail infrastructure.

In accordance with the scope, risks relating to the impacts on the railway line and associated infrastructure were identified, considered and recorded by the risk assessment team that included ARTC. Where necessary mitigation strategies were developed to prevent disruptions to railway operations and reduce the level of risk So Far As Is Reasonably Practicable (SFAIRP) for the safety and health of persons travelling on the railway line.

The identified risk issue associated with the fill embankments was impact on serviceability with potential displacement leading to loss of track support. Potential causes of embankment displacement were identified as:

- Mining induced ground movements.
- Potential valley closure.
- Leakage from a cracked culvert.
- Significant rain event / flooding.

The potential impact of the above was assessed to be changes to track geometry leading to operating restrictions and possibly short term track closure less than 6 hours. Based on existing controls comprising access roads along the embankment sides acting as stabilising berms, the identified risk category was assets with a rare likelihood of change in track geometry on embankments with a not significant consequence giving a low risk category.

The identified risk issue associated with the culverts was loss of integrity due to cracking or shearing leading to unplanned intervention for the culvert with potential causes identified as:

- Mining induced ground movements.
- Potential valley closure.
- Piping failure along the access road at the interface between the brick headwall and concrete pipe extension.

The potential impact of the above on culverts was assessed to include changes to track geometry, blockage of the waterway and development of a sinkhole leading to operating restrictions and possibly short term track closure less than 6 hours. The identified risk category was assets with a rare likelihood and not significant consequence giving a low risk category. It is noted that a subsequent Culvert Dilapidation Report by Robinson Rail (August 2022) has recommended installing a rail baulk above culverts which are positioned directly above longwall panels.

The identified risk issue associated with the cuttings was blockage of cess drainage due to debris falling into the cess drains with potential causes identified as:

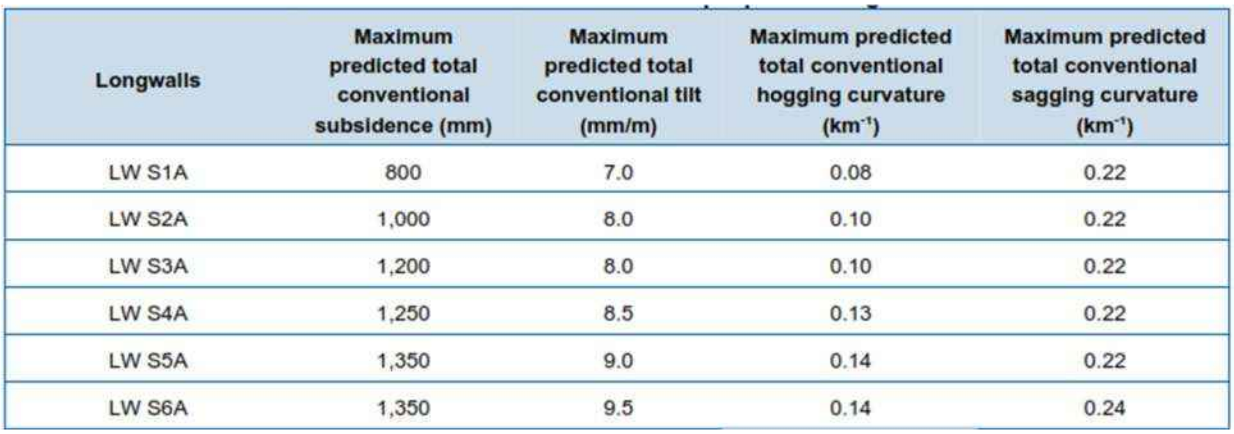
- Mining induced ground movements.
- Natural weathering and erosion.
- Significant rain event.

The potential impact of the above was limited to unplanned intervention. Based on existing controls comprising small cuttings with shallow competent rock favourable to stability and wide cess drains, the identified risk category was assets with a rare likelihood and not significant consequence giving a low risk category.

4 PREDICTED SUBSIDENCE

Predicted mining-induced conventional subsidence movements were provided by MSEC in Report 1192. A summary of the maximum predicted values of total conventional subsidence, tilt and curvature, after the extraction of each of the proposed amended longwall series, is provided in Table 1.

Table 1 – Maximum predicted total conventional subsidence, tilt and curvature after the extraction of each of the proposed longwalls (MSEC)



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	800	7.0	0.08	0.22
LW S2A	1,000	8.0	0.10	0.22
LW S3A	1,200	8.0	0.10	0.22
LW S4A	1,250	8.5	0.13	0.22
LW S5A	1,350	9.0	0.14	0.22
LW S6A	1,350	9.5	0.14	0.24

The maximum predicted total subsidence, after the completion of the proposed longwalls; is 1,350 mm which represents around 61% of the extraction height. The maximum predicted total conventional tilt is 9.5 mm/m (i.e. 0.95 %), which represents a change in grade of 1 in 95. The maximum predicted total conventional curvatures are 0.14 km^{-1} hogging and 0.24 km^{-1} sagging, which represent minimum radii of curvature of 7.1 kilometres and 4.2 kilometres, respectively.

The above information is only included to highlight the likely magnitude and distribution of subsidence and reference should be made to MSEC data and reports that provided detailed comparison of measured and predicted subsidence at Tahmoor Mine.

MSEC have noted that 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”./

Longwall S1A commences a distance of approximately 1km from the MSR and as such there is likely to be a period of in the order of 3 months before subsidence along the MSR is recorded.

5 FIELD AND LABORATORY INVESTIGATIONS

Investigation has involved walk over inspection, mapping and photography of the cuttings, embankments and culverts by a Principal Engineering Geologist between 97km and 101km, primarily undertaken during rail possessions in January, April and September 2022.

Drilling investigation was undertaken in January 2022 to assess embankment subsurface conditions. Drilling of 7 boreholes in the upside access road and down main four foot was undertaken using a tracked mounted drilling rig with:

- Boreholes advanced by 100mm continuous flight auger to establish bedrock level with holes advanced into bedrock to confirm rock condition.
- Standard penetration testing was undertaken at regular 1.5m intervals within the embankment fill and foundation materials to assess strength and provide samples for laboratory testing.
- Logging of the soil and rock profile by a Principal Engineering Geologist.

It is noted that borehole location was constrained by the presence of services along the embankment crests, notably Telstra optic fibre on the downside and rail signal cable on the upside. Service clearance was undertaken by Ted Johansen (Signal Support Services).

Engineering logs off the bores are presented in Appendix B with borehole locations shown in Table 2 and Drawing GI-1 in Appendix A.

Cross section survey of the embankment profiles at the borehole locations was undertaken by Southern Rail Survey.

Table 2 – Borehole Locations

Borehole	Rail Km	Location	MGA coordinates	Comment
1	98.440	Up access road	277141E 6207087N	Standpipe piezometer
2	98.745	Up access road	277028E 6206808N	
3	99.037	Down main 4’	276924E 6206535N	
Inclo 1	99.333	Up access road	276746E 6206302N	Inclinometer to 15.1m
4	99.338	Down main 4’	276757E 6206294N	
5	99.396	Up access road	276737E 6206243N	Standpipe piezometer
6	100.143	Up access road	276793E 6205520N	
7	100.429	Down main 4’	276790E 6205240N	

Drilling and inclinometer installation was undertaken on the upside access road at 99.333km in September 2022 by a tracked drill rig during a rail possession. This involved HQ3 rock core drilling from 6m to 15.1m with installation of inclinometer casing in a grouted hole. Baseline measurement of the inclinometer is yet to be undertaken by Lynton Survey. A separate report covering the inclinometer installation (493-6 28/9/2022) has been prepared and is attached as Appendix E. The report includes engineering logs of the borehole, rock core photographs and the results of point load strength testing.

Geotechnical classification testing of the embankment and underling natural soil materials was undertaken by a NATA accredited laboratory with testing comprising:

- Fourteen (14) moisture contents to assess the moisture status of soils.
- Ten (10) Atterberg limit and linear shrinkage tests to assess clay plasticity and reactivity.
- Nine (9) particle size distribution tests to assess the relative gravel, sand and fines (clay and silt) content of the soil.

Results of laboratory testing are presented in Appendix C and are summarised in Table 3.

Laboratory triaxial testing of embankment fill and natural clay along nearby Remembrance Drive was undertaken by Douglas Partners in September 2022 (ref 210597.02). Consolidated undrained triaxial testing with pore pressure measurement testing on 5 samples indicated:

- Remoulded clay fill samples (compacted to 95% standard) – 4 tests with effective cohesion ranging 1.5kPa to 10kPa (average 6.4) and effective angle of friction ranging 27° to 30° (average 28.3).
- One undisturbed residual sandy clay sample - effective cohesion 5kPa and effective angle of friction 32°.

Table 3 - Summary Soil Classification Laboratory Test Results

Test Method (AS1289)	**Soil Type**			
	Fill		**Natural Soil**	
	Values	Range / (Ave)	Values	Range / (Ave)
Moisture Content %	17.4 23.8 12 9.4 8.1 13.2 16 16.2 23.8 15.8 10.4	8.1–23.8 (15.1)	23 24.7 20.5	20.5-24.7 (22.7)
Particle Size - Grading				
Gravel %	5 42 12 30 7 33	5-42 (21.5)	1 7 14	1-14 (7.3)
Sand %	65 26 44 20 61 37	20-65 (36.1)	68 61 73	61 -73 (67.3)
<75µm %	30 32 46 40 32 30	30-46 (35)	31 32 13	13-32 (25.3)
Atterberg Limits				
Liquid Limit %	35 54 25 27 26 39 38 20	20-54 (33)	26 67	26-67 (46.5)
Plasticity Index %	19 33 13 12 11 24 21 8	8-33 (17.6)	12 44	12-44 (28)
Linear shrinkage %	9.5 13 6.5 6.5 6.5 11.5 10 5	5-13 (8.6)	7 15	7-15 (11)

6 LOCATION AND SETTING

6.1 Surface Conditions

Approximately 3 km of dual track is located directly above proposed Longwalls S1A to S6A, between 98.6 km and 100.7 km. The dual track alignment was constructed in 1919 as part of the Picton to Mittagong deviation.

Construction of the upside and downside access roads was most likely undertaken in the 1960’s to 1980’s with placement of reinforced concrete pipes (RCP’s) abutting existing culvert headwalls and fill placed over. Based on experience with similar rail embankment access road widening in the region, the join between the RCP and brick headwalls was typically poorly sealed, if at all.

Topographically the alignment occurs in an area of gently undulating hillside with gentle slopes with drainage via a number of small ephemeral rounded watercourses directed to the east to Teatree Hollow Creek with all drainage systems flowing from the western upside of the rail alignment towards the eastern downside.

Embankments are generally low, less than 4m in height, with localised deeper sections up to 7m in height across rounded waterway sections with batter gradients generally in the order of 1V:1.5H (33°) and locally up to 35° or steeper. The embankments are characterised by access roads along the downside and upside generally constructed as fill berms at mid embankment or upper embankment height that act as stabilising berms, decreasing the risk of embankment instability impacting the track.

The expectation is that embankments have been predominantly constructed using sandstone and shale derived soil and rock materials won from adjacent cuttings and as such are expected to include a reasonable rock content that is favourable for stability.

Cuttings are generally low, less than 2 to 3m in depth with localised sections up to 4m. The cuttings are generally battered at 35° to 45° with some steeper batters in competent sandstone rock sections. The cuttings are characterised by wide cess drains with the distance from toe of cutting to rail generally in the order of 4m. The cuttings generally occur in competent sandstone rock material with a shallow cover of residual soil.

6.2 Geology and Faults

The 1:100,000 Wollongong – Port Hacking Geological Sheet (1985) indicates the site is mainly located in the Hawkesbury Sandstone which is characterised by quartzose and lithic fine to medium grained sandstone bedrock, sub-horizontally bedded and widely spaced jointing and bedding. The overlying residual soils weathered from the bedrock are typically Clayey Sands and Sandy Clays.

An area of Wianamatta Group rock most likely comprising the Mittagong Formation, a transitionary unit between the Ashfield Shale and underlying Hawkesbury Sandstone, occurs in the area of LWS1A and LWS2A. The Mittagong Formation comprises interbedded shale, fine sandstone and siltstone. The depth to bedrock here appears to be slightly greater and the residual soils more clayey in nature.

Structure contours shown on the 1:100,000 Wollongong – Port Hacking Geological Sheet to the top of the top of the Illawarra Coal Measures indicate a bedding dip of the rock strata of about 1° to 2° to the north-east. Exposure of rock strata in the study area confirms sub-horizontal bedding.

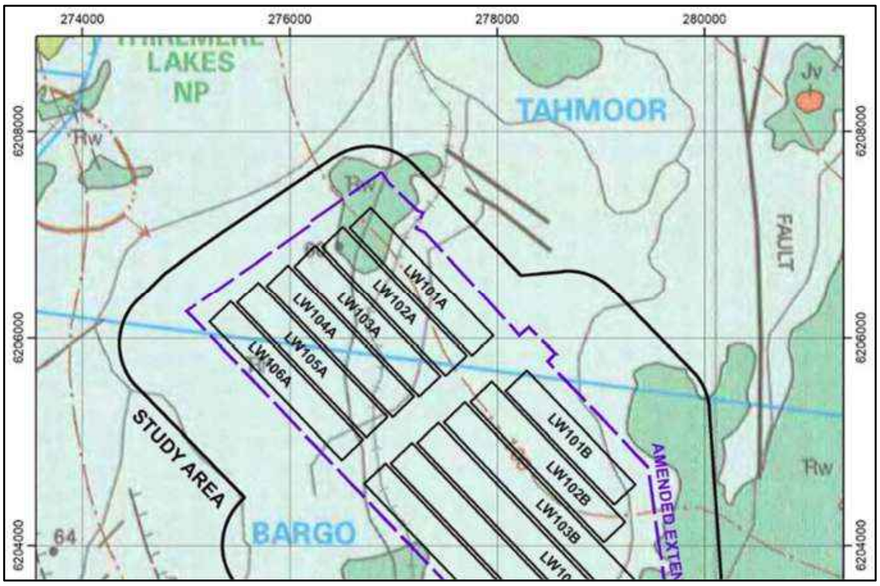


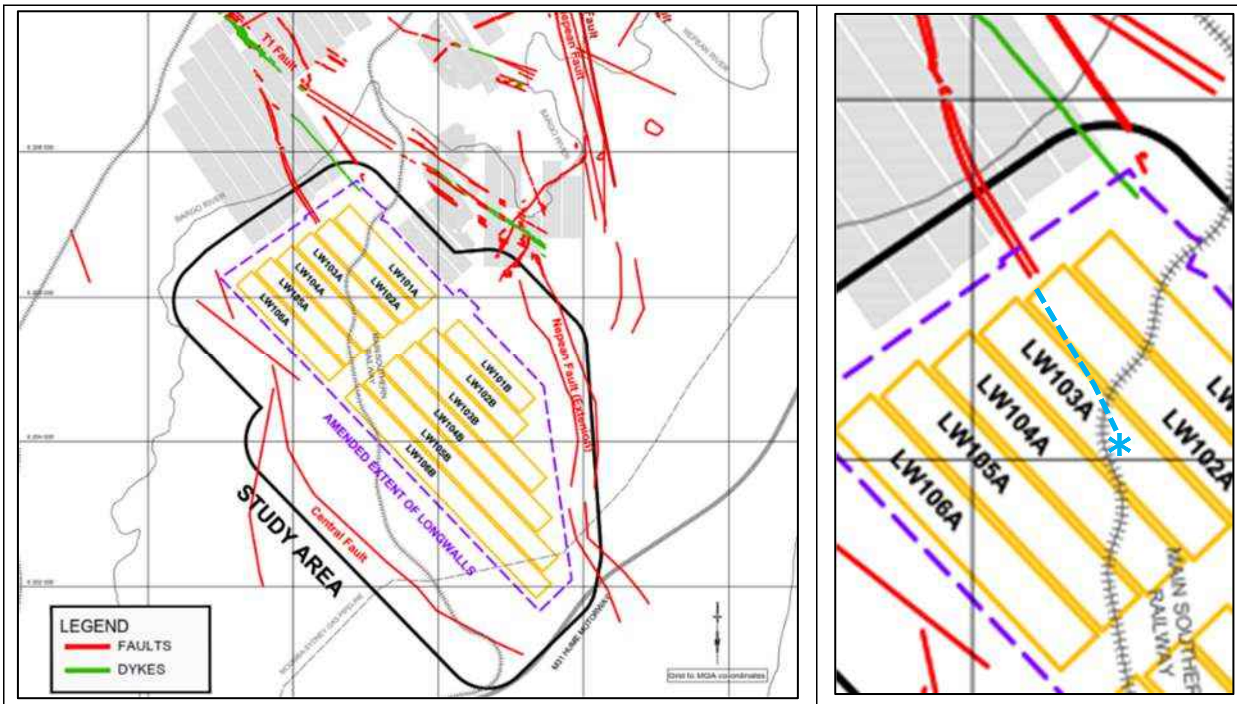
Figure 1 – Surface Geology (light green = Hawkesbury Sandstone & dark green = Wianamatta Group) Courtesy MSEC

Tahmoor Mine has undertaken comprehensive geological exploration within the Subsidence Study Area using several geological and geotechnical consultants and a number of geological structures have been identified as presented on Drawing MSEC1123-RFI-03 (2020) and shown in Figure 2. Several fault structures were identified (at Bulli Seam level) with the two main structures comprising:

- Nepean Fault zone (Southern extension) located well to the east of the rail.
- Central Fault zone located to the southwest of the longwall panels and not crossing the rail until about 104km.

An additional fault structure encountered in the Bulli Seam in previous Tahmoor longwall panels to the northwest is projected to intersect the rail near LW2A and LW3A. No surface expression of faulting was observed in adjacent cuttings at 99.165km and 99.690km, however some evidence of possible shearing and faulting in weathered interbedded sandstone and shale rock was observed in the heritage well on the downside at 99.530km that is located close to the cut and fill interface (as shown in Figure 3). The location of this and the inferred projection of the fault is shown in Figure 2.

No evidence of faulting was observed during inspection of cutting batters between 98.130km and 101.162km. It is noted that no surface expression of faulting would be evident where faults occur on grade or below fill embankments.



MSEC (2020) Geological Structures at Bulli Seam Level.

Inferred fault projection to 99.530km.

Figure 2 – Geological Structures at Bulli Seam Level.

Figure 3 – 99.530 downside well with fractured shale rock indicating a possible fault

6.3 Cut and Fill Delineation

The delineation of the alignment into earthwork units comprising fill embankments and culverts, cuttings and on grade sections is presented in Table 4. The fill embankments have been named based on culvert rail kilometres and the cuttings named based on cutting midpoint rail kilometres. The locations have been based on rail kilometre markings made by Southern Rail Survey on the rail at 20m intervals.

Table 4 – Location of Cuts, Fills and Culverts

Feature	Start (km)	End (km)	Length (m)	Comment
On grade	97.500	98.000	500	
Cutting (98.130)	98.000	98.260	260	Cutting up to 3m deep in HW shale battered at 45deg. Wide cess.
Conveyor over	98.160			Conveyor gantry - based on cutting profile most likely founded on weathered shale rock
On grade	98.260	98.380	120	
Fill embankment 98.445	98.380	98.540	160	Fill to 6m high with batter slopes to 33° with wide access road berm on US at toe of ballast and mid height access road berm on DS.
Culvert (98.445)	98.435	98.454 Up	Skew 19m	Skewed 0.9m dia brick arch culvert with 0.9m dia concrete pipe extension US and DS.
Cutting 98.610	98.540	98.680	140	Cutting up to 1m deep in sandstone rock and soil battered at 40deg. Wide cesses.
Fill embankment (98.739)	98.680	98.780	100	Fill to 5m high with batter slopes to 30° upside and 35° on downside with 4m wide access road berms on both sides.
Culvert (98.739)	98.739			0.9m dia brick arch culvert with 0.9m dia concrete pipe extension US and DS.
Cutting 98.895)	98.800	98.990	190	Cutting up to 1.5m deep battered at 35-40deg. Wide cesses. Sandstone rock exposed in cess and batters. No evidence of instability or fault structures.
Fill embankment (99.035)	99.000	99.080	80	Fill up to 6m high with batter slopes up to 35° with 4m wide access road berms on US and DS.
Culvert (99.035)	99.035			1.2m dia BAC with dia brick arch culvert with 1.2m dia concrete pipe extension US and 0.9m dia DS. Piping failure (2020) on DS above RCP and BAC join.
Cutting (99.165)	99.100	99.230	130	Cutting up to 1m deep in sandstone rock and soil battered at 35deg. Wide cesses.
Fill embankment (99.338)	99.230	99.500	270	Fill to 7m high with batters generally in order of 35°. Wide access road on US. Embankment on DS variable height (ballast slope) up to 3m above access road. Access road narrows to 3m above DS culvert at 99.340km with very steep batter below down to culvert.

Feature	**Start (km)**	**End (km)**	**Length (m)**	**Comment**
Culvert (99.338)	99.340	99.355 Up	Skew 15m	Skewed 1.5m dia brick arch culvert with 1.2m dia concrete pipe extension US. On DS pipe extension washed out exposing original wingwall with over-steep batter up to 45 degrees above outlet with narrow access road above.
Heritage well	99.530			Downside well offset 5m from corridor boundary - Wirrimbirra Sanctuary
Cutting (99.690)	99.500	99.880	380	Cut to 3.5m deep battered at 35-40° in soil and 70° in competent sandstone rock with minor sub-horizontal shale layers up to 100mm thick. Wide cess up to 3m.
On grade	99.880	100.030	150	
Fill embankment (100.121)	100.030	100.230	200	Fill to 6m high with batter slopes up to 35°. Wide access road berm on US. Downside 1.5m shoulder from ballast toe to crest 4m high embankment at 30° with access road below.
Culvert (100.121)	100.127	100.142 Up	Skew 15m	Skewed 1.5m dia brick arch culvert with 1.5m dia concrete pipe extension US and DS. Separation DS pipe extension from brick headwall.
Cutting (100.310)	100.250	100.370	120	Cut up to 2m deep in competent sandstone rock battered at 40-45deg. Wide cess with access road along toe of cut US.
Fill embankment (100.425)	100.370	100.500	130	Wide access road berms up to 3.5m on US and DS at toe of ballast. Embankment up to 6m high with batter slopes up to 35°
Culvert (100.425)	100.422	100.430	Skew 8m	Skewed 1.5m dia brick arch culvert with brick wingwalls US and DS.
Cutting (100.700)	100.500	100.900	400	Cut up to 4m deep in Gravelly Sandy CLAY residual soil over weak weathered sandstone rock battered at 35-45deg. Wide cess - rail to toe cutting 4 - 5m.
On grade	100.900	100.970	70	
Fill embankment (101.000)	100.970	101.030	50	Fill up to 5m high with batter slopes locally up to 35°. Wide access road berms on US and DS.
Culvert (101.000)	101.000			1.2m dia brick arch culvert with 0.9m dia concrete pipe extension US and DS.
On grade	101.030	101.080	50	
Cutting (100.162)	101.080	101.400	320	Not inspected - estimated up to 2m of fill above cutting at bridge abutment.
Bridge	101.162			Wellers Road overbridge 101.162km

6.4 Subsurface Conditions

The ground profile encountered during the drilling investigation has been characterised into geotechnical units as summarised in Table 5 with the depth of the soil layers and depth to rock summarised in Table 6. Reference should be made to the borehole logs in Appendix B for details.

Table 5 - Geotechnical Units and Soil Types

Unit	Material Type	Description
1a	Rail Formation	Ballast - highly fouled
1b		Capping / structural fill - Clayey Sandy Gravel
2a	Fill	CLAY, Gravelly CLAY, Sandy Gravelly CLAY - medium plasticity, stiff to very stiff consistency, variable sand and gravel content, some weathered sandstone fragments
2b	Fill	Clayey SAND, Gravelly Clayey SAND, fine to medium grained, est 30%-40% medium plasticity clay, some weathered sandstone rock fragments
2c	Access Road	Clayey GRAVEL, fouled ballast in a medium plasticity clay matrix – thin surface layer along access roads
3	Alluvium / Slopewash	Clayey SAND, fine to medium grained, est 30% -40% medium plasticity clay, loose to medium dense
4a	Residual	Sandy CLAY, medium plasticity, stiff consistency becoming very stiff, some CLAY, medium to high plasticity, very stiff
4b	Residual	Clayey SAND, fine to medium grained, est 30% -40% medium plasticity clay, loose to medium dense
5	Rock	Sandstone, fine to medium grained extremely to highly weathered, estimated very low to low strength becoming medium strength with depth. Minor shale beds, sub-horizontal.

Groundwater levels observed during drilling and recorded in standpipe piezometers in bores 1 and 5 are presented in Table 6. The groundwater level predominantly occurs below embankment filling in the natural soils or bedrock.

Groundwater level in bore 5 was recorded on 28 March 2022 after a significant east coast low rainfall event with only a minor increase (0.4m) in groundwater level from the groundwater level recorded during drilling with groundwater level only 0.3m above the base of fill after this significant rainfall event.

It should be noted that groundwater levels, seepage and soil moisture conditions are likely to fluctuate with variations in climatic and site conditions.

Based on the depth to rock encountered in the boreholes and the invert levels of the culvert inlets and outlets; it appears that the culvert foundations along the rail alignment have been constructed within the natural soils above or on rock level. It appears that the culverts have not been excavated into rock or constructed along drainage paths with rock sides.

Table 6 - Depth of Soil Layers and Depth to Rock

Geotechnical Unit		**Depth of Layer (m)**				**Groundwater depth (m)** Date recorded
		2	**3**	**4**	**5**	
Borehole	Rail km	Fill	Slopewash	Residual	Rock	
1 (P)	98.440	0 - 4.5	4.5 – 5.0	5.0 – 5.8	5.8 - >6.0	4.8 29.1.22
2	98.745	0 – 2.5		2.5 – 3.0	3.0 - >3.5	Not encountered
3	99.037	0 – 4.8		4.8 – 5.5	5.5 - >6.0	Not encountered
Inclo 1	99.333	0 -5.4		5.4 – 6.0	6.0 - >15.2	Not encountered
4	99.338	0 – 5.2		5.2 – 5.8	5.8 - >7.05	6.8 29.1.22
5 (P)	99.396	0 – 5.0	5.0 – 5.2	5.2 – 6.0	6.0 - >7.0	5.1 30.1.22 4.7 28.3.22
6	100.143	0 – 4.7	4.7 – 5.0	5.0 – 5.5	5.5 - >6.0	5.0 30.1.22
7	100.429	0 – 5.3	5.3 – 5.5	5.5 – 6.6	6.6 - >7.0	5.9 30.1.22

(P) – Standpipe piezometer to measure groundwater level installed

7 GEOTECHNICAL ASSESSMENT OF CUTTINGS AND EMBANKMENTS

Reference is made to the Culvert Dilapidation Report by Robinson Rail (August 2022)

7.1 Cutting 98.130km

Double sided cutting from 98.000km to 98.260km (260m) up to 3m deep on a right hand curve through a broad very gentling sloping hillside area that falls to the south-east from upside to downside.

Cutting uniformly battered at approximately 45° with wide cess area on both upside and downside ranging 3.5m to 4m from cutting toe to rail and 0.5m to 1m in depth below rail. This provides significant containment width for any small scale rock falls or shallow soil slips that may occur along the cutting. The upside and downside cesses drain to the city with some ponding water present in the upside cess.

Cutting in highly weathered shale rock of estimated very low to low strength, sub-horizontally and very closely bedded with about 0.5m of Gravelly Clay residual soil cover.

Past track formation issue at 98.100km. Mine overhead conveyor supported on concrete footings 99.160km.

Based on the existing cutting profile and the performance of similar cuttings on the main line subject to subsidence; the impact of the predicted minimal subsidence at this location (<20mm) on batter stability and cess drainage is expected to be minimal. The cutting is located 350m or greater from LWS1A.

Geotechnical assessment of the cutting at 98.130km confirms:

- No evidence of current or past cutting instability observed.
- No evidence of fault structures or sheared fractured ground observed in cutting exposures.
- No requirement for any remedial works identified.

Cutting listed in ARTC Geotechnical Risk Site database as site 12563. Site added to database in 2016 with a very low risk classification of 6 (non-active site). The database notes that the cutting has a history of track formation problems.

	
98.050km cutting view to country	98.160km shale rock and clay soil in downside cut

7.2 Fill Embankment 98.435km

Free standing fill embankment from 98.380km to 98.540km (160m) across a gently sloping drainage path that falls to the south-east from upside to downside. The downside drainage path leads to a small dam located on Tahmoor Coal property.

The embankment is up to approximately 6m in height along the drainage path reducing to 5m in height or less in adjoining sections. The embankment is characterised by:

- Upside access road 4m to 5m wide at a level less than 1m below rail with batter slopes of 33° or less below.
- Downside ballast shoulder up to 1.5m in width from edge of sleeper extending at about 33° down to the access road at about 3.5m below rail level. The access road is approximately 5m in width and occurs about 2m in elevation above the culvert invert with batter slopes up to 35°.

Borehole 1 drilled in the upside access road at 98.440km on the city side of the culvert encountered fill to 4.5m depth over slopewash and residual soil with sandstone bedrock at 6m depth. Groundwater was encountered at 4.8m depth at the time of drilling. No evidence of rock outcrop observed along the embankment toe or at culvert invert.

The culvert (listed as 98.435km) is skewed in alignment and occurs under the upside embankment crest at about 98.454km and under the downside crest at about 98.435km. The culvert comprises a 0.9m diameter brick arch culvert with 0.9m diameter reinforced concrete pipe extensions on both the upside and downside beneath the access road. Survey indicates the upside invert level is 284.60m AHD and the downside 284.65m AHD with a length of 35.5m. Dilapidation assessment of the culvert has been undertaken by Robinson Rail.

Based on the existing embankment profile and the performance of similar embankments on the main line subject to subsidence; the impact of the predicted subsidence at this location (<100mm) on batter stability is expected to be minimal. The embankment is located 100m or greater from LWS1A.

Geotechnical assessment of the embankment at 98.435km confirms:

- No evidence of current or past embankment instability observed.
- No evidence of culvert piping erosion observed.
- No requirement for any remedial works identified.

Embankment not listed in ARTC Geotechnical Risk Site database.

 98.380km downside embankment view to country	 98.430km upside embankment view to country
 98.435km downside culvert (downstream)	 98.489km upside culvert (upstream)

7.3 Cutting 98.610km

Double sided shallow cutting from 98.540km to 98.680km (140m) up to 1m deep on right hand curve through a broad very gentling sloping hillside area that falls to south-east from upside to downside. Cutting uniformly battered at approximately 40° with wide cess area on both upside and downside with sandstone rock exposed along the cess and batters.

The impact of the predicted subsidence on the shallow rock cutting is expected to be minimal. The cutting is located along the north-eastern edge of LWS1A.

Geotechnical assessment of the cutting at 98.610km confirms:

- No evidence of current or past cutting instability observed.
- No evidence of fault structures or sheared fractured ground observed in cutting exposures.
- No requirement for any remedial works identified.

Cut not listed in ARTC Geotechnical Risk Site database.

 98.600km cutting view to city	 98.600km sandstone rock in batter and cess

7.4 Fill Embankment 98.739km

Free standing fill embankment from 98.680km to 98.780km (100m) on a right hand curve across a gently sloping drainage path that falls to the east from upside to downside.

The embankment is up to approximately 5m in height along the drainage path reducing to 4m in height or less in adjoining sections. The embankment is characterised by:

- Upside access road 4m wide at a level less than 1m below rail with batter slopes of 30°.
- Downside access road 4m wide at a level less than 1.5m below rail with batter slopes of 35° or less below.

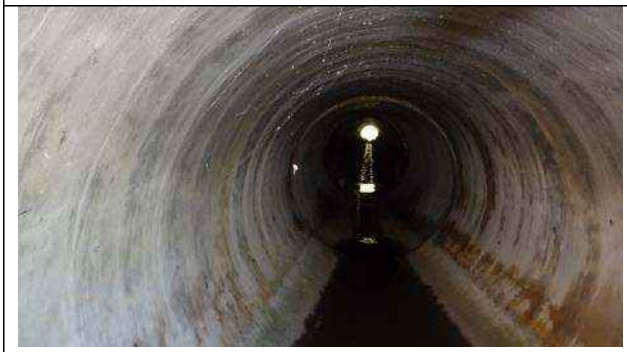
Borehole 2 drilled in the upside access road at 98.745km on the country side of the culvert encountered fill to 2.5m depth over residual soil with sandstone bedrock at 3m depth. Groundwater was not encountered in the bore at the time of drilling. No evidence of rock outcrop observed along the embankment toe or at culvert invert.

The culvert (listed as 98.739km) comprises a 0.9m diameter brick arch culvert with 0.9m diameter reinforced concrete pipe extensions on both the upside and downside beneath the access road. Survey indicates the upside invert level is 289.14m AHD and the downside 287.57m AHD with a length of 28.7m. Dilapidation assessment of the culvert has been undertaken by Robinson Rail.

Based on the existing embankment profile and the performance of similar embankments on the main line subject to subsidence; the impact of the predicted subsidence at this location on batter stability is expected to be minimal. The embankment is located close to the centreline of LWS1A.

98.700km downside embankment view to country

98.720km upside embankment view to country



98.739km downside culvert RCP extension

98.739km upside culvert (upstream)

Geotechnical assessment of the embankment at 98.739km confirms:

- No evidence of current or past embankment instability observed.
- No evidence of culvert piping erosion observed.
- No requirement for any remedial works identified.

Embankment not listed in ARTC Geotechnical Risk Site database.

7.5 Cutting 98.895km

Double sided shallow cutting from 98.800km to 98.990km (190m) up to 1.5m deep through a broad very gentling sloping hillside area that falls to east from upside to downside. Cutting uniformly battered at approximately 35° to 40° with wide cess area on both upside and downside with sandstone rock exposed along the cess and batters with a shallow cover of Sandy Clay residual soil. Competent sandstone rock outcrop locally present along downside access road at crest of cutting.

The impact of the predicted subsidence on the shallow rock cutting is expected to be minimal. The cutting is located along the south-western edge of LWS1A.

98.860km cutting downside view to country

98.980km downside sandstone in access road

Geotechnical assessment of the cutting at 98.985km confirms:

- No evidence of current or past cutting instability observed.
- No evidence of fault structures or sheared fractured ground observed in cutting exposures.
- No requirement for any remedial works identified.

Cutting listed in ARTC Geotechnical Risk Site database as site 12564. Site added to database in 2016 with a very low risk classification of 6 (non-active site).

7.6 Fill Embankment 99.035km

Free standing fill embankment from 99.000km to 99.080km (80m) across a gently sloping drainage path that falls to the east from upside to downside.

The embankment is up to approximately 6m in height along the drainage path reducing to 4m in height or less in adjoining sections. The embankment is characterised by:

- Upside access road 5m wide at a level in the order of 0.5m below rail with batter slopes of 30° or less below.
- Downside access road 4m wide at a level less about 1m below rail with batter slopes of 35° or less below.

Borehole 3 drilled in the down main four foot at 99.037km on the country side of the culvert encountered fill to 4.8m depth over residual soil with sandstone bedrock at 5.5m depth. Groundwater was not encountered in the bore at the time of drilling.

No evidence of rock outcrop observed along the embankment toe with sandstone rock outcrop observed below downside culvert invert level.

The culvert (listed as 99.035km) comprises a 1.2m diameter brick arch culvert with 0.9m diameter reinforced concrete pipe extensions on both the upside and downside beneath the access road. Survey indicates the upside invert level is 291.91m AHD and the downside 290.01m AHD with a length of 33.6m. Dilapidation assessment of the culvert has been undertaken by Robinson Rail.

On the downside at 99.035km there is a piping hole / void between the access road and embankment crest associated with a broken roof section in the 0.9m diameter reinforced concrete pipe culvert extension resulting in wash in and collapse of the 3.8m deep fill cover to the surface (as shown in photograph below). The piping hole that developed in about 2020 is about 4m from the ballast toe and as such is not currently constraining access or affecting track stability. The key issue is that further collapse of the hole may potentially result in culvert blockage during a rainfall event resulting in potential impoundment of water along the upside embankment. Remedial works to rectify this have been presented in Newcastle Geotech report 493-4 dated 7/4/2022 that is presented in Appendix E.

Based on the existing embankment profile and the performance of similar embankments on the main line subject to subsidence; the impact of the predicted subsidence at this location on batter stability is expected to be minimal. The embankment is located along the north-eastern edge of LWS2A.

Geotechnical assessment of the embankment at 99.035km confirms:

- No evidence of current or past embankment instability observed.
- Downside culvert piping erosion associated with culvert extension.
- Requirement for remedial works to repair downside sinkhole above culvert extension identified.

Embankment listed in ARTC Geotechnical Risk Site database as site 13493. Site added to database in June 2020 after reports of a sinkhole at 99.035km above the culvert on the downside edge of the access road with a very low risk classification of 6 (non-active site).

 99.020km downside embankment view to country	 99.025km upside embankment view to country
 99.035km downside piping hole above RCP extension	 99.035km upside culvert (upstream)

7.7 Cutting 99.165km

Double sided shallow cutting from 99.100km to 99.230km (130m) up to 1m deep through a broad very gentling sloping hillside area that falls to the south-east from upside to downside. Cutting uniformly battered at approximately 35° with wide cess area on both upside and downside with sandstone rock exposed along the cess and batters with a shallow cover of Sandy Clay residual soil. Sheet outcrop of competent sandstone rock present along downside access road.

The impact of the predicted subsidence on the shallow rock cutting is expected to be minimal. The cutting is located along the centreline of LWS2A.

Geotechnical assessment of the cutting at 99.165km confirms:

- No evidence of current or past cutting instability observed.
- No evidence of fault structures or sheared fractured ground observed in cutting exposures.
- No requirement for any remedial works identified.

Cutting not listed in ARTC Geotechnical Risk Site database.

99.160km cutting upside view to country

7.8 Fill Embankment 99.338km

Free standing fill embankment from 99.230km to 99.500km (270m) on a left hand curve across a broad gently sloping drainage path along Teatree Hollow Creek that falls to the south-east from upside to downside. The creek alignment comprises a broad rounded profile that is not incised.

The embankment is up to approximately 7m in height along the drainage path reducing to 5m in height or less in adjoining sections. The embankment is characterised by:

- Upside access road 4m wide at a level of less than 1m below rail with batter slopes of 35° or less below.
- Downside access road generally 4m wide or greater at a mid-embankment level about 3m below rail level with 35° batters above and below the access road. The access road width above the culvert at 99.338km reduces to 3.3m over about a 15m length with the access road raised to about 1.5m below rail level. At this location the batter slope below the access road locally steepens up to 45° associated with past washout of the culvert extension.

Borehole 4 drilled in the down main four foot at 99.338km on the city side of the culvert encountered fill to 5.2m depth over residual soil with sandstone bedrock at 5.8m depth. Groundwater was encountered at 6.8m depth at the time of drilling. The inclinometer borehole at 99.333km on the upside access road encountered 5.4m of fill and rock at 6m depth. Sandstone rock outcrop was observed along the toe of the upside embankment on the city side of the culvert.

Borehole 5 drilled in the upside access road at 99.396km on the country side of the culvert encountered fill to 5m depth over slopewash and residual soil with sandstone bedrock at 6m depth. Groundwater was encountered at 5.1m at the time of drilling with a higher level of 4.7m encountered on 28/3/2022 shortly after the significant March 2022 rainfall event.

The culvert (listed as 99.338km) is skewed in alignment and occurs under the upside embankment crest at about 99.355km and under the downside crest at about 99.340km. It comprises a 1.5m diameter brick arch culvert with a 1.2m diameter reinforced concrete pipe extensions on the upside. On the downside the original 1.2m diameter RCP culvert pipe extension and overlying fill has failed presumably under a peak flow / flood event resulting in a very steep fill batter / scarp below the access road. The original RCP extensions can be observed downstream from the culvert. Remedial works to rectify this have been presented in Newcastle Geotech report 493-4 attached in Appendix E.

Survey at the culvert indicates the upside invert level is 293.70m AHD. Survey of the downside invert was not undertaken due to ponding water and thick vegetation. The culvert is approximately 28m in length. Dilapidation assessment of the culvert has been undertaken by Robinson Rail.

Based on the existing embankment profile and the performance of similar embankments on the main line subject to subsidence; the impact of the predicted subsidence on batter stability is expected to be minimal. The embankment is located along the north-eastern edge to the centreline of LWS3A.

Geotechnical assessment of the embankment at 99.338km confirms:

- No evidence of current or past embankment instability observed apart from the past washout failure of the downside culvert extension at 99.338km.
- Requirement for remedial works to reinstate the downside culvert extension and batter slopes.

Embankment listed in ARTC Geotechnical Risk Site database as site 12565. Site added to database in 2021 with a very low risk classification of 6 (non-active site). It is noted that this assessment was unlikely to be aware of the washout and steep batters in the downside culvert.

 99.340km downside embankment view to city	 99.320km upside embankment toe view to country
 99.338km downside 1.5m diameter original culvert headwall with very steep batter slope above	 99.390km upside embankment crest view to country (borehole 5)
 99.338km downside culvert with 1.2m diameter RCP extension from washout located downstream	 99.395km downside view to country

7.9 Heritage Well 99.530km

A well that has been excavated into bedrock is present on the downside at 99.530km with the well located about 5m from the rail corridor boundary in Wirrimbirra Sanctuary. It is understood that the well is old and has heritage significance.

Interbedded sandstone and shale bedrock with some evidence of possible shearing and faulting is present in the well walls and this feature may have resulted in a groundwater spring with localised elevated water levels.

	
99.530km location downside heritage well	99.530km heritage well

7.10 Cutting 99.690km

Double sided cutting from 99.500km to 99.880km (380m) up to 3.5m deep on a left hand to right hand curve through a broad very gentling sloping hillside area that falls to the north-east from upside to downside.

Cutting uniformly battered at 35° to 40° in the upper part in Sandy Clay and Clayey Sand residual soils with the lower part of the cutting locally battered up to 70° in competent sandstone rock with minor sub-horizontally bedded shale layers up to 100mm thick. Wide cess area on both upside and downside ranging 3.5m to 4m from cutting toe to rail and 0.5m to 0.7m in depth below rail. This provides significant containment width for any small scale rock falls or shallow soil slips that may occur along the cutting. The upside and downside cesses drain to the city with some ponding water present on upside.

Based on the existing cutting profile and the performance of similar cuttings on the main line subject to subsidence; the impact of the predicted subsidence at this location on batter stability and cess drainage is expected to be minimal. The cutting extends from the centreline of LWS3A to the chain pillar between LWS3A and LWS4A.

Cutting listed in ARTC Geotechnical Risk Site database as site 12566. Site added to database in 2016 with a very low risk classification of 6 (non-active site).

	
99.690km cutting view to country	99.700km sandstone rock in downside cutting

Geotechnical assessment of the cutting at 99.360km confirms:

- No evidence of current or past cutting instability observed.
- No evidence of fault structures or sheared fractured ground observed in cutting exposures.
- No requirement for any remedial works identified.

Cutting listed in ARTC Geotechnical Risk Site database as site 12566. Site added to database in 2016 with a very low risk classification of 6 (non-active site).

7.11 Fill Embankment 100.121km

Free standing fill embankment from 100.030km to 100.230km (200m) on a straight to left hand curve across a gently sloping drainage path that falls to the south-east from upside to downside. The embankment is up to approximately 6m in height along the drainage path reducing to 4m in height or less in adjoining sections. The embankment is characterised by:

- Upside access road 3.5m to 4m wide at a level of about 1m below rail with batter slopes of 35° or less below.
- Downside ballast shoulder 1.5m to 2m in width from edge of sleeper extending at about 30° to 33° down to the access road at about 4.5m below rail level. The access road along the embankment toe is approximately 4m in width and occurs about 2m in elevation above the culvert invert with batter slopes up to 35°.

Borehole 6 drilled in the upside access road at 100.143km on the city side of the culvert encountered fill to 4.7m depth over slopewash and residual soil with sandstone bedrock at 5.5 depth. Groundwater was encountered at 5m depth at the time of drilling. Extremely weathered sandstone rock outcrop was observed at about invert level near the upside culvert inlet.

The culvert (listed as 100.121km) is skewed in alignment and occurs under the upside embankment crest at about 100.147km and under the downside crest at about 100.127km. The culvert comprises a 1.5m diameter brick arch culvert with 1.5m diameter reinforced concrete pipe extensions on both the upside and downside beneath the access road. On the downside the original brick headwall and wingwalls occurs at the toe of the embankment with the 1.5m diameter pipe extension abutted against the wall with a gap in between that was covered by soil but has recently opened. Due to the angled nature of the wingwalls, the pipe extension is unable to be abutted directly against the headwall. Survey indicates the downside invert level is 301.99m AHD with a culvert length of about 40m. Dilapidation assessment of the culvert has been undertaken by Robinson Rail.

Based on the existing embankment profile and the performance of similar embankments on the main line subject to subsidence; the impact of the predicted subsidence at this location on batter stability is expected to be minimal. The embankment is located centreline to the south-west edge of LWS4A.

Geotechnical assessment of the embankment at 100.121km confirms:

- No evidence of current or past embankment instability observed.
- No evidence of culvert piping erosion observed apart from gap between downside pipe extension and headwall.
- No requirement for any remedial works identified apart from sealing of the downside gap between the culvert headwall and pipe extension.

Embankment listed in ARTC Geotechnical Risk Site database as site 12567. Site added to database in 2021 with a very low risk classification of 6 (non-active site).

 100.150km downside embankment view to city	 100.080km upside embankment view to country
 100.127km downside original BAC headwall with pipe extension at shallow depth below access road	 100.147km upside 1.5m diameter brick arch culvert and pipe extension

7.12 Cutting 100.310km

Double sided cutting from 100.250km to 100.370km (120m) up to 2m deep on a right hand curve through a broad very gentling sloping hillside area that falls to the east from upside to downside.

Cutting uniformly battered at 40° to 45° in residual Sandy Clay and Clayey Sand soils over competent sandstone rock. Wide cess area on both upside and downside with access road along toe of upside. The wide cess areas provide significant containment width for any small scale rock falls or shallow soil slips that may occur along the cutting. The upside and downside cesses drain to the city.

Based on the existing cutting profile and the performance of similar cuttings on the main line subject to subsidence; the impact of the predicted subsidence at this location on batter stability and cess drainage is expected to be minimal. The cutting between LWS4A and LWS5A.

Cutting listed in ARTC Geotechnical Risk Site database as site 12568. Site added to database in 2016 with a very low risk classification of 6 (non-active site).

 100.280km cutting view to country	 100.320km upside cutting in sandstone rock

Geotechnical assessment of the cutting at 100.310km confirms:

- No evidence of current or past cutting instability observed.
- No evidence of fault structures or sheared fractured ground observed in cutting exposures.
- No requirement for any remedial works identified.

7.13 Fill Embankment 100.425km

Free standing fill embankment from 100.370km to 100.500km (130m) across a gently sloping drainage path that falls to the south-east from upside to downside.

The embankment is up to approximately 6m in height along the drainage path reducing to 4m in height or less in adjoining sections. The embankment is characterised by:

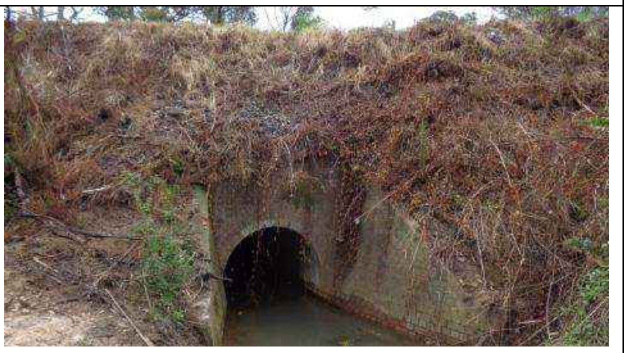
- Upside access road 3.5m wide above culvert and greater elsewhere at a level less than 1m below rail with batter slopes of 35° or less below.
- Downside access road 3.5m wide above culvert and greater elsewhere at a level about 1m below rail with batter slopes of 35° or less below.

Borehole 7 drilled in the down main four foot at 100.429km on the country side of the culvert encountered fill to 5.3m depth over slopewash and residual soil with sandstone bedrock at 6.6m depth. Groundwater was encountered at 5.9m depth at the time of drilling.

No evidence of rock outcrop observed along the embankment toe or at culvert invert.

The culvert (listed as 100.425km) is skewed in alignment and occurs under the upside embankment crest at about 100.430km and under the downside crest at about 100.422km. The culvert comprises a 1.5m diameter brick arch culvert with brick wingwalls on both the upside and downside (no pipe extension). Survey has been limited due to vegetation. Dilapidation assessment of the culvert has been undertaken by Robinson Rail.

Embankment not listed in ARTC Geotechnical Risk Site database.

 100.425km downside embankment view to city	 100.460km upside embankment view to city
 98.422km downside culvert (downstream)	 100.430km upside culvert (upstream)

Based on the existing embankment profile and the performance of similar embankments on the main line subject to subsidence; the impact of the predicted subsidence at this location on batter stability is expected to be minimal. The embankment is located near the centreline of LWS5A.

Geotechnical assessment of the embankment at 100.425km confirms:

- No evidence of current or past embankment instability observed.
- No evidence of culvert piping erosion observed.

No requirement for any remedial works identified.

7.14 Cutting 100.700km

Double sided cutting from 100.500km to 100.900km (400m) up to 4m deep on straight track through a broad very gentling sloping hillside area that falls to the east from upside to downside.

Cutting battered at 35° to 45° in Gravelly Sandy Clay and Gravelly Clayey Sand residual soils with the lower part in extremely to highly weathered weak sandstone. A deeper soil profile occurs in this cutting compared to the other cuttings; however the base of the cutting occurs in weathered rock. Minor localised shallow sheet erosion of the cutting batters is occurring with derived sediment along the toe of the cutting.

Wide cess area on both upside and downside ranging 4m to 5m from cutting toe to rail and 0.5m to 0.7m in depth below rail. This provides significant containment width for any small scale rock falls or shallow soil slips that may occur along the cutting. The upside and downside cesses drain to the city.

Based on the existing cutting profile and the performance of similar cuttings on the main line subject to subsidence; the impact of the predicted subsidence at this location on batter stability and cess drainage is expected to be minimal. The cutting extends from the centreline of LWS5A to beyond the southern limit of the panel.

Geotechnical assessment of the cutting at 100.700km confirms:

- No evidence of current or past cutting instability observed.
- No evidence of fault structures or sheared fractured ground observed in cutting exposures.
- No requirement for any remedial works identified.

Cutting listed in ARTC Geotechnical Risk Site database as site 12569. Site added to database in 2016 with a very low risk classification of 6 (non-active site).

100.500km cutting downside view to country

100.620m upside cutting with minor erosion

7.15 Fill Embankment 101.000km

Free standing fill embankment from 100.970km to 101.030km (60m) across a gently sloping drainage path that falls to the east from upside to downside.

The embankment is up to approximately 5m in height along the drainage path reducing to 3m in height or less in adjoining sections. The embankment is characterised by:

- Upside access road 3.5m wide above culvert only over a narrow length and significantly greater elsewhere at a level about 1m below rail with batter slopes of 35° or less below.
- Downside access road 4m wide above culvert only over a narrow length and significantly greater elsewhere at a level about 1m below rail with batter slopes of 35° or less below.

No evidence of rock outcrop observed along the embankment toe or at culvert invert.

The culvert (101.000km) comprises a 1.2m diameter brick arch culvert with 0.9m diameter concrete pipe extensions on both the upside and downside. The downside outlet has dense vegetation that limits inspection and survey. Dilapidation assessment of the culvert has been undertaken by Robinson Rail.

Based on the existing embankment profile and the performance of similar embankments on the main line subject to subsidence; the impact of the predicted subsidence at this location on batter stability is expected to be minimal. The embankment is located about 200m beyond the southern limit of LWS5A and LWS6A.

Geotechnical assessment of the embankment at 100.425km confirms:

- No evidence of current or past embankment instability observed.
- No evidence of culvert piping erosion observed.
- No requirement for any remedial works identified.

	
101.000km downside embankment view to country	101.000km upside culvert inlet

7.16 Cutting and Overbridge 101.162km

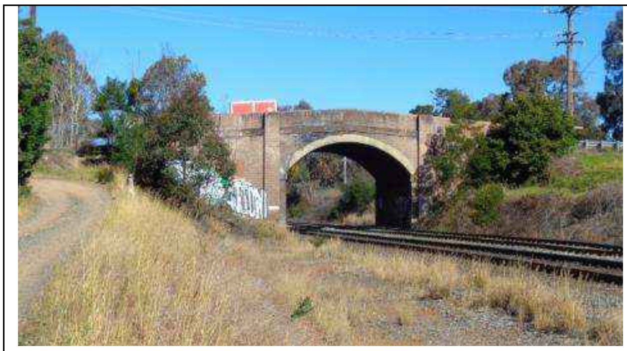
Double sided cutting from 101.080km on left hand curve extending beyond Wellers Road overbridge (101.162km) to about 101.400km. The cutting occurs through a broad very gentling sloping hillside area that falls to the east from upside to downside. The cutting at the overbridge is up to 3m deep with up to 2m of embankment fill over the crest of the cutting at the bridge abutments.

Structural assessment of the Wellers Road overbridge has been undertaken by John Matheson and Associates.

Based on the existing cutting profile and the performance of similar cuttings on the main line subject to subsidence; the impact of the predicted subsidence at this location on batter stability and cess drainage is expected to be minimal. The cutting is located about 400m beyond the southern limit of LWS6A.

Brief geotechnical assessment of the cutting at 101.162km did not note any evidence of current or past cutting instability or fault structures.

Cutting listed in ARTC Geotechnical Risk Site database as site 12570. Site added to database in 2016 with a very low risk classification of 6 (non-active site).

	
101.162km Wellers Road overbridge view from city	101.180km cutting view to country

8 STABILITY ASSESSMENT

8.1 Performance of Geotechnical Assets Subject to Longwall Mining by Tahmoor Coal

Tahmoor Coal has extensive recent experience of mining beneath the Main Southern Rail (MSR) in LW22 to LW32 and the Picton to Mittagong Loop Line (PMLL) in LW W1 to W4 at similar depths of cover and predicted subsidence to that proposed for Tahmoor South with control measures successfully implemented to manage potential impacts on rail embankments, culverts and cuttings with performance extensively monitored by the Rail Management Group (RMG) and documented by MSEC. This has involved definition of potential subsidence related hazards, monitoring, progressive assessment and review of performance and where required response to change and implementation of control measures.

The potential subsidence related geotechnical hazards identified for LW S1A to S6A are presented in Table 7 together with the established performance history on the MSR and the PMLL. The key potential geotechnical hazards identified during risk assessment are:

- Development of track geometry defects due to deformation of track formation and foundation.
- Loss of track support due to instability of fill embankments.
- Embankment collapse or instability due to culvert failure.
- Debris on track due to instability of cuttings or slopes above.

Table 7 - Performance History of Geotechnical Assets on MSR and PMLL Subject to Subsidence

Subsidence Related Geotechnical Hazard	Established Performance History
Abrupt track geometry change due to the development of a step or hump due to concentration of localised high ground strains potentially along a geological structure.	Changes in track geometry have been minor with track serviceability maintained through progressive monitoring and adjustment. Subsidence impacts are gradual. No step or hump in the embankments observed even where changes in vertical ground alignment and high strain levels measured.
Impact of ground closure on culverts with loss of serviceability or blockage due to collapse.	Significant culvert closure only encountered where larger culverts founded in rock strata. Culverts along LW S1A to S6A founded above rock level. Minimal subsidence impact where smaller diameter brick arch culverts are directly undermined.

Subsidence Related Geotechnical Hazard	Established Performance History
Collapse of the embankment caused by inundation by flood impoundment due to culvert collapse.	Not encountered. Embankments have ben subject to a number of significant rainfall events.
Embankment slope failure in heavy rain due to steep batter slopes, ponding of water on the uphill side and water infiltration due to tension features.	No evidence of instability encountered on undermined embankments even when subject to significant rainfall events.
Piping failure induced by tension cracks from embankment base producing sinkholes.	Not encountered. Piping hole at 99.035km downside due to poorly fitted pipe extension.
Cutting batter instability induced by strains and non-systematic subsidence along geological structures.	No evidence of instability of cuttings or natural slopes above encountered even when subject to significant rainfall events.

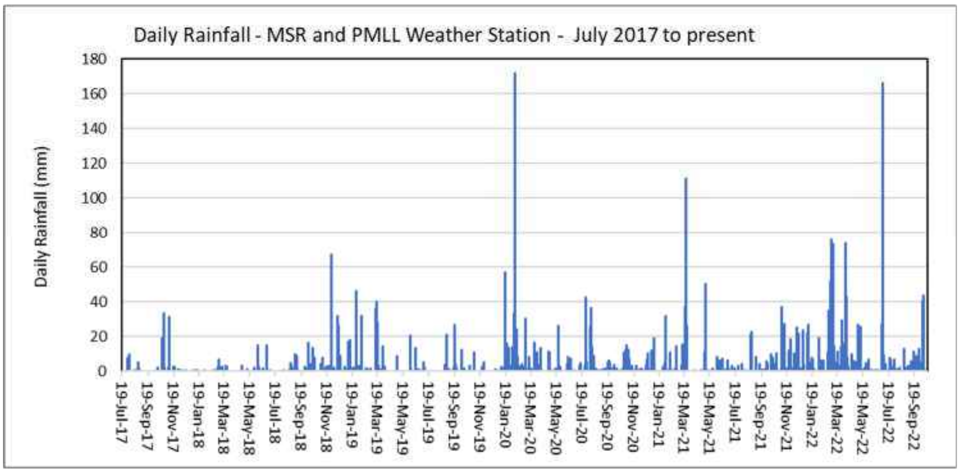
The established performance history is that fill embankments, culverts and embankments can tolerate considerable mining-induced ground deformations without experiencing impacts.

This performance history has included at least five significant rainfall events with rainfall from July 2017 to present recorded by Tahmoor Coal in an automated weather station on the MSR and PMLL:

- June 2016 rainfall event that saw significant flooding of Picton township with the storm event likely equating to a 1 in 100 year event.
- February 2020 with 172mm of rainfall on 9 February with 332mm over 7 days.
- March 2021 with 111mm on 21 March and a total 6 day rainfall 19 to 24 March of 287mm.
- February and March 2022 with 76mm on 3 March and a total 15 day rainfall 23 February to 9 March of 452mm.
- June 2022 with 166mm on 3 July and a total 4 day rainfall of 232mm from 2 to 5 July.

The rainfall event of June 2016 was in the order of a 100 year annual exceedance probability (AEP) with the four subsequent rain events in the order of 20 year AEP events. In all these cases significant saturation of rail embankments on the MSR would have occurred with no evidence of fill embankment instability in the Picton areas subject to mine subsidence influence noted in geotechnical inspections and survey monitoring undertaken by the Rail Management Group.

Figure 4 – Daily Rainfall Recorded on MSR and PMLL since July 2017



Newcastle Geotech as part of the Rail Management Group (RMG) has previously been involved with the assessment of cutting and embankments stability on the Main Southern Rail (MSR) and the Picton to Mittagong Loop Line (PMLL) subject to mining influence from Tahmoor Coal longwall panels LW31, LW32, and LW W1 to W4 that has included:

- Weekly geotechnical inspection and analysis of survey and instrumentation data and reporting.
- Analysis of geotechnical data from instrumentation in embankments that recorded groundwater level (piezometers), crest width (extensometers) and ground deformation (inclinometers).
- Response and inspection during wet weather events.

Relevant details and learnings from these previous assessments have been incorporated into the current assessment. In summary this experience indicates:

- In cuttings no impact has been recorded in relation to batter slope stability. At some locations non-conventional subsidence movements have been observed to develop within railway cuttings, resulting in impacts on track geometry but negligible impact on the cutting batters. The sides of some cuttings (but not all) have been observed to exhibit minor closure in response to mine subsidence. No subsidence related batter instability incidents recorded for cuttings over 10 years with occasional minor batter erosion associated with significant rainfall events.
- Fill embankments are able to tolerable considerable mining-induced ground deformations without experiencing impacts, are not prone to development of tension cracks and exhibit no “steps or humps” in spite of changes in vertical alignment and high strain levels measured.

8.2 Existing Embankment and Cutting Performance at Tahmoor South

Detailed geotechnical inspection and mapping of embankments, culverts and cuttings on the MSR between 97.0km and 101.0km has been undertaken as detailed in Section 7. In relation to embankments, this has confirmed no evidence of:

- Tension cracks, batter deformation or track misalignment.
- Deeper seated medium to large scale rotational and translational slip of the embankment batters that may have affected the track alignment or stability of the formation.
- Shallow rotational and translational slips of the outer batter surface impacting the access roads or the ballast. The only exception to this is the slip along the downside above the culvert at 99.338km associated with past washout of the culvert pipe extensions and fill.
- Past remedial works involving batter reconstruction or berm construction evident.

It is possible that some areas of past shallow batter instability of the outer batter veneer to depths in the order of 1m or less may have occurred and not be observable, however if present these are likely to have only affected the embankment batters and access roads without impacting the track formation.

The assessment of geotechnical risk for the fill embankments is made on the assumption that the culverts are performing satisfactorily and the risk of significant culvert blockage or collapse and impoundment of water along the upstream embankment batter is very low where track baulks are installed.

The assessed adequate performance of the fill embankments over 100 years since construction that has incorporated numerous significant wet weather events can be generally attributed to:

- Embankments of limited height generally about 4m or less in height and locally up to 7m across drainage paths with embankments constructed on gentle planar surfaces of gradient less than 5°.
- Construction using sandstone and shale rock and soil derived fill materials. These clay and sand mixtures with a variable rock content are generally moderately drained and have reasonable angles of internal friction capable of providing long term support of the batter slopes.

- Wide embankment crest shoulders with access roads greater than 3m in width that have been constructed along the upside and downside that act as stabilising berms.
- Uniform batter slopes with a moderate vegetation cover.
- Foundation comprising competent soil materials or shallow bedrock.
- Culvert inverts positioned at embankment low points with no evidence of water impoundment or scour along the embankment toes.

Review of the ARTC Geotechnical Database notes that there is no documentation or observation in relation to embankment instability or issues.

The existing cuttings between 97.0km and 101.0km are minor, generally less than 2m in depth with a maximum of 3.5m, with shallow rock present in most. The cuttings are characterised by wide cess areas with toe of cut to rail distance in the order 4m. As such, the risk of batter instability comprising small scale slips and rock falls is low with the likelihood of these impacting the track assessed to be not credible. Inspection of the cuttings indicates no evidence of current or past cutting instability and no evidence of fault structures or sheared fractured ground.

Performance of existing culverts has been assessed by Robinson Rail in Pre-Mining Condition Report August 2022. It is understood that remote camera inspection of the culverts is currently being undertaken to further assess the condition of the brick arch culverts.

8.3 ARTC Risk Assessment Matrix

Qualitative assessment of the risk to rail operations has been undertaken based on the ARTC geotechnical risk assessment matrix presented in Table 7. It is highlighted that the assessment is based on the risk to rail operations and the likelihood of an event occurring in the next 12 months under adverse weather conditions and affecting the track. The matrix does not take into consideration the risk to ancillary infrastructure such as the access road or the consequence of ongoing maintenance requirements.

Category 1 to 5 sites are generally classified as active geotechnical sites with category 6 as inactive sites. A general classification of the risk level associated with each category and the associated responsibility and actions is:

- Category 1 - Very high risk level with immediate action and mitigation required (line closure).
- Category 2 - High risk level with preparation of mitigation actions and other initiatives with short term mitigation measures adopted such as speed restriction and monitoring. Regular feedback on status / progress of risk mitigation to management. Implementation of treatment options required to reduce risk to acceptable levels.
- Category 3 – Medium risk level. Tolerable, provided treatment plan is implemented to maintain or reduce risk levels. Maybe accepted, but generally requires investigation and planning of treatment options.
- Category 4 – Low to medium risk. Usually accepted. Treatment requirements and responsibility to be defined to maintain or reduce risk.
- Category 5 – Low risk. Usually accepted. Monitoring and maintenance requirements and responsibility to be defined to maintain or reduce risk.
- Category 6 – Very low risk. Acceptable. Manage by normal slope maintenance procedures.

Table 7 - ARTC Risk Assessment Matrix

	PROBABILITY of event occurring and affecting the track, in the short term (12 months) under adverse weather conditions			
CONSEQUENCE of the event affecting the track	**HIGH** Event Highly Likely (H)	**MODERATE** Event is Likely (M)	**LOW** Event is Probable (L)	**VERY LOW** Event is Possible (VL)
EXTREME - Loss of life expected - Extensive damage and disruption	1	2	3 Priority 3	4
SEVERE - Loss of life is possible, not expected - Appreciable damage and disruption	2	3 Priority 1	4 Priority 1	5
MODERATE - Loss of life or serious injury not expected - Minor damage to structures and facilities	3 Priority 2	4 Priority 2	5	6
MINOR	4	5	6	6

Based on site conditions and established performance history of embankments and cuttings subject to mine subsidence on the MSR, the existing pre-mining risk to rail operations associated with geotechnical hazards is presented in Table 8 together with the assessed risk level during and post mining.

Table 8 – Assessed Risk Level LW S1A to S6A – Existing and Mining Related

Asset	**Event**	**Existing – Pre LW S1A to S6A Mining**				**During and Post LW S1A to S6A Mining**			
		Probability of Event		Conse-quence	Risk Category	Probability of Event		Conse-quence	Risk Category
		Occurring	**Affecting Track**			Occurring	**Affecting Track**		
Fill embankments	Shallow slip of embankment batter along shoulder or access road	Low	Very Low	Minor	6	Low	Very Low	Minor	6
	Deep seated slip of embankment	Very Low	Very Low	Moderate	6	Low	Very Low	Moderate	6
	Deep seated slip due to subsidence collapse or blockage of culvert	Very Low	Very Low	Moderate	6	Low	Very Low	Moderate	6
Fill embankment 99.338km downside above culvert	Shallow slip of access road above culvert	Moderate	Low	Moderate	5	High	Low	Moderate	5
	Deep seated slip at culvert	Low	Low	Severe	4.1	Low	Low	Severe	4.1
Cuttings	Shallow rotational slip	Low	Very Low	Minor	6	Low	Very Low	Minor	6
	Small rock fall	Low	Very Low	Minor	6	Low	Very Low	Minor	6

The following is noted:

- The existing geotechnical risk level to rail operations is assessed as very low to low. This level of risk is usually acceptable to rail operators and regulators and is managed under routine track monitoring and maintenance requirements with no requirement for intervention or remedial works to reduce risk level.
- On the downside at 99.338km there is a low probability of a deep seated failure under adverse weather conditions extending from the culvert washout below the access road to affect the ballast slope and formation support below the downside rail. This potential failure mechanism is reflected in the results of stability modelling in Section 8.4. It is highlighted that the downside loss of batter support at the culvert is only very localised over 10m or less with the expected failure mechanism involving shallower failure of the steep batter slope back into the 3m wide access road. A scope of works to remediate this area is presented in Appendix E.
- Based on established performance history of embankments and cuttings subject to mine subsidence on the MSR, the impact of predicted subsidence on the geotechnical assets, hazards and assessed risk level has been assessed as minor. Minor increase in the probability of existing geotechnical hazards occurring due to subsidence effects has been assessed, however this would be restricted to the access roads with no increase in probability of affecting the rail track.
- Even allowing for the possibility that subsidence predictions may not be sufficiently accurate and that high strain spikes from non-systematic subsidence may locally occur; the assessed geotechnical risk level to rail operations is still low.

8.4 Finite Element Stability Modelling

Detailed stability analysis has been carried out for the rail embankments using PLAXIS 2D. which is a finite element package intended for the two dimensional analysis of deformation and stability in geotechnical engineering.

Analysis was undertaken by Morrow Geotechnics as presented in report P2607_02 as attached in Appendix D. The analysis was undertaken at six embankment locations as shown in Table 10 based on the following data provided by Newcastle Geotech:

- Embankment cross sections based on survey by Southern Rail Survey supplemented by detailed mapping by Newcastle Geotech where required. The sections incorporate both upside and downside batters.
- Interpreted embankment subsurface materials, geotechnical units and layers based on results of investigation and mapping.
- Geotechnical parameters for the geotechnical units as shown in Table 9.
- Interpreted maximum groundwater piezometric surface at 0.5m to 1m above the base of the fill.
- Applied rail surcharge loading of 50kPa.

Table 9 - Geotechnical Parameters

Unit	Material Type	Drained Cohesion c′ (kPa)	Friction Angle ϕ′ (°)	Dilatancy Angle ψ (°)	Unsaturated Bulk Density γ_{unsat} kN/m^3)	Saturated Bulk Density γ_{sat} (kN/m^3)	Elastic Modulus E′ (MPa)	Poisson's Ratio v′
1a	Rail Formation	0	40	5	20	20.5	50	0.25
1b		0	36	5	20	20.5	50	0.25
2a	Fill	5	28	0	18	19	15	0.30
2b	Fill	5	30	0	19	20	20	0.25
2c	Access Road	0	33	3	20	20.5	30	0.25
3	Alluvium / Slopewash	0	30	0	19	20	15	0.25
4a	Residual	5	25	0	18	19	15	0.30
4b	Residual	0	30	0	19	20	20	0.25
5	Rock	20	35	0	23	24	80	0.25

The philosophy adopted for the analysis is similar to the methodology adopted in the assessment of other embankments along the MSR with analysis based on effective stress parameters including apparent cohesion. It is highlighted that the inclusion of unsaturated soil suction values (negative pore pressures) as adopted in other MSR stability analyses has not been made and in this regard the results can be considered conservative. Adoption of negative pore pressures in the analysis would result in a higher factor of safety.

Impacts from flood levels have not been incorporated in recognition of the relatively short duration of flooding not permitting time for significant changes to occur to the unsaturated nature of the embankment.

Groundwater levels have been recorded in embankment foundations on the MSR and PMLL over a number of years that has included the rainfall events noted in Section 8.1 and Figure 4. Results have shown that groundwater levels have remained relatively static, generally below the base of the embankment fill with only minor response to rainfall events. Limited monitoring of groundwater levels on this project confirms this observation with only a minor increase in groundwater level recorded in response to the March 2022 rainfall event with groundwater rising to only 0.3m above the base of fill.

The interpretation of the analysis has been based on the following criteria:

- Analysis for both upside and downside rail embankments.
- Discounting of shallow surface failures along the access track batters with only FoS for failures of 0.75m or greater depth reported. Shallow translational failures of loose batter surface material is a common type of failure mechanism on steeply battered rail embankments that often have a surface veneer of loose material. The failure mechanism for these shallow slips is often associated with concentrated discharge of surface water due to variation in access road grade and camber rather than inherent instability in the embankment. The impact of these shallow slips on embankment and access road serviceability is generally negligible and as such they have been disregarded.

- Selection of potential failures affecting the rail formation has been based on deeper seated instability extending to the ballast toe, generally located along the access road at about 1m below rail level. Where the access road occurs at a lower level, the potential for the failure to impact on the track formation has been taken based on a distance of 2m from the end of sleeper. These factor of safety (FoS) values are of importance are those which represent potential failure surfaces that adversely impact track safety.
- Failures affecting the rail have been treated together, with worst case failure taken to represent risk to rail for both up and down lines.

The results of the PLAXIS analysis are presented in Table 10.

Table 10 – Results of Analysis FoS

Embankment Factor of Safety (FoS)						
Section	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6
Rail km	**98.440**	**98.745**	**99.037**	**99.338**	**100.143**	**100.427**
Failures Affecting Down Line Access Track	1.61	1.33	1.27	1.20	1.50	1.31
Failures Affecting Rail Formation	1.61	1.65	1.69	**1.20**	1.54	>2.00
Failures Affecting Up Line Access Track	1.61	>2.00	>2.00	1.36	>2.00	1.47

The FoS along the downside culvert washout at 99.338km is 1.20 with a failure surface extending up through the access road to the toe of the downside ballast slope that extends up to 1.5m in height up to the rail. Whilst such a failure surface would not directly remove support for the track formation, the concern would be that regression of the slip further back up the ballast slope would eventually affect lateral track stability.

It is highlighted that the modelled section at 99.338km is a worst case condition associated with localised loss of batter support at the culvert over a distance of about 10m with adjacent batter sections uniformly constructed with expected FoS similar to that modelled for the other sections.

Options for stabilisation of the downside culvert washout are presented in Appendix E. The culvert at 99.338km is located below LW W3A and as such will only experience minimal subsidence effects associated with LW W1A. It is recommended that remedial works to re-instate the culvert extension and batter slope are undertaken prior to LW W2A impacts.

All other modelled sections / embankments has FoS greater that 1.54 for failures affecting the rail formation and FoS greater than 1.27 for failures affecting the access roads.

Discussion of what is an acceptable factor of safety for existing infrastructure is widely debated. A minimum factor of safety of 1.4 under static loading is recommended as an acceptable criteria for existing embankment support of the track formation based on:

- Acknowledgement that these factors are known conditions (measured geometry, observed performance, material properties etc.) and not based on design values which are typically elevated to account for unknowns.
- Acknowledgement that these embankments have proven reliability over the past 100 years.

- Adoption of negative pore pressure (soil suction) parameters into the analysis as previously undertaken for other embankments on the MSR would result in increased factors of safety.
- The current and proposed system of surveillance, condition reporting, triggered actions, and continuous review during the period of potential mining impact.

A minimum factor of safety of 1.25 under static loading is recommended as an acceptable criteria for support of the access roads along the upside and downside of the embankment where the impact of instability is limited to potential loss of maintenance road access.

9 RISK MANAGEMENT

9.1 Mitigation Works

Assessment of cutting condition and risk level has not identified any requirement for risk mitigation works. The only potential adverse impact of the predicted subsidence on cutting performance is the potential for subsidence related grade change along the wide cess drain with potential for ponding water to locally develop. Due to the rock subgrade along the cess drains and base of cutting, this would have negligible impact on cutting stability. The ponding of water in shallow cess drains can however result in saturation of the rail formation subgrade with the potential to adversely impact on track performance. Contingency for localised regrading of cess drains should be made to address ponding water where this develops.

Assessment of the relatively small brick arch culverts, notes that they are generally founded on or above rock level and across broad rounded drainage paths and as such are less likely to experience significant valley closure impact. It is however noted that the is a degree of uncertainty in relation to the potential for culvert deformation due to subsidence and based on the generally limited cover between the culvert obvert and track formation, risk mitigation for the culverts should involve installation of a track baulk. This has been recommended by Robinson Rail in the culvert assessment report. Recommended risk mitigation work for culverts comprises:

- Installation of a track baulk at each culvert in advance of active subsidence effects.
- Sealing of the gap between downside brick arch culvert headwall and 1.5m diameter pipe extension along the base of the downside embankment batter above access road at 100.121km.
- Remediation of the downside sinkhole in the access road at 99.035km. This feature is located remote from the track and remedial works are recommended to address culvert serviceability rather than to address risk to the track formation or embankment stability. Refer to scope of works in Appendix E.
- Remediation of the downside culvert pipe extension at 99.338km where washout of the pipe extension and fill above has resulted in a localised over-steep batter and reduction in the access road width. The factor of safety along the access road at this location is 1.20 with further shallow failure at this location likely to reduce the access road width to a point where closure is required. Remedial works are recommended to reinstate the culvert outlet and access road batter support. Refer to scope of works in Appendix E (note report lists culvert as 99.384km based on structures km).

The embankments are characterised by access roads along the downside and upside that act as stabilising berms, decreasing the risk of embankment instability impacting the rail. Based on the assessed factors of safety and performance of the embankments, Newcastle Geotech does not recommend mitigation work (apart for 99.338km downside batter above culvert) to strengthen any sections of the embankments prior to the development of subsidence impacts from LW S1A to S6A.

9.2 Management and Monitoring Controls

Tahmoor Coal has extensive experience in successively managing potential impacts on railway embankments and cuttings along the MSR as documented in previous subsidence management plans.

The key control in managing potential impact is the existing track expansion system to accommodate rail extension and compression from mine subsidence together with the rail monitoring system that provides alerts for the track.

Whilst the risk level to embankments, culverts and cuttings from the proposed mining is assessed to be low, appropriate management measures will be implemented and the potential for impacts managed using an established subsidence management methodology to be documented in a detailed Subsidence Management Plan to be prepared by MSEC for LW S1A to S6A.

The Management Plan will include implementation of a Trigger Action and Response Plan (TARP) to reduce the risk of embankment, culvert and cutting instability by early detection of the development of potential adverse subsidence movements and changes in condition, so that contingency response measures can be implemented before impacts on the safety and serviceability of the embankments and railway track develop. The following controls from a geotechnical perspective are recommended:

- Cuttings – no requirement for specific survey monitoring along toe and crest of cuttings. Survey through cuttings can be limited to monitoring line along the railway. Risk management for cuttings can be limited to visual geotechnical inspection during the active subsidence stage together with routine inspection by track examiner.
- Culverts – Survey of culverts marks established on brick arch culvert spring points and wingwalls at outlets and inlets (due to restricted culvert diameter of 1.5m or less, installation of mid-point survey marks not feasible). Visual geotechnical inspection during the active subsidence stage together with routine inspection by track examiner.
- Embankments - Absolute 3D surveys and relative 3D surveys along monitoring lines on the crests and/or toes of the embankments on both sides. Visual geotechnical inspection during the active subsidence stage together with routine inspection by track examiner.

Installation of extensometers to monitor change in embankment crest width is not recommended due to the presence of access roads close to track level along both sides of the rail embankment that results in the actual movement monitoring positions located remote from the rail formation. Any change in embankment crest width at access road level can be effectively monitored by survey of embankment crest marks.

Installation of a borehole inclinometer has been undertaken in the upside access road at 99.333km along the fill embankment that extends from 99.230km to 99.500km. The inclinometer has been installed to monitor any lateral deformation of the fill embankment relative to the underlying rock that may develop as part of LW S1A to S6A mining by providing downhole horizontal displacement data.

The capacity to measure groundwater levels in the embankments is available via two standpipe piezometers installed in upside access road bores at 98.440km and 99.396km. Measurement of groundwater levels would be undertaken during geotechnical inspection with the capability to instal a data logger available if required.

It is noted that planned management and monitoring measures to control risks to the embankments will be continuously reviewed during the extraction of LW S1A to S6A. As each longwall progressively extracts closer to the embankments it will be possible to introduce additional controls if required in the event that unexpected adverse changes are observed.

9.3 Contingency Measures

The embankment management and monitoring controls provide information on key factors related to the embankment condition for track safety and serviceability. The indicators can alert the RMG to changes in the condition of the embankment and to provide early warning of potentially adverse conditions that have the potential to impact track safety and serviceability.

These controls could be activated whether due to subsidence or extreme weather with a series of responses to actual or developing conditions affecting the embankment aimed at maintaining safe and serviceable conditions for rail traffic whilst the changes occur. The implementation of planned responses in relation to embankments can comprise:

- Increased visual surveillance and geotechnical inspection.
- Geotechnical assessment and mapping including subsurface investigation.
- Increased frequency of survey and installation of additional survey marks.
- Installation of targeted instrumentation such as inclinometers, piezometers and extensometers.
- Implementation of planned responses / intervention works.

In the unlikely event that intervention works are required, short term temporary works can be undertaken at track level where access is available along the upside and downside roadways for conventional rail construction plant including excavators, backhoes, rollers and dump trucks together with access for excavator mounted tamping and undercutting equipment. Where access along the existing roads is restricted, hi-rail excavators and dump trucks can be utilised with access to both rail tracks for hi-rail equipment available at upside and downside take off points within the limits of the project. Tahmoor Coal's appointed Rail Maintenance Contractor Bloor Rail has a range of rail construction equipment available to undertake intervention works at short notice.

Planned intervention works that can be undertaken under geotechnical direction include but are not limited to.

- Ballast re-surfacing of the railway track with lifting and tamping to restore track geometry.
- Temporary support of ballast shoulder by placing and compacting additional ballast material.
- Excavation of failed materials and placement of geotextile and rock fill to provide lateral support.
- Excavation of drainage slots (finger drains) and backfilling with ballast.
- Placement of permanent or temporary free draining granular or rock fill to the base of the embankment.
- Installing additional forms of track support under or adjacent to the track as may be appropriate or feasible.
- Additional strengthening of culvert and headwall by props, sleeving or grouting.

A key factor in implementing short notice planned intervention works is the onsite availability of ballast stockpiles, that need to be maintained for the duration of the project.

Upside and downside access along the roadways can be maintained during extreme wet weather conditions as there are no causeway restrictions. Rail operations can be maintained under appropriate controls during the intervention works with a worst case condition involving operation restricted to the opposite track during the works.

The response time to undertake intervention works to a level that facilitates train operations on both tracks is expected to be less than 24 hours, noting that ongoing remedial works adjacent to the track may be required with appropriate track speed restrictions and controls adopted.

Once short term intervention works have been completed to maintain track safety and serviceability, a detailed geotechnical review of site conditions can be undertaken with design of permanent works as required.

Based on the low height of the existing rock cuttings and the wide existing cess clearances from the rail to the cut toes, no specific controls have been nominated for cuttings as the potential for development of adverse conditions that may impact track safety and serviceability is assessed to be remote. In the event that small scale cutting instability involving a soil slip or rock fall occurs into the cess, the likelihood of this fouling the rails is negligible.

Planned intervention works for cuttings can include:

- Clean-up of slip materials from the cess by excavator working from the cutting crest, remote from the track.
- Regrading of cess drains where differential subsidence along the grade of the drain impacts established flow paths and results in ponding water.

10 CONCLUSION

The report has reviewed the pre-condition of rail embankments, culverts and cuttings along the MSR between rail kilometres 97.0 and 101.0 that may be affected by potential impacts as a result of subsidence from the mining of the Southern Domain Longwalls from S1A to S6A. Key findings of the investigation are:

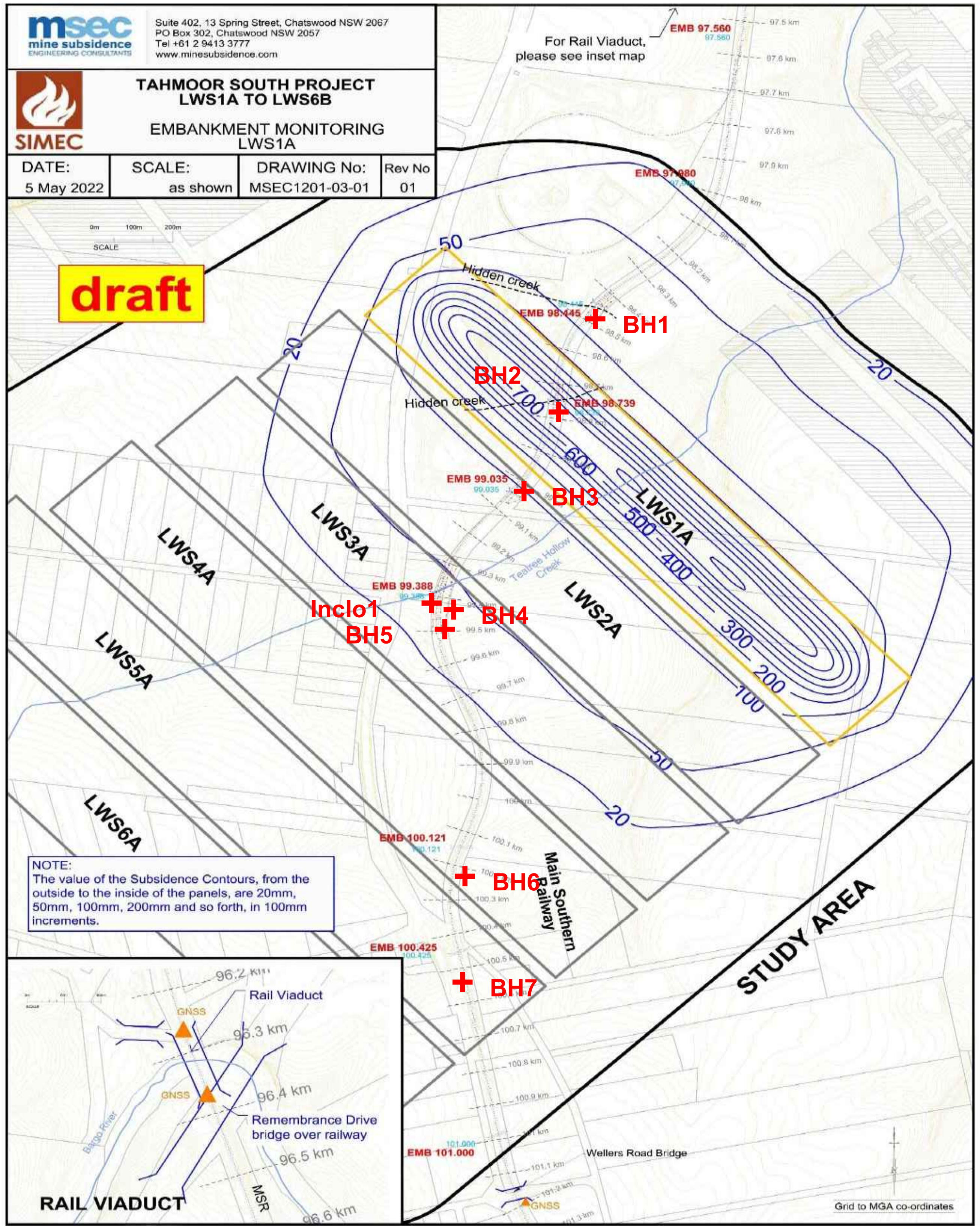
- The existing geotechnical risk level to rail operations based on the ARTC Risk Matrix is assessed as very low to low. This level of risk is usually acceptable to rail operators and regulators and is managed under routine track monitoring and maintenance requirements with no requirement for intervention or remedial works to reduce risk level.
- No evidence of current or past instability or fault structures observed in cuttings with no requirement for any remedial works identified.
- Based on the low height of the rock cuttings and the wide cess clearances from the rail, the potential for development of adverse conditions along the cuttings that has potential to impact track safety and serviceability is assessed to be remote and no specific management and monitoring controls have been recommended for the cuttings.
- The embankments are characterised by access roads along the downside and upside that act as stabilising berms, decreasing the risk of embankment instability impacting the rail. Based on the assessed factors of safety and performance of the embankments, no mitigation work required to strengthen any sections of the embankments prior to the development of subsidence impacts.
- The embankments have maintained an acceptable level of stability and performance over an extended asset timeframe that has incorporated significant rainfall events. Extensive monitoring of MSR embankments undermined by Tahmoor Coal indicates that they are able to tolerate considerable mining-induced ground deformations without experiencing impacts.
- Stability modelling of embankment indicates factors of safety (FoS)of 1.50 or greater for instability affecting the rail formation and 1.27 of greater for instability affecting the access roads. The exception to this is the localised downside culvert washaway at 99.338km where the FoS is 1.20. Reinstatement of the culvert outlet and batter slope at this location is recommended prior to LW W2A.
- The relatively small brick arch culverts are generally founded on or above rock level and across broad rounded drainage paths and as such are less likely to experience significant valley closure impact. Specific mitigation works have been identified for downside culverts at 99.035km (piping hole), 99.388km (reinstatement of pipe extension and batter) and 100.121km (sealing of joint).

Whilst the risk level to embankments, culverts and cuttings from the proposed mining is assessed to be low, appropriate management, monitoring and control measures have been identified together with planned responses and intervention measures in the event that adverse subsidence movements and changes occur. This established subsidence management methodology will be documented in a Subsidence Management Plan for the MSR to be prepared by MSEC for LW S1A to S6A.

Based on performance history and the results of stability assessment, there is sufficient robustness in the current stability of the fill embankments to accommodate the projected subsidence movements and impacts from the extraction of LW S1A to S6A. Planned contingency measures can be effectively implemented in a timely manner to ensure that the embankments remain safe and serviceable even if deviations from the results of the risk assessments and/or uncertainties are identified during the development of subsidence.

Appendix A

Drawings



+ Approximate borehole location Jan 2022

TAHMOOR SOUTH - GEOTECHNICAL ASSESSMENT 97.500KM TO 101.200KM

Feature	Start (km)	End (km)	Length (m)
On grade	97.500	98.000	500
Cutting	98.000	98.260	260
Structure - Conveyor	98.160		
On grade	98.260	98.380	120
Fill embankment	98.380	98.540	160
Borehole 1 (Piezometer)	98.440	Up access road	
Culvert (98.445) - skewed	98.435	98.454 Up	Skew 19m
Cutting	98.540	98.680	140
Fill embankment	98.680	98.780	100
Borehole 2	98.745	Up access road	
Culvert (98.739)	98.739		
Cutting	98.800	98.990	190
Fill embankment	99.000	99.080	80
Borehole 3	99.037	Down main	
Culvert (99.035)	99.035		
Cutting	99.100	99.230	130
Fill embankment	99.230	99.500	270
Inclinometer Inclo1	99.333	Up access road	
Borehole 4	99.338	Down main	
Borehole 5 (Piezometer)	98.396	Up access road	
Culvert (99.338) - skewed	99.340	99.355 Up	Skew 15m
Heritage well downside	99.530		
Cutting	99.500	99.880	380
On grade	99.880	100.030	150
Fill embankment	100.030	100.230	200
Borehole 6	100.143	Up access road	
Culvert (100.121) - skewed	100.127	100.142 Up	Skew 15m
Cutting	100.250	100.370	120
Fill embankment	100.370	100.500	130
Borehole 7	100.429	Down main	
Culvert - skewed	100.422	100.430	8
Cutting	100.500	100.900	400
On grade	100.900	100.970	70
Fill embankment	100.970	101.030	60
Culvert (101.000)	101.000		
On grade	101.030	101.080	50
Cutting	101.080	101.4	320
Structure - Wellers Road	101.162		

Scale	Scale	As shown
	Drawn by	MGD
Revision	Approved by	MGD
	Date	6-Jun-22
	Original size	A3

Newcastle Geotech

Newcastle Geotech Pty Ltd
ABN 55 140 203 247
0428 689 509

Client:	Simec Mining - Tahmoor Coking Coal Operations
Project:	Tahmoor South Project
Location:	Main Southern Rail 97.5km to 101km - Bargo
Title:	Geotechnical Investigation of Embankment and Cutting Stability - Site Plan
Job Number:	493
Drawing No:	GI-1

Appendix B

Engineering logs

Geotechnical Log - Borehole

Newcastle Geotech

Borehole No. 1

Sheet 1 of 1

Client	***Simec Mining - Tahmoor Coal***	Job No.	*493*
Project	***Tahmoor South Project***	Date	*29/01/2022*
Location	***Bargo***	Logged by	*MGD*
Borehole Location	***98.440km Upside access road at toe of ballast***	Checked by	*MGD*

Equipment type & model: Acker RAD - tracked rig Hole diameter (mm): 100 Hole inclination / bearing: vertical

R.L surface: 288.00m AHD Existing access road MGA Co-ordinates: 277141 E 6207087 N

Method	**S**ample Test	Ground-water	Geotechnical Unit	USC	Depth (m)	**Material** soil name, plasticity or particle size, colour, secondary and minor components	Moisture status	Consistency Density	Origin, Structure, Observation
			2C	GC	0.1	**Clayey GRAVEL** - fouled ballast, grey	D		FILL - access road
				CI		**Gravelly CLAY** - medium plasticity, mottled grey	D-M		FILL
AT						and brown, ironstone and siltstone rock fragments,	<Wp		Embankment fill
						subangular up to 40mm in size			
					0.5				
					0.8				
						CLAY - medium plasticity, brown mottled red and	M>	St	
	1				1.0	orange, with some fine to medium grained gravel	Wp		
	SPT								
	2,2,4								
									pp - approx 200kPa
	N=6								
	1.45		**2A**		1.5				
					2.0				
	2.2					Atterberg limits 2.2m - Liquid limit 35%	MC%		
	D					Plasticity index 19%, Linear shrinkage 9.5%	17.4		
	2.3								
	2.5				2.5				
	SPT								
	3,2,3								pp - approx 150kPa
					2.8				
	N=5			SC		**Clayey SAND** - fine to medium grained, grey,	M-W		
	2.95				3.0	trace fine to medium ironstone gravel,			
						estimated 30-40% clay			
	3.2		**2B**						
	D					Atterberg limits 3.2m - Liquid limit 20%	MC%		
						Plasticity index 8%, Linear shrinkage 5%	15.8		
	3.4				3.5 3.5	Particle size - Gravel 7%, Sand 61%, Clay / Silt 32%			
				CI-		**CLAY** - medium to high plasticity, brown mottled,	M=		
				CH		orange wth some fine to medium subangular ironstone	Wp		
						and silstone gravel			
	4		**2A**		4.0				
	SPT								
	3,3,5					Atterberg limits 4m - Liquid limit 54%	MC%		
						Plasticity index 33%, Linear shrinkage 13%	23.8		pp - approx 250kPa
	N=8								
	2.95				4.5 4.5	Base of fill			
				SC		**Clayey SAND** - fine to medium grained, grey and	M-W		ALLUVIUM
		29.1.22	**3**			brown, estimated 30-40% clay			
		▼							Groundwater level
		4.8			4.9				4.8m 29/1/2022
			4A	CI	5.0	**SANDY CLAY** - refer sheet 2	M	St	RESIDUAL

Method

HA	Hand auger
AV	Auger V bit drilling
AT	Auger TC bit drilling
RR	Roller tricone drilling
M,C	Mud, Casing support
NMLC	Rock coring

Samples / Tests

U_{50}	Undisturbed tube (50mm)
D	Disturbed sample
Bs	Bulk sample
SPT	Standard penetration test
N	SPT blow count / 300mm
E	Environmental sample

Moisture

D	dry
M	moist
W	wet
Wp	plastic limit
LL	liquid limit
OMC	optimum moisture content (std)

Groundwater

Groundwater level (time of drilling or date) ▼

Inflow / seepage ▶

Consistency

VS	very soft
S	soft
F	firm
St	stiff
Vst	very stiff
H	hard

Density

VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

Geotechnical Log - Borehole

Borehole No. 1

Sheet 2 of 2

Newcastle Geotech

Client	***Simec Mining - Tahmoor Coal***	Job No.	*493*
Project	***Tahmoor South Project***	Date	*29/01/2022*
Location	***Bargo***	Logged by	*MGD*
Borehole Location	***98.440km Upside access road at toe of ballast***	Checked by	*MGD*

Equipment type & model: Acker RAD - tracked rig | Hole diameter (mm): 100 | Hole inclination / bearing: vertical

R.L surface: 288.00m AHD Existing access road | MGA Co-ordinates: 277141 E 6207087 N

Method	Sample Test	Ground-water	Geotechnical Unit	USC	Depth (m)	**Material** soil name, plasiticity or particle size, colour, secondary and minor components	Moisture status	Consistency Density	Origin, Structure, Observation
	5 D		4A	CI		**SANDY CLAY** - medium plasticity, mottled grey, red / brown and orange, fine to medium grained sand, estimated 40% sand content	M > Wp	St	RESIDUAL
AT	5.2								
	5.5				5.5	Particle size - Gravel 1%, Sand 68%, Clay / Silt 31%			
	SPT 5,4,10 R N>14				5.8	Atterberg limits 5m - Liquid limit 26% Plasticity index 12%, Linear shrinkage 7%	MC% 23		
	5.8		5			**SANDSTONE** - fine to medium grained, red / brown and orange, extremely to highly weathered	D - M		ROCK Estimated very low strength
					6.0				
					6.4				
					6.5	End of borehole at 6.0m approaching auger refusal on rock			
					7.0	**STANDPIPE PIEZOMETER** 50mm PVC installed to 6.1m Slotted 3.1m to 6.1m			
					7.5	Gattic cover concreted flush with access road level Water level 4.8m 29/1/2022			
					8.0				
					8.5				
					9.0				
					9.5				
					10				

Method		**Samples / Tests**		**Moisture**		**Groundwater**		**Consistency**		**Density**	
HA	Hand auger	U_{50}	Undisturbed tube (50mm)	D	dry	Groundwater level	▼	VS	very soft	VL	very loose
AV	Auger V bit drilling	D	Disturbed sample	M	moist	(time of drilling or date)		S	soft	L	loose
AT	Auger TC bit drilling	Bs	Bulk sample	W	wet	Inflow / seepage	▶	F	firm	MD	medium dense
RR	Roller tricone drilling	SPT	Standard penetration test	Wp	plastic limit			St	stiff	D	dense
M,C	Mud, Casing support	N	SPT blow count / 300mm	LL	liquid limit			Vst	very stiff	VD	very dense
NMLC	Rock coring	E	Environmental sample	OMC	optimum moisture content (std)			H	hard		

Geotechnical Log - Borehole

Borehole No. 2

Sheet 1 of 1

Newcastle Geotech

Client	*Simec Mining - Tahmoor Coal*	Job No.	*493*
Project	*Tahmoor South Project*	Date	*29/01/2022*
Location	*Bargo*	Logged by	*MGD*
Borehole Location	*98.745km Upside access road at toe of ballast*	Checked by	*MGD*

Equipment type & model: Acker RAD - tracked rig | Hole diameter (mm): 100 | Hole inclination / bearing: vertical

R.L surface: 291.72m AHD Existing access road | MGA Co-ordinates: 277028 E 6206808 N

Method	**S**ample Test	Ground-water	Geotechnical Unit	USC	Depth (m)	**Material** soil name, plasticity or particle size, colour, secondary and minor components	Moisture status	Consistency Density	Origin, Structure, Observation
AT		None encountered	2C	GC	0.1	**Clayey GRAVEL** - fouled ballast, grey	D		FILL - access road
	1 SPT 3,3,3 N=6 1.45		2A	CI	0.5 1.0 1.5 2.0 2.5 2.5	**Sandy CLAY** - medium plasticity, mottled orange light grey and brown, fine to medium sand (estimated 25%), with some weathered sandstone rock fragments	D-M <Wp M> Wp M> Wp	Vst St St	FILL Embankment fill
	2.5 SPT 2,2,2 N=4 2.95		4B	SC	3.0 3.0	**Clayey SAND** - fine to medium grained, orange and brown, estimated 30% clay, trace of ironstone gravel up to 10mm	M-W		RESIDUAL
			5		3.5 3.5	**SANDSTONE** - fine to medium grained, brown, orange and light grey, extremely to highly weathered becoming highly to moderately weathered End of borehole at 3.5m	D- M		ROCK Estimated very low strength
					4.0 4.5 5.0	End of borehole at 3.5m			

Method

HA	Hand auger
AV	Auger V bit drilling
AT	Auger TC bit drilling
RR	Roller tricone drilling
M,C	Mud, Casing support
NMLC	Rock coring

Samples / Tests

U_{50}	Undisturbed tube (50mm)
D	Disturbed sample
Bs	Bulk sample
SPT	Standard penetration test
N	SPT blow count / 300mm
E	Environmental sample

Moisture

D	dry
M	moist
W	wet
Wp	plastic limit
LL	liquid limit
OMC	optimum moisture content (std)

Groundwater

Groundwater level ▼ (time of drilling or date)

Inflow / seepage ▶

Consistency

VS	very soft
S	soft
F	firm
St	stiff
Vst	very stiff
H	hard

Density

VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

Geotechnical Log - Borehole

Borehole No. 3

Sheet 1 of 2

Client	***Simec Mining - Tahmoor Coal***	Job No.	*493*
Project	***Tahmoor South Project***	Date	*29/01/2022*
Location	***Bargo***	Logged by	*MGD*
Borehole Location	***99.037km Down Main four foot***	Checked by	*MGD*

Equipment type & model: Acker RAD - tracked rig Hole diameter (mm): 100 Hole inclination / bearing: vertical

R.L surface: 296.10m AHD top of sleeper level MGA Co-ordinates: 276924 E 6206535 N

Method	Sample Test	Ground-water	Geotechnical Unit	USC	Depth (m)	**Material** soil name, plasticity or particle size, colour, secondary and minor components	Moisture status	Consistency Density	Origin, Structure, Observation
			1A	GM -		**BALLAST - Sandy GRAVEL** - medium to coarse	D		TRACK FORMATION
				GP		grained subangular basalt gravel, grey and dark grey			
AT						with some silt and clay fines,			Ballast highly
									fouled
					0.5		M		
		None encountered							Formation
						Depth of ballast and presence of capping and			
						structural fill layers difficult to determine from			
					1.0 1.0	auger - profile to be confirmed by test pits			
			2A	CI		**Sandy CLAY** - medium plasticity, mottled orange	D-M	Vst	FILL
						light grey and brown, fine to medium sand	<Wp		Embankment fill
						(estimated 40-50%), with some weathered			
						sandstone rock fragments			
	1.5				1.5	Some **Clayey SAND** zones present			
	SPT								
	2,4,4					Note: Size of sandstone rock fragments not			
						determined from auger drilling, with sandstone gravel			
	N=8					and cobbles likely to be present			
	1.95				2.0				
	2.2					Atterberg limits 2.2m - Liquid limit 25%	MC%		
	D					Plasticity index 13%, Linear shrinkage 6.5%	12		
	2.3					Particle size - Gravel 5%, Sand 65%, Clay / Silt 30%			
	2.5				2.5 2.5				
	SPT		**2B**	SC		**Gravelly Clayey SAND** - fine to medium grained,	M		
	3,3,3					mottled orange / brown, grey and yellow / brown,			
						estimated 30-40% clay, weatherd sandstone rock			
	N=6					fragments up to 50mm and potentially larger			
	2.95				3.0				
					3.5				
						3.5m harder drilling - sandstone cobble / boulder?			
	4				4.0				
	SPT					4m harder drilling - sandstone cobble / boulder?			
	3,4,5								
				CI		Some Sandy CLAY layers, medium plasticity, brown			
	N=9					estimated 30-40% sand, some siltstone rock			
	4.45				4.5	fragments			
					4.8				
			4B	SC		**Clayey SAND** - fine to medium grained, grey and	M-W		RESIDUAL
					5.0	grey / brown, estimated 30% clay			

Method

HA	Hand auger
AV	Auger V bit drilling
AT	Auger TC bit drilling
RR	Roller tricone drilling
M,C	Mud, Casing support
NMLC	Rock coring

Samples / Tests

U_{50}	Undisturbed tube (50mm)
D	Disturbed sample
Bs	Bulk sample
SPT	Standard penetration test
N	SPT blow count / 300mm
E	Environmental sample

Moisture

D	dry
M	moist
W	wet
Wp	plastic limit
LL	liquid limit
OMC	optimum moisture content (std)

Groundwater

Groundwater level ▼
(time of drilling or date)
Inflow / seepage ►

Consistency

VS	very soft
S	soft
F	firm
St	stiff
Vst	very stiff
H	hard

Density

VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

Geotechnical Log - Borehole

Borehole No. 3

Sheet 2 of 2

Newcastle Geotech

Client	***Simec Mining - Tahmoor Coal***	Job No.	*493*
Project	***Tahmoor South Project***	Date	*29/01/2022*
Location	***Bargo***	Logged by	*MGD*
Borehole Location	***99.037km Down Main four foot***	Checked by	*MGD*

Equipment type & model: Acker RAD - tracked rig Hole diameter (mm): 100 Hole inclination / bearing: vertical

R.L surface: 296.10m AHD top of sleeper level MGA Co-ordinates: 276924 E 6206535 N

Method	**S**ample Test	Ground-water	Geotechnical Unit	USC	Depth (m)	**Material** soil name, plasticity or particle size, colour, secondary and minor components	Moisture status	Consistency Density	Origin, Structure, Observation
	5.1			SC		**Clayey SAND** - fine to medium grained, grey and	M-W		RESIDUAL
	D					grey / brown, estimated 30% clay, trace of ironstone	MC%		Particle size 5.1m
AT	5.2		4B			gravel up to 10mm	20.5		Gravel 7%
									Sand 61%
	5.5				5.5 5.5				Clay / Silt 32%
	SPT					**SANDSTONE** - fine to medium grained, brown**,** orange	D-		ROCK
	5.6		**5**			and light grey, highly weathered	M		Estimated low
	15 R								strength
					5.9	becoming moderately weathered, est medium strength			
					6.0				
					6.5	End of borehole at 5.9m approaching auger refusal on rock			
					7.0				
					7.5				
					8.0				
					8.5				
					9.0				
					9.5				
					10				

Method		**Samples / Tests**	
HA	Hand auger	U_{50}	Undisturbed tube (50mm)
AV	Auger V bit drilling	D	Disturbed sample
AT	Auger TC bit drilling	Bs	Bulk sample
RR	Roller tricone drilling	SPT	Standard penetration test
M,C	Mud, Casing support	N	SPT blow count / 300mm
NMLC	Rock coring	E	Environmental sample

Moisture		**Groundwater**	
D	dry	Groundwater level	▼
M	moist	(time of drilling or date)	
W	wet	Inflow / seepage	►
Wp	plastic limit		
LL	liquid limit		
OMC	optimum moisture content (std)		

Consistency		**Density**	
VS	very soft	VL	very loose
S	soft	L	loose
F	firm	MD	medium dense
St	stiff	D	dense
Vst	very stiff	VD	very dense
H	hard		

Geotechnical Log - Borehole

Newcastle Geotech

Borehole No. 1

Sheet 1 of 2

Client	***Simec Mining - Tahmoor Coal***	Job No.	*493*
Project	***Tahmoor South Project***	Date	*29/01/2022*
Location	***Bargo***	Logged by	*MGD*
Borehole Location	***99.338km Down Main four foot***	Checked by	*MGD*

Equipment type & model: Acker RAD - tracked rig
Hole diameter (mm): 100
Hole inclination / bearing: vertical

R.L surface: Existing top of sleeper level
MGA Co-ordinates: 276757 E 6206294 N

Method	**S**ample Test	Ground-water	Geotechnical Unit	USC	Depth (m)	**Material** soil name, plasticity or particle size, colour, secondary and minor components	Moisture status	Consistency Density	Origin, Structure, Observation
				GM -		**BALLAST - Sandy GRAVEL** - medium to coarse	D		TRACK FORMATION
				GP		grained subangular basalt gravel, grey and dark grey			
AT						with some silt and clay fines,			Ballast highly
									fouled
			1A		0.5		M		
						Depth of ballast and presence of capping and			Formation
						structural fill layers difficult to determine from			
					0.9	auger - profile to be confirmed by test pits			
				CI	1.0	**Gravelly Sandy CLAY / Gravelly Clayey SAN**	M ≤	St-	FILL
				SC		medium plasticity, fine to medium sand,	Wp	Vst	Embankment fill
	1.1					mottled light grey, orange and brown,			
	SPT					weathered sandstone rock fragments up to	MC%		Particle size 5.1m
	8,8,7		**2A - 2B**			50mm size or greater	10.4		Gravel 33%
					1.5				Sand 37%
	N=15								Clay / Silt 30%
	1.55								
					2.0 2.0				
				CI		**Gravelly Sandy CLAY** - medium plasticity, light grey	M <	Vst	
						mottled orange, fine to medium sand, siltstone and	Wp		
						sandstone rock fragments up to 50mm size or greater			
						estimated 40-50% sand and gravel content			
	2.5				2.5				
	SPT								
	4,6,6					Atterberg limits 2.5m - Liquid limit 27%	MC%		
						Plasticity index 12%, Linear shrinkage 6.5%	9.4		
	N=12								
	2.95				3.0				
			2A		3.5				
	4				4.0				
	SPT								
	5,6,7						MC%		
							8.1		
	N=13								
	4.45				4.5				
							M ≤	Vst	
							Wp		
						4.9m harder drilling - sandstone cobble / boulder?			
					5.0				

Method

HA	Hand auger
AV	Auger V bit drilling
AT	Auger TC bit drilling
RR	Roller tricone drilling
M,C	Mud, Casing support
NMLC	Rock coring

Samples / Tests

U_{50}	Undisturbed tube (50mm)
D	Disturbed sample
Bs	Bulk sample
SPT	Standard penetration test
N	SPT blow count / 300mm
E	Environmental sample

Moisture

D	dry
M	moist
W	wet
Wp	plastic limit
LL	liquid limit
OMC	optimum moisture content (std)

Groundwater

Groundwater level ▼
(time of drilling or date)
Inflow / seepage ►

Consistency

VS	very soft
S	soft
F	firm
St	stiff
Vst	very stiff
H	hard

Density

VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

Geotechnical Log - Borehole

Borehole No. 4 Sheet 2 of 2

Newcastle Geotech

Client	*Simec Mining - Tahmoor Coal*	Job No.	*493*
Project	*Tahmoor South Project*	Date	*29/01/2022*
Location	*Bargo*	Logged by	*MGD*
Borehole Location	*99.338km Down Main four foot*	Checked by	*MGD*

Equipment type & model: Acker RAD - tracked rig Hole diameter (mm): 100 Hole inclination / bearing: vertical

R.L surface: Existing top of sleeper level MGA Co-ordinates: 276757 E 6206294 N

Method	**S**ample Test	Ground-water	Geotechnical Unit	USC	Depth (m)	**Material** soil name, plasticity or particle size, colour, secondary and minor components	Moisture status	Consistency Density	Origin, Structure, Observation
			2A	CI	5.2	**Gravelly Sandy CLAY** - as above	M = Wp		FILL
AT	5.5 SPT 3,4,7 N=11 5.95		**4A**	CI	5.5 5.8	**SANDY CLAY** - medium plasticity, mottled red / brown, and orange, fine to medium grained sand, estimated 30-40% sand content	M ≥ Wp	St	RESIDUAL
			5		6.0	**SANDSTONE** - fine to medium grained, white and pale grey mottled orange, with some clayey zones / seams extremely to highly weathered	M		ROCK Estimated very low srtrength
					6.5	becoming orange / brown mottled red with some harder ironstone bands			
		29.1.22 ▼ 6.8							Groundwater level 6.8m 29/1/2022
	7 SPT 10 R 7.05				7.0 7.05	End of borehole at 7.05m			
					7.5				
					8.0				
					8.5				
					9.0				
					9.5				
					10				

Method

HA	Hand auger
AV	Auger V bit drilling
AT	Auger TC bit drilling
RR	Roller tricone drilling
M,C	Mud, Casing support
NMLC	Rock coring

Samples / Tests

U_{50}	Undisturbed tube (50mm)
D	Disturbed sample
Bs	Bulk sample
SPT	Standard penetration test
N	SPT blow count / 300mm
E	Environmental sample

Moisture

D	dry
M	moist
W	wet
Wp	plastic limit
LL	liquid limit
OMC	optimum moisture content (std)

Groundwater

Groundwater level (time of drilling or date)	▼
Inflow / seepage	►

Consistency

VS	very soft
S	soft
F	firm
St	stiff
Vst	very stiff
H	hard

Density

VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

Geotechnical Log - Borehole

Newcastle Geotech

Borehole No. 5

Sheet 1 of 2

Client	***Simec Mining - Tahmoor Coal***	Job No.	*493*
Project	***Tahmoor South Project***	Date	*30/01/2022*
Location	***Bargo***	Logged by	*MGD*
Borehole Location	***99.396km Upside access road at toe of ballast***	Checked by	*MGD*

Equipment type & model: Acker RAD - tracked rig Hole diameter (mm): 100 Hole inclination / bearing: vertical

R.L surface: Existing access road MGA Co-ordinates: 276735 E 6206243 N

Method	Sample Test	Ground-water	Geotechnical Unit	USC	Depth (m)	**Material** soil name, plasticity or particle size, colour, secondary and minor components	Moisture status	Consistency Density	Origin, Structure, Observation
			2C	GC		**Clayey GRAVEL** - fine to coarse gravel, grey / brown			FILL
					0.2	in a clayey matrix			Access road
AT				CI		**Sandy Gravelly CLAY** - medium plasticity, brown	M <	Vst	FILL
						mottled light grey and red, fine to coarse subangular	Wp		Embankment fill
					0.5	siltstone and sandstone rock fragments up to 50mm			
						size or greater, fine to medium sand			
	1				1.0				
	SPT		**2A**				M ≥	St	
	3,3,3						Wp		Particle size 1.1m
							MC%		Gravel 42%
	N=6						13.2		Sand 26%
	1.45				1.5				Clay / Silt 32%
	2				2.0 2.0				
				CI		**Sandy Gravelly CLAY** - medium plasticity, grey /			Particle size 2m
	D					brown, fine to coarse subrounded sandstone	MC%		Gravel 12%
						rock fragments up to 50mm size or greater	16		Sand 44%
	2.3					fine to medium sand			Clay / Silt 46%
	2.5				2.5	Atterberg limits 2.2m - Liquid limit 26%			
	SPT					Plasticity index 11%, Linear shrinkage 6.5%			
	3,3,2						M=	St	
							Wp		
	N=5								pp - approx 250kPa
	2.95				3.0				
						3 - 3.3m harder drilling - sandstone cobble / boulder?			
	3.5		**2A**		3.5				
	D								Particle size 3.5m
						Atterberg limits 3.5m - Liquid limit 39%	MC%		Gravel 30%
	3.7					Plasticity index 24%, Linear shrinkage 11.5%	16.2		Sand 20%
									Clay / Silt 40%
	4				4.0				
	SPT								
	2,2,3								
	N=5								
	4.45				4.5				
		28.3.22					M ≥	St	
		▼					Wp		Groundwater level
		4.7							4.7m 28/3/2022
									after 500mm rain
					5.0 5.0	Base of fill at 5m			23/2-28/3/2022

Method		**Samples / Tests**		**Moisture**		**Groundwater**		**Consistency**		**Density**	
HA	Hand auger	U_{50}	Undisturbed tube (50mm)	D	dry	Groundwater level	▼	VS	very soft	VL	very loose
AV	Auger V bit drilling	D	Disturbed sample	M	moist	(time of drilling or date)		S	soft	L	loose
AT	Auger TC bit drilling	Bs	Bulk sample	W	wet	Inflow / seepage	►	F	firm	MD	medium dense
RR	Roller tricone drilling	SPT	Standard penetration test	Wp	plastic limit			St	stiff	D	dense
M,C	Mud, Casing support	N	SPT blow count / 300mm	LL	liquid limit			Vst	very stiff	VD	very dense
NMLC	Rock coring	E	Environmental sample	OMC	optimum moisture content (std)			H	hard		

Geotechnical Log - Borehole

Borehole No. 5

Sheet 2 of 2

Client	***Simec Mining - Tahmoor Coal***	Job No.	*493*
Project	***Tahmoor South Project***	Date	*30/01/2022*
Location	***Bargo***	Logged by	*MGD*
Borehole Location	***98.440km Upside access road at toe of ballast***	Checked by	*MGD*

Equipment type & model: Acker RAD - tracked rig | Hole diameter (mm): 100 | Hole inclination / bearing: vertical

R.L surface: Existing access road | MGA Co-ordinates: 277141 E 6207087 N

Method	Sample Test	Ground-water	Geotechnical Unit	USC	Depth (m)	Material soil name, plasticity or particle size, colour, secondary and minor components	Moisture status	Consistency Density	Origin, Structure, Observation
		▼ 5.1 30.1.22	3	SC	5.0 5.2	**Clayey SAND** - fine to medium grained, dark grey / grey, estimated 30% clay	M-W		ALLUVIUM
AT	5.5		4A	CI	5.5 5.5	**SANDY CLAY** - medium plasticity, brown, fine to medium grained sand (residual sandstone)	M > Wp	St	RESIDUAL
	SPT 3,6,11 N=17 5.95		4A	CI-CH	6.0 6.0	**CLAY** - medium to high plasticity, light grey mottled orange and red, trace of sand and fine to medium igrained ironstone gravel (residual siltstone / shale)	M ≤ Wp MC% 24.7	Vst	RESIDUAL Atterberg limits 5.5m Liquid limit 67% Plasticity index 44% Linear shrink 15%
			5		6.5 7.0 7.0	**SANDSTONE** - fine to medium grained, brown and orange, extremely to highly weathered	D-M		ROCK Estimated low strength
						End of borehole at 7.0m			

STANDPIPE PIEZOMETER
50mm PVC installed to 6.8m
Slotted 3.8m to 6.8m
Gattic cover concreted flush with access road level
Water level 5.1m 29/1/2022 and 4.8m 28/3/2022

10

Method		Samples / Tests		Moisture		Groundwater	
HA	Hand auger	U_{50}	Undisturbed tube (50mm)	D	dry	Groundwater level	▼
AV	Auger V bit drilling	D	Disturbed sample	M	moist	(time of drilling or date)	
AT	Auger TC bit drilling	Bs	Bulk sample	W	wet	Inflow / seepage	►
RR	Roller tricone drilling	SPT	Standard penetration test	Wp	plastic limit		
M,C	Mud, Casing support	N	SPT blow count / 300mm	LL	liquid limit		
NMLC	Rock coring	E	Environmental sample	OMC	optimum moisture content (std)		

Consistency		Density	
VS	very soft	VL	very loose
S	soft	L	loose
F	firm	MD	medium dense
St	stiff	D	dense
Vst	very stiff	VD	very dense
H	hard		

Geotechnical Log - Borehole

Newcastle Geotech

Borehole No. 6

Sheet 1 of 2

Client	*Simec Mining - Tahmoor Coal*	Job No.	*493*
Project	*Tahmoor South Project*	Date	*30/01/2022*
Location	*Bargo*	Logged by	*MGD*
Borehole Location	*100.143km Upside access road at toe of ballast*	Checked by	*MGD*

Equipment type & model: Acker RAD - tracked rig Hole diameter (mm): 100 Hole inclination / bearing: vertical

R.L surface: Existing access road MGA Co-ordinates: 276793 E 6205520 N

Method	Sample Test	Ground-water	Geotechnical Unit	USC	Depth (m)	Material soil name, plasticity or particle size, colour, secondary and minor components	Moisture status	Consistency Density	Origin, Structure, Observation
			2C	GC	0.1	**Clayey GRAVEL** - fouled ballast and clay, grey/brown	D		FILL - access road
AT	0.5 D 0.8 1 SPT 2,2,3 N=5 1.45		2A	CI	0.5 1.0 1.5	**Gravelly CLAY** - medium plasticity, brown mottled orange and red, fine to coarse siltstone and sandstone rock fragments, subangular up to 50mm in size or greater, trace of sandstone cobbles to 100mm with some sand	D-M M > Wp	Vst St	FILL Embankment fill
	2.5 SPT 2,2,4 N=6 2.95				2.0 2.5 3.0 3.1	Some **Sandy Gravelly CLAY** layers with increased sand content			
			2A	CI	3.5 3.7	**CLAY** - medium plasticity, orange / brown mottled red and light grey, with some fine to medium sand and fine to coarse sandstone gravel	M > Wp	St	
	4 SPT 2,2,3 N=5 4.45		2A	CI	4.0 4.5 4.7	**Gravelly CLAY** - medium plasticity, brown mottled orange and red, fine to coarse siltstone and sandstone rock fragments, subangular up to 50mm in size or greater			
		30.1.22 5.0 ▼	3	SC	5.0 5.0	**Clayey SAND** - fine to medium grained, dark grey / grey, estimated 30-40% clay	M-W		ALLUVIUM Groundwater level 5.0m 30/1/2022

Method

HA	Hand auger
AV	Auger V bit drilling
AT	Auger TC bit drilling
RR	Roller tricone drilling
M,C	Mud, Casing support
NMLC	Rock coring

Samples / Tests

U_{50}	Undisturbed tube (50mm)
D	Disturbed sample
Bs	Bulk sample
SPT	Standard penetration test
N	SPT blow count / 300mm
E	Environmental sample

Moisture

D	dry
M	moist
W	wet
Wp	plastic limit
LL	liquid limit
OMC	optimum moisture content (std)

Groundwater

Groundwater level (time of drilling or date) ▼

Inflow / seepage ►

Consistency

VS	very soft
S	soft
F	firm
St	stiff
Vst	very stiff
H	hard

Density

VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

Geotechnical Log - Borehole

Borehole No. 6 Sheet 2 of 2

Newcastle Geotech

Client	*Simec Mining - Tahmoor Coal*	Job No.	*493*
Project	*Tahmoor South Project*	Date	*30/01/2022*
Location	*Bargo*	Logged by	*MGD*
Borehole Location	*100.143km Upside access road at toe of ballast*	Checked by	*MGD*

Equipment type & model: Acker RAD - tracked rig Hole diameter (mm): 100 Hole inclination / bearing: vertical

R.L surface: Existing access road MGA Co-ordinates: 276793 E 6205520 N

Method	Sample Test	Ground-water	Geotechnical Unit	USC	Depth (m)	Material soil name, plasticity or particle size, colour, secondary and minor components	Moisture status	Consistency Density	Origin, Structure, Observation
AT			4A	CI	5.0	**SANDY CLAY** - medium plasticity, brown, fine to medium grained sand (estimated 30-40%)	M > Wp	St	RESIDUAL
	5.5 SPT 20 R 5.6		5		5.5	**SANDSTONE** - fine to medium grained, grey, red and orange, extremely to highly weathered	D-M		ROCK Estimated low strength
					6.0	End of borehole at 6.0m			
					6.5				
					7.0				
					7.5				
					8.0				
					8.5				
					9.0				
					9.5				
					10				

Method
- HA Hand auger
- AV Auger V bit drilling
- AT Auger TC bit drilling
- RR Roller tricone drilling
- M,C Mud, Casing support
- NMLC Rock coring

Samples / Tests
- U_{50} Undisturbed tube (50mm)
- D Disturbed sample
- Bs Bulk sample
- SPT Standard penetration test
- N SPT blow count / 300mm
- E Environmental sample

Moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- LL liquid limit
- OMC optimum moisture content (std)

Groundwater
- Groundwater level ▼ (time of drilling or date)
- Inflow / seepage ▶

Consistency
- VS very soft
- S soft
- F firm
- St stiff
- Vst very stiff
- H hard

Density
- VL very loose
- L loose
- MD medium dense
- D dense
- VD very dense

Geotechnical Log - Borehole

Borehole No. 7

Sheet 1 of 2

Newcastle Geotech

Client	***Simec Mining - Tahmoor Coal***	Job No.	*493*
Project	***Tahmoor South Project***	Date	*30/01/2022*
Location	***Bargo***	Logged by	*MGD*
Borehole Location	***100.429km Down Main four foot***	Checked by	*MGD*

Equipment type & model: Acker RAD - tracked rig   Hole diameter (mm): 100   Hole inclination / bearing: vertical

R.L surface: Existing top of sleeper level   MGA Co-ordinates: 276790 E 6205240 N

Method	**S**ample Test	Ground-water	Geotechnical Unit	USC	Depth (m)	**Material** soil name, plasticity or particle size, colour, secondary and minor components	Moisture status	Consistency Density	Origin, Structure, Observation
				GM-		**BALLAST - Sandy GRAVEL** - medium to coarse	D		TRACK FORMATION
				GP		grained subangular basalt gravel, grey and dark grey			
AT						with some silt and clay fines,			Ballast highly
									fouled
					0.5		D-M		
			1A						
						Depth of ballast and presence of capping and			
						structural fill layers difficult to determine from			
						auger - profile to be confirmed by test pits			
	1				1.0				
	SPT				1.1				
	8,13,15			GP		**Sandy GRAVEL** - fine to coarse subangular	M		Formation
			1B			quartzose (sandstone) gravel, white, with some			Capping?
	N=28				1.4	clay fines			
	1.45			CI	1.5	**Sandy Gravelly CLAY** - medium plasticity, brown	M ≤	St-	FILL
						mottled light grey, fine to coarse subangular	Wp	Vst	Embankment fill
						sandstone rock fragments up to 50mm or greater			
						fine to medium sand			
					2.0				
	2.5				2.5				
	SPT						M ≥	St	
	2,3,4 No sample						Wp		
	N=7								
	2.95				3.0				
			2A						
					3.5				
					4.0				
	4.5				4.5				
						Atterberg limits 4.5m - Liquid limit 38%	MC%		
	D					Plasticity index 21%, Linear shrinkage 10%	23.8		
	5				5.0				

Method		**Samples / Tests**		**Moisture**		**Groundwater**		**Consistency**		**Density**	
HA	Hand auger	U_{50}	Undisturbed tube (50mm)	D	dry	Groundwater level	▼	VS	very soft	VL	very loose
AV	Auger V bit drilling	D	Disturbed sample	M	moist	(time of drilling or date)		S	soft	L	loose
AT	Auger TC bit drilling	Bs	Bulk sample	W	wet	Inflow / seepage	►	F	firm	MD	medium dense
RR	Roller tricone drilling	SPT	Standard penetration test	Wp	plastic limit			St	stiff	D	dense
M,C	Mud, Casing support	N	SPT blow count / 300mm	LL	liquid limit			Vst	very stiff	VD	very dense
NMLC	Rock coring	E	Environmental sample	OMC	optimum moisture content (std)			H	hard		

Geotechnical Log - Borehole

Borehole No. 7

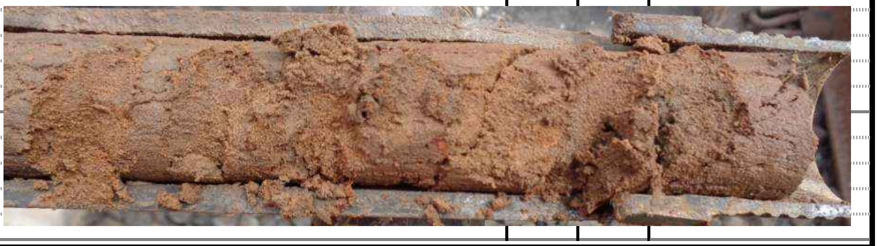
Sheet 2 of 2

Newcastle Geotech

Client	*Simec Mining - Tahmoor Coal*	Job No.	*493*
Project	*Tahmoor South Project*	Date	*30/01/2022*
Location	*Bargo*	Logged by	*MGD*
Borehole Location	*100.429km Down Main four foot*	Checked by	*MGD*

Equipment type & model:	Acker RAD - tracked rig	Hole diameter (mm):	100	Hole inclination / bearing:	vertical
R.L surface:	Existing top of sleeper level	MGA Co-ordinates:	276790 E	6205240 N	

Method	Sample Test	Ground-water	Geotechnical Unit	USC	Depth (m)	**Material** soil name, plasticity or particle size, colour, secondary and minor components	Moisture status	Consistency Density	Origin, Structure, Observation
AT			2A	CI	5.3	**Sandy Gravelly CLAY** -as above	M > Wp	St	FILL
	5.5		3	SC	5.5 5.5	**Clayey SAND** - fine to medium grained, dark grey / grey, estimated 30-40% clay	M-W		ALLUVIUM
	SPT 3,6,9 N=15 5.95	30.1.22 ▼ 5.9	4B	CI	6.0 6.5 6.6	**Clayey SAND** - fine to medium grained, brown mottled orange, trace of weathered sandstone rock fragments and ironstone gravel up to 20mm Estimated 15-20% clay content Particle size 5.5m Gravel 14%, Sand 73%, Clay / Silt 13%	M		RESIDUAL Groundwater level 59m 30/1/2022
			5		7.0 7.0	**SANDSTONE** - fine to medium grained, grey, red and orange, extremely to highly weathered	D-M		ROCK Estimated low strength
					7.5 8.0 8.5 9.0 9.5 10	End of borehole at 7.0			



Method		Samples / Tests		Moisture		Groundwater		Consistency		Density	
HA	Hand auger	U_{50}	Undisturbed tube (50mm)	D	dry	Groundwater level	▼	VS	very soft	VL	very loose
AV	Auger V bit drilling	D	Disturbed sample	M	moist	(time of drilling or date)		S	soft	L	loose
AT	Auger TC bit drilling	Bs	Bulk sample	W	wet	Inflow / seepage	▶	F	firm	MD	medium dense
RR	Roller tricone drilling	SPT	Standard penetration test	Wp	plastic limit			St	stiff	D	dense
M,C	Mud, Casing support	N	SPT blow count / 300mm	LL	liquid limit			Vst	very stiff	VD	very dense
NMLC	Rock coring	E	Environmental sample	OMC	optimum moisture content (std)			H	hard		

Appendix C

Laboratory Results

QUALTEST Laboratory (NSW) Pty Ltd (20708)
2 Murray Dwyer Circuit, Mayfield West, NSW 2304
T: 02 4968 4468
F: 02 4960 9775
E: admin@qualtest.com.au
W: www.qualtest.com.au
ABN: 98 153 268 896

Material Test Report

Report No: MAT:NEW22W-0631-S01
Issue No: 1

Client:	Newcastle Geotech 188 The Weir Rd Teralba NSW 2284
Project No.:	13/00060
Project Name:	Various Material Testing
Project Location:	Bargo, NSW

Accredited for compliance with ISO/IEC 17025-Testing.
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
Results provided relate only to the items tested or sampled.

Approved Signatory: Dane Cullen
(Senior Geotechnician)
NATA Accredited Laboratory Number: 18686
Date of Issue: 29/03/2022

Sample Details

Sample ID:	NEW22W-0631-S01
Date Sampled:	29/01/2022
Date Received:	02/03/2022
Source:	On-Site Insitu
Material:	Clay
Specification:	No Specification The results outlined below apply to the sample as received
TRN:	493
Sample Location:	BH1 - (2.2 - 2.3m)

Test Results

Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	17.4	
Date Tested		11/03/2022	
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	9.5	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Cracking		No	
Liquid Limit (%)	AS 1289.3.1.1	35	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	16	
Plasticity Index (%)	AS 1289.3.3.1	19	
Date Tested		24/03/2022	

Comments

N/A

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Report No: MAT:NEW22W-0631-S02
Issue No: 1

Material Test Report

Client: Newcastle Geotech
188 The Weir Rd
Teralba NSW 2284

Project No.: 13/00060
Project Name: Various Material Testing
Project Location: Bargo, NSW

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Approved Signatory: Dane Cullen
(Senior Geotechnician)
NATA Accredited Laboratory Number: 18686
Date of Issue: 29/03/2022

Sample Details

Sample ID: NEW22W-0631-S02
Date Sampled: 29/01/2022
Date Received: 02/03/2022
Source: On-Site Insitu
Material: Clayey Sand
Specification: No Specification
The results outlined below apply to the sample as received
TRN: 493
Sample Location: BH1 - (3.2 - 3.4m)

Other Test Results

Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	15.8	
Date Tested		11/03/2022	
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	5.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Cracking		No	
Liquid Limit (%)	AS 1289.3.1.1	20	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	12	
Plasticity Index (%)	AS 1289.3.3.1	8	
Date Tested		24/03/2022	

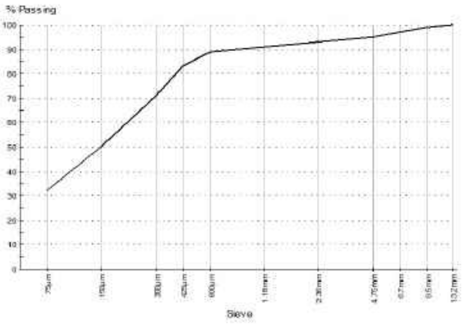
Particle Size Distribution

Method: AS 1289.3.6.1
Drying by: Oven
Date Tested: 29/03/2022

Note: Sample Washed

Sieve Size	% Passing	Limits
13.2mm	100	
9.5mm	99	
6.7mm	97	
4.75mm	95	
2.36mm	93	
1.18mm	91	
600µm	89	
425µm	83	
300µm	71	
150µm	50	
75µm	32	

Chart



Comments

N/A

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Report No: MAT:NEW22W-0631-S03
Issue No: 1

Material Test Report

Client: Newcastle Geotech
188 The Weir Rd
Teralba NSW 2284

Project No.: 13/00060
Project Name: Various Material Testing
Project Location: Bargo, NSW

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Approved Signatory: Dane Cullen
(Senior Geotechnician)
NATA Accredited Laboratory Number: 18686
Date of Issue: 29/03/2022

Sample Details

Sample ID: NEW22W-0631-S03
Date Sampled: 29/01/2022
Date Received: 02/03/2022
Source: On-Site Insitu
Material: Clay
Specification: No Specification
The results outlined below apply to the sample as received
TRN: 493
Sample Location: BH1 - (4.0 - 4.45m)

Test Results

Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	23.8	
Date Tested		11/03/2022	
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	13.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Cracking		No	
Liquid Limit (%)	AS 1289.3.1.1	54	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	21	
Plasticity Index (%)	AS 1289.3.3.1	33	
Date Tested		24/03/2022	

Comments

N/A

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Report No: MAT:NEW22W-0631-S04
Issue No: 1

Material Test Report

Client:	Newcastle Geotech 188 The Weir Rd Teralba NSW 2284
Project No.:	13/00060
Project Name:	Various Material Testing
Project Location:	Bargo, NSW

Accredited for compliance with ISO/IEC 17025-Testing.
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D. Cullen

Approved Signatory: Dane Cullen
(Senior Geotechnician)
NATA Accredited Laboratory Number: 18686
Date of Issue: 29/03/2022

Sample Details

Sample ID:	NEW22W-0631-S04
Date Sampled:	29/01/2022
Date Received:	02/03/2022
Source:	On-Site Insitu
Material:	Sandy Clay
Specification:	No Specification The results outlined below apply to the sample as received
TRN:	493
Sample Location:	BH1 - (5.0 - 5.2m)

Other Test Results

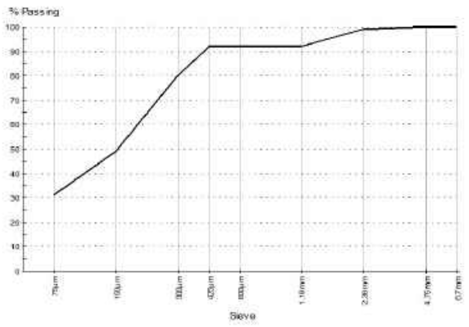
Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	23.0	
Date Tested		11/03/2022	
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	7.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Cracking		No	
Liquid Limit (%)	AS 1289.3.1.1	26	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	14	
Plasticity Index (%)	AS 1289.3.3.1	12	
Date Tested		24/03/2022	

Particle Size Distribution

Method:	AS 1289.3.6.1
Drying by:	Oven
Date Tested:	29/03/2022
Note:	Sample Washed

Sieve Size	% Passing	Limits
6.7mm	100	
4.75mm	100	
2.36mm	99	
1.18mm	92	
600µm	92	
425µm	92	
300µm	80	
150µm	49	
75µm	31	

Chart



Comments

N/A

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Report No: MAT:NEW22W-0631-S05
Issue No: 1

Material Test Report

Client: Newcastle Geotech
188 The Weir Rd
Teralba NSW 2284

Project No.: 13/00060
Project Name: Various Material Testing
Project Location: Bargo, NSW

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Approved Signatory: Dane Cullen
(Senior Geotechnician)
NATA Accredited Laboratory Number: 18686
Date of Issue: 29/03/2022

Sample Details

Sample ID: NEW22W-0631-S05
Date Sampled: 29/01/2022
Date Received: 02/03/2022
Source: On-Site Insitu
Material: Sandy Clay
Specification: No Specification
The results outlined below apply to the sample as received
TRN: 493
Sample Location: BH3 - (2.2 - 2.3m)

Other Test Results

Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	12.0	
Date Tested		11/03/2022	
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	6.5	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Cracking		Yes	
Liquid Limit (%)	AS 1289.3.1.1	25	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	12	
Plasticity Index (%)	AS 1289.3.3.1	13	
Date Tested		25/03/2022	

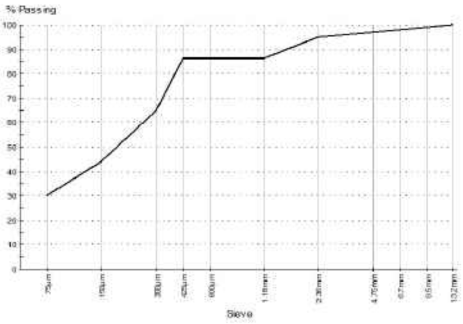
Particle Size Distribution

Method: AS 1289.3.6.1
Drying by: Oven
Date Tested: 29/03/2022

Note: Sample Washed

Sieve Size	% Passing	Limits
13.2mm	100	
9.5mm	99	
6.7mm	98	
4.75mm	97	
2.36mm	95	
1.18mm	86	
600µm	86	
425µm	86	
300µm	65	
150µm	44	
75µm	30	

Chart



Comments

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Report No: MAT:NEW22W-0631-S06
Issue No: 1

Material Test Report

Client:	Newcastle Geotech 188 The Weir Rd Teralba NSW 2284
Project No.:	13/00060
Project Name:	Various Material Testing
Project Location:	Bargo, NSW

Accredited for compliance with ISO/IEC 17025-Testing.
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
Results provided relate only to the items tested or sampled.

D Cullen

Approved Signatory: Dane Cullen
(Senior Geotechnician)
NATA Accredited Laboratory Number: 18686
Date of Issue: 29/03/2022

Sample Details

Sample ID:	NEW22W-0631-S06
Date Sampled:	29/01/2022
Date Received:	02/03/2022
Source:	On-Site Insitu
Material:	Clayey Sand
Specification:	No Specification
	The results outlined below apply to the sample as received
TRN:	493
Sample Location:	BH3 - (5.1 - 5.2m)

Other Test Results

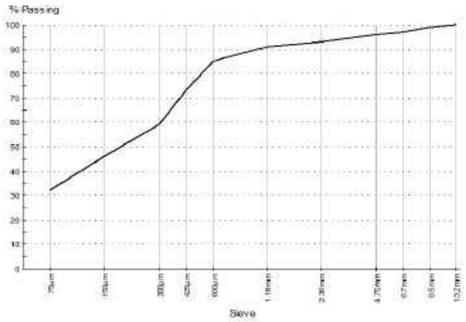
Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	20.5	
Date Tested		11/03/2022	

Particle Size Distribution

Method:	AS 1289.3.6.1
Drying by:	Oven
Date Tested:	21/03/2022
Note:	Sample Washed

Sieve Size	% Passing	Limits
13.2mm	100	
9.5mm	99	
6.7mm	97	
4.75mm	96	
2.36mm	93	
1.18mm	91	
600µm	85	
425µm	73	
300µm	59	
150µm	46	
75µm	32	

Chart



Comments

N/A

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Material Test Report

Report No: MAT:NEW22W-0631-S07
Issue No: 1

Client:	Newcastle Geotech 188 The Weir Rd Teralba NSW 2284
Project No.:	13/00060
Project Name:	Various Material Testing
Project Location:	Bargo, NSW

Accredited for compliance with ISO/IEC 17025-Testing.
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
Results provided relate only to the items tested or sampled.

Approved Signatory: Dane Cullen
(Senior Geotechnician)
NATA Accredited Laboratory Number: 18686
Date of Issue: 29/03/2022

WORLD RECOGNISED ACCREDITATION

Sample Details

Sample ID:	NEW22W-0631-S07
Date Sampled:	29/01/2022
Date Received:	02/03/2022
Source:	On-Site Insitu
Material:	Clayey Sand
Specification:	No Specification
	The results outlined below apply to the sample as received
TRN:	493
Sample Location:	BH4 - (1.1 - 1.55m)

Other Test Results

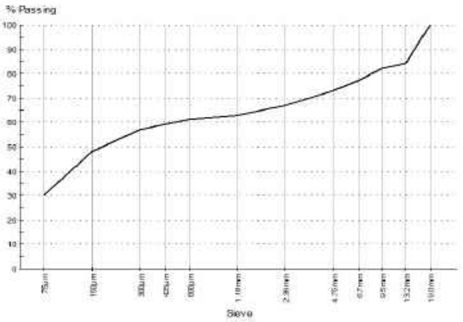
Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	10.4	
Date Tested		11/03/2022	

Particle Size Distribution

Method:	AS 1289.3.6.1
Drying by:	Oven
Date Tested:	21/03/2022
Note:	Sample Washed

Sieve Size	% Passing	Limits
19.0mm	100	
13.2mm	84	
9.5mm	82	
6.7mm	77	
4.75mm	73	
2.36mm	67	
1.18mm	63	
600µm	61	
425µm	59	
300µm	57	
150µm	48	
75µm	30	

Chart



Comments

N/A

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Report No: MAT:NEW22W-0631-S08
Issue No: 1

Material Test Report

Client: Newcastle Geotech
188 The Weir Rd
Teralba NSW 2284

Project No.: 13/00060
Project Name: Various Material Testing
Project Location: Bargo, NSW

Accredited for compliance with ISO/IEC 17025-Testing.
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Approved Signatory: Dane Cullen
(Senior Geotechnician)
NATA Accredited Laboratory Number: 18686
Date of Issue: 29/03/2022

Sample Details

Sample ID: NEW22W-0631-S08
Date Sampled: 29/01/2022
Date Received: 02/03/2022
Source: On-Site Insitu
Material: Gravelly Sandy Clay
Specification: No Specification
The results outlined below apply to the sample as received
TRN: 493
Sample Location: BH4 - (2.4 - 2.95m)

Test Results

Description	**Method**	**Result**	**Limits**
Moisture Content (%)	AS 1289.2.1.1	9.4	
Date Tested		11/03/2022	
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	6.5	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Cracking		No	
Liquid Limit (%)	AS 1289.3.1.1	27	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	15	
Plasticity Index (%)	AS 1289.3.3.1	12	
Date Tested		24/03/2022	

Comments

N/A

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ABN: 98 153 268 896

Report No: MAT:NEW22W-0631-S09
Issue No: 1

Material Test Report

Client: Newcastle Geotech
188 The Weir Rd
Teralba NSW 2284

Project No.: 13/00060
Project Name: Various Material Testing
Project Location: Bargo, NSW

Accredited for compliance with ISO/IEC 17025-Testing.
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
Results provided relate only to the items tested or sampled.

Approved Signatory: Dane Cullen
(Senior Geotechnician)
NATA Accredited Laboratory Number: 18686
Date of Issue: 29/03/2022

Sample Details

Sample ID: NEW22W-0631-S09
Date Sampled: 29/01/2022
Date Received: 02/03/2022
Source: On-Site Insitu
Material: Gravelly Sandy Clay
Specification: No Specification
The results outlined below apply to the sample as received
TRN: 493
Sample Location: BH4 - (4.0 - 4.45m)

Test Results

Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	8.1	
Date Tested		11/03/2022	

Comments

N/A

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ABN: 98 153 268 896

Report No: MAT:NEW22W-0631-S10
Issue No: 1

Material Test Report

Client:	Newcastle Geotech 188 The Weir Rd Teralba NSW 2284
Project No.:	13/00060
Project Name:	Various Material Testing
Project Location:	Bargo, NSW

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The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
Results provided relate only to the items tested or sampled.

D Cullen

Approved Signatory: Dane Cullen
(Senior Geotechnician)
NATA Accredited Laboratory Number: 18686
Date of Issue: 29/03/2022

Sample Details

Sample ID:	NEW22W-0631-S10
Date Sampled:	30/01/2022
Date Received:	02/03/2022
Source:	On-Site Insitu
Material:	Gravelly Sandy Clay
Specification:	No Specification
	The results outlined below apply to the sample as received
TRN:	493
Sample Location:	BH5 - (1.0 - 1.45m)

Other Test Results

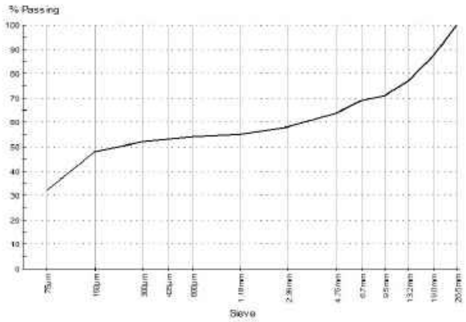
Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	13.2	
Date Tested		11/03/2022	

Particle Size Distribution

Method:	AS 1289.3.6.1
Drying by:	Oven
Date Tested:	21/03/2022
Note:	Sample Washed

Sieve Size	% Passing	Limits
26.5mm	100	
19.0mm	87	
13.2mm	77	
9.5mm	71	
6.7mm	69	
4.75mm	64	
2.36mm	58	
1.18mm	55	
600µm	54	
425µm	53	
300µm	52	
150µm	48	
75µm	32	

Chart



Comments

N/A

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Material Test Report

Report No: MAT:NEW22W-0631-S11
Issue No: 1

Client:	Newcastle Geotech 188 The Weir Rd Teralba NSW 2284
Project No.:	13/00060
Project Name:	Various Material Testing
Project Location:	Bargo, NSW

Accredited for compliance with ISO/IEC 17025-Testing.
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Results provided relate only to the items tested or sampled.

Approved Signatory: Dane Cullen
(Senior Geotechnician)
NATA Accredited Laboratory Number: 18686
Date of Issue: 29/03/2022

Sample Details

Sample ID:	NEW22W-0631-S11
Date Sampled:	30/01/2022
Date Received:	02/03/2022
Source:	On-Site Insitu
Material:	Sandy Gravelly Clay
Specification:	No Specification The results outlined below apply to the sample as received
TRN:	493
Sample Location:	BH5 - (2.0 - 2.3m)

Other Test Results

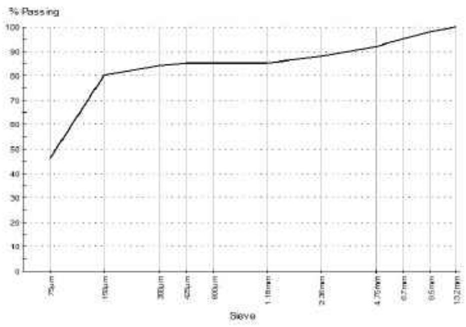
Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	16.0	
Date Tested		11/03/2022	
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	6.5	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Cracking		No	
Liquid Limit (%)	AS 1289.3.1.1	26	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	15	
Plasticity Index (%)	AS 1289.3.3.1	11	
Date Tested		24/03/2022	

Particle Size Distribution

Method:	AS 1289.3.6.1
Drying by:	Oven
Date Tested:	21/03/2022
Note:	Sample Washed

Sieve Size	% Passing	Limits
13.2mm	100	
9.5mm	98	
6.7mm	95	
4.75mm	92	
2.36mm	88	
1.18mm	85	
600µm	85	
425µm	85	
300µm	84	
150µm	80	
75µm	46	

Chart



Comments

N/A

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2 Murray Dwyer Circuit, Mayfield West, NSW 2304
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E: admin@qualtest.com.au
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ABN: 98 153 268 896

Material Test Report

Report No: MAT:NEW22W-0631-S12
Issue No: 1

Client: Newcastle Geotech
188 The Weir Rd
Teralba NSW 2284

Project No.: 13/00060
Project Name: Various Material Testing
Project Location: Bargo, NSW

Accredited for compliance with ISO/IEC 17025-Testing.
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
Results provided relate only to the items tested or sampled.

WORLD RECOGNISED ACCREDITATION

Approved Signatory: Dane Cullen
(Senior Geotechnician)
NATA Accredited Laboratory Number: 18686
Date of Issue: 29/03/2022

Sample Details

Sample ID: NEW22W-0631-S12
Date Sampled: 30/01/2022
Date Received: 02/03/2022
Source: On-Site Insitu
Material: Sandy Gravelly Clay
Specification: No Specification
The results outlined below apply to the sample as received
TRN: 493
Sample Location: BH5 - (3.5 - 3.7m)

Other Test Results

Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	16.2	
Date Tested		11/03/2022	
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	11.5	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Cracking		No	
Liquid Limit (%)	AS 1289.3.1.1	39	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	15	
Plasticity Index (%)	AS 1289.3.3.1	24	
Date Tested		23/03/2022	

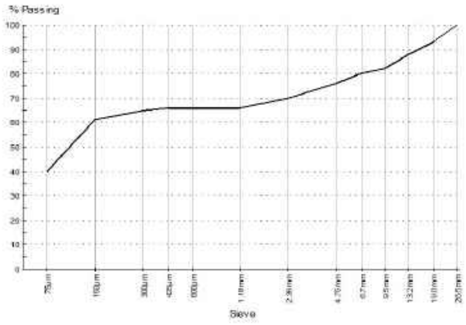
Particle Size Distribution

Method: AS 1289.3.6.1
Drying by: Oven
Date Tested: 21/03/2022

Note: Sample Washed

Sieve Size	% Passing	Limits
26.5mm	100	
19.0mm	93	
13.2mm	88	
9.5mm	82	
6.7mm	80	
4.75mm	76	
2.36mm	70	
1.18mm	66	
600µm	66	
425µm	66	
300µm	65	
150µm	61	
75µm	40	

Chart



Comments

N/A

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Report No: MAT:NEW22W-0631-S13
Issue No: 1

Material Test Report

Client:	Newcastle Geotech 188 The Weir Rd Teralba NSW 2284
Project No.:	13/00060
Project Name:	Various Material Testing
Project Location:	Bargo, NSW

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Results provided relate only to the items tested or sampled.

Approved Signatory: Dane Cullen
(Senior Geotechnician)
NATA Accredited Laboratory Number: 18686
Date of Issue: 29/03/2022

Sample Details

Sample ID:	NEW22W-0631-S13
Date Sampled:	30/01/2022
Date Received:	02/03/2022
Source:	On-Site Insitu
Material:	Clay
Specification:	No Specification
	The results outlined below apply to the sample as received
TRN:	493
Sample Location:	BH5 - (5.5 - 5.95m)

Test Results

Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	24.7	
Date Tested		11/03/2022	
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	15.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Cracking		No	
Liquid Limit (%)	AS 1289.3.1.1	67	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	23	
Plasticity Index (%)	AS 1289.3.3.1	44	
Date Tested		24/03/2022	

Comments

N/A

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E: admin@qualtest.com.au
W: www.qualtest.com.au
ABN: 98 153 268 896

Report No: MAT:NEW22W-0631-S14
Issue No: 1

Material Test Report

Client: Newcastle Geotech
188 The Weir Rd
Teralba NSW 2284

Project No.: 13/00060
Project Name: Various Material Testing
Project Location: Bargo, NSW

Accredited for compliance with ISO/IEC 17025-Testing.
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
Results provided relate only to the items tested or sampled.

NATA
WORLD RECOGNISED ACCREDITATION

Approved Signatory: Dane Cullen
(Senior Geotechnician)
NATA Accredited Laboratory Number: 18686
Date of Issue: 29/03/2022

Sample Details

Sample ID: NEW22W-0631-S14
Date Sampled: 30/01/2022
Date Received: 02/03/2022
Source: On-Site Insitu
Material: Sandy Gravelly Clay
Specification: No Specification
The results outlined below apply to the sample as received
TRN: 493
Sample Location: BH7 - (4.5 - 5.0m)

Test Results

Description	**Method**	**Result**	**Limits**
Moisture Content (%)	AS 1289.2.1.1	13.7	
Date Tested		11/03/2022	
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	10.0	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Cracking		No	
Liquid Limit (%)	AS 1289.3.1.1	38	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	17	
Plasticity Index (%)	AS 1289.3.3.1	21	
Date Tested		23/03/2022	

Comments

N/A

QUALTEST Laboratory (NSW) Pty Ltd (20708)
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ABN: 98 153 268 896

Report No: MAT:NEW22W-0631-S15
Issue No: 1

Material Test Report

Client:	Newcastle Geotech 188 The Weir Rd Teralba NSW 2284
Project No.:	13/00060
Project Name:	Various Material Testing
Project Location:	Bargo, NSW

Accredited for compliance with ISO/IEC 17025-Testing.
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
Results provided relate only to the items tested or sampled.

D. Cullen

Approved Signatory: Dane Cullen
(Senior Geotechnician)
NATA Accredited Laboratory Number: 18686
Date of Issue: 29/03/2022

Sample Details

Sample ID:	NEW22W-0631-S15
Date Sampled:	30/01/2022
Date Received:	02/03/2022
Source:	On-Site Insitu
Material:	Clayey Sand
Specification:	No Specification
	The results outlined below apply to the sample as received
TRN:	493
Sample Location:	BH7 - (5.5 - 5.95m)

Other Test Results

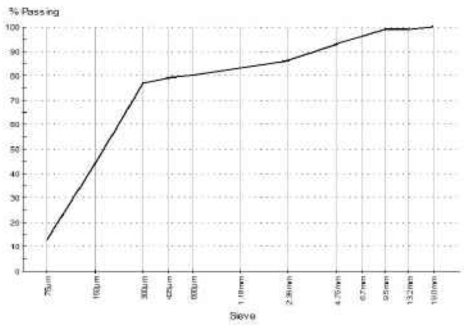
Description	**Method**	**Result**	**Limits**
Moisture Content (%)	AS 1289.2.1.1	15.0	
Date Tested		11/03/2022	

Particle Size Distribution

Method:	AS 1289.3.6.1
Drying by:	Oven
Date Tested:	21/03/2022
Note:	Sample Washed

Sieve Size	**% Passing**	**Limits**
19.0mm	100	
13.2mm	99	
9.5mm	99	
6.7mm	96	
4.75mm	93	
2.36mm	86	
1.18mm	83	
600µm	80	
425µm	79	
300µm	77	
150µm	44	
75µm	13	

Chart



Comments

N/A

Appendix D

Morrow Geotechnics - Finite Element Analysis of Batter Stability – Report P2607 Oct 22

Ref: P2607_01 rev1
26/10/2022

morrow

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Finite Element Analysis of Batter Stability
Tahmoor South Project, Bargo NSW

1.0 Introduction

Morrow Geotechnics Pty Ltd has carried out finite element analysis for assessment of current batter conditions at Tahmoor South Project, Bargo NSW. The area under consideration is further described as Main Southern Rail 97.5km to 101km and consists of existing rail embankments.

Six cross sections of the rail embankments have been provided by Newcastle Geotechnical Pty Ltd (NG) for analysis, namely:

- Section 1 – 98.440 km
- Section 2 – 98.745 km
- Section 3 – 99.037 km
- Section 4 – 99.338. km
- Section 5 – 100.143 km
- Section 6 – 100.427 km

The NG cross sections have been attached to this report as reference.

Geotechnical parameters based on boreholes and lab testing have been provided by NG. The NG geotechnical model has been relied on in the formation of a finite element model for analysis.

2.0 Methodology

Morrow Geotechnics has carried out analysis for the assessment in accordance with the relevant Australian Standards, including:

- AS1170.1:2002 Structural Design Actions
- AS4678:2002 Earth-retaining Structures
- AS5100:2004 Bridge Design

Modelling has been carried out using PLAXIS 2D. PLAXIS 2D is a finite element package intended for the two dimensional analysis of deformation and stability in geotechnical engineering. Plaxis identifies critical failure surfaces by c-phi reduction factor. In order to generate failure surfaces which impact on the tracks slight stiffening of near surface material has been incorporated in modelling of final safety factor stages for track stability.

2.1 Finite Element Inputs

The NG slope models and borehole logs have been considered in the formation of a geotechnical model for the analysis. The inferred geotechnical model provided by NG is summarised in **Table 1** below. The depth and thickness of each geotechnical unit have been provided in the NG Slope Sections.

TABLE 1 SUMMARY OF INFERRED SUBSURFACE CONDITIONS PROVIDED BY NEWCASTLE GEOTECHNICAL

Unit	Material	Material Description [1]
1A	**Rail Formation**	Ballast - highly fouled
1B		Capping / structural fill - Clayey Sandy Gravel
2A	**Embankment Fill**	Clay, Gravelly CLAY, Sandy Gravelly CLAY - medium plasticity, stiff to very stiff consistency, variable sand and gravel content, some weathered sandstone fragments
2B		Clayey SAND, Gravelly Clayey SAND, fine to medium grained, est 30% - 40% medium plasticity clay, some weathered sandstone rock fragments
2C		Access road surfacing - Clayey GRAVEL, fouled ballast in a medium plasticity clay matrix Not in stability anal3ysis
3	**Alluvium / Slopewash**	Clayey SAND, fine to medium grained, est 30% - 40% medium plasticity clay, loose to medium dense
4A	**Residual**	Sandy CLAY, medium plasticity, stiff consistency becoming very stiff, some CLAY, medium to high plasticity, very stiff
4B		Clayey SAND, fine to medium grained, est 30% - 40% medium plasticity clay, loose to medium dense
5	**Rock**	Sandstone, fine to medium grained extremely to highly weathered, estimated very low to low strength

Notes:

1 Descriptions provided above are taken from emails, borehole logs and NG interpretive sections provided by NG.

Parameters for modelling have been chosen in consultation between Morrow Geotechnics and NG and are presented in **Table 2**, below.

TABLE 2 GEOTECHNICAL PARAMETERS

Geotechnical Unit	Drained Cohesion c' (kPa)	Friction Angle φ' (°)	Dilatancy Angle ψ (°)	Unsaturated Bulk Density γ_{unsat} (kN/m^3)	Saturated Bulk Density γ_{sat} (kN/m^3)	Elastic Modulus E' (MPa)	Poisson's Ratio, v'
1A	0	40	5	20	20.5	50	0.25
1B	0	36	5	20	20.5	50	0.25
2A	5	28	0	18	19	15	0.30
2B	5	30	0	19	20	20	0.25
2C	0	33	3	20	20.5	30	0.25
3	0	30	0	19	20	15	0.25
4A	5	25	0	18	19	15	0.30
4B	0	30	0	19	20	20	0.25
5	20	35	0	23	24	80	0.25

Design groundwater table has been modelled at levels shown on the NG cross sections.

2.2 Applied Loading

A 50 kPa surcharge loading has been adopted to rail loading as provided by NG.

3.0 Analysis Results

Finite Element Analysis for design has been carried out with a target Factor of Safety (FoS) of 1.5 following remediation. The results of the PLAXIS analysis are presented in **Table 4**.

For failures affecting the access track the minimum failure depth is greater than 750 mm. For failures affecting the rail, failures must reach the toe of the ballast. Failures affecting the rail have been treated together, with worst case failure taken to represent risk to rail for both up and down lines.

TABLE 4 RESULTS OF PLAXIS ANALYSIS

		FoS
Section 1	Failures Affecting Down Line Access Track	1.61
	Failures Affecting Rail	1.61
	Failures Affecting Up Line Access Track	1.61
Section 2	Failures Affecting Down Line Access Track	1.33
	Failures Affecting Rail	1.65
	Failures Affecting Up Line Access Track	> 2.00
Section 3	Failures Affecting Down Line Access Track	1.27
	Failures Affecting Rail	1.69
	Failures Affecting Up Line Access Track	> 2.00
Section 4	Failures Affecting Down Line Access Track	1.20
	Failures Affecting Rail	1.20
	Failures Affecting Up Line Access Track	1.36
Section 5	Failures Affecting Down Line Access Track	1.50
	Failures Affecting Rail	1.54
	Failures Affecting Up Line Access Track	> 2.00
Section 6	Failures Affecting Down Line Access Track	1.31
	Failures Affecting Rail	> 2.00
	Failures Affecting Up Line Access Track	1.47

Notes:

1 For Section 1 a global slope failure occurs at FoS 1.61 affecting Rail and both access on Up and Down Lines.

4.0 Closure

Your attention is drawn to the attached document titled “Important Information.” The statements presented in this document are intended to advise you of what your realistic expectations of this report should be. The document is not intended to reduce the level of responsibility accepted by Morrow Geotechnics, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

Morrow Geotechnics makes no warranty of the stability of the slope either upslope or downslope of the soil nail support. Drainage design must be implemented to prevent further surface water infiltration or scour to the slope. No site inspections have been undertaken in order to verify the validity of the Newcastle Geotechnical geotechnical model.

Please do not hesitate to contact Morrow Geotechnics if you have any questions about the contents of this report.

For and on behalf of Morrow Geotechnics Pty Ltd,

Alan Morrow
Principal Geotechnical Engineer
BE (Civil) BSc MIEAust CPEng NER

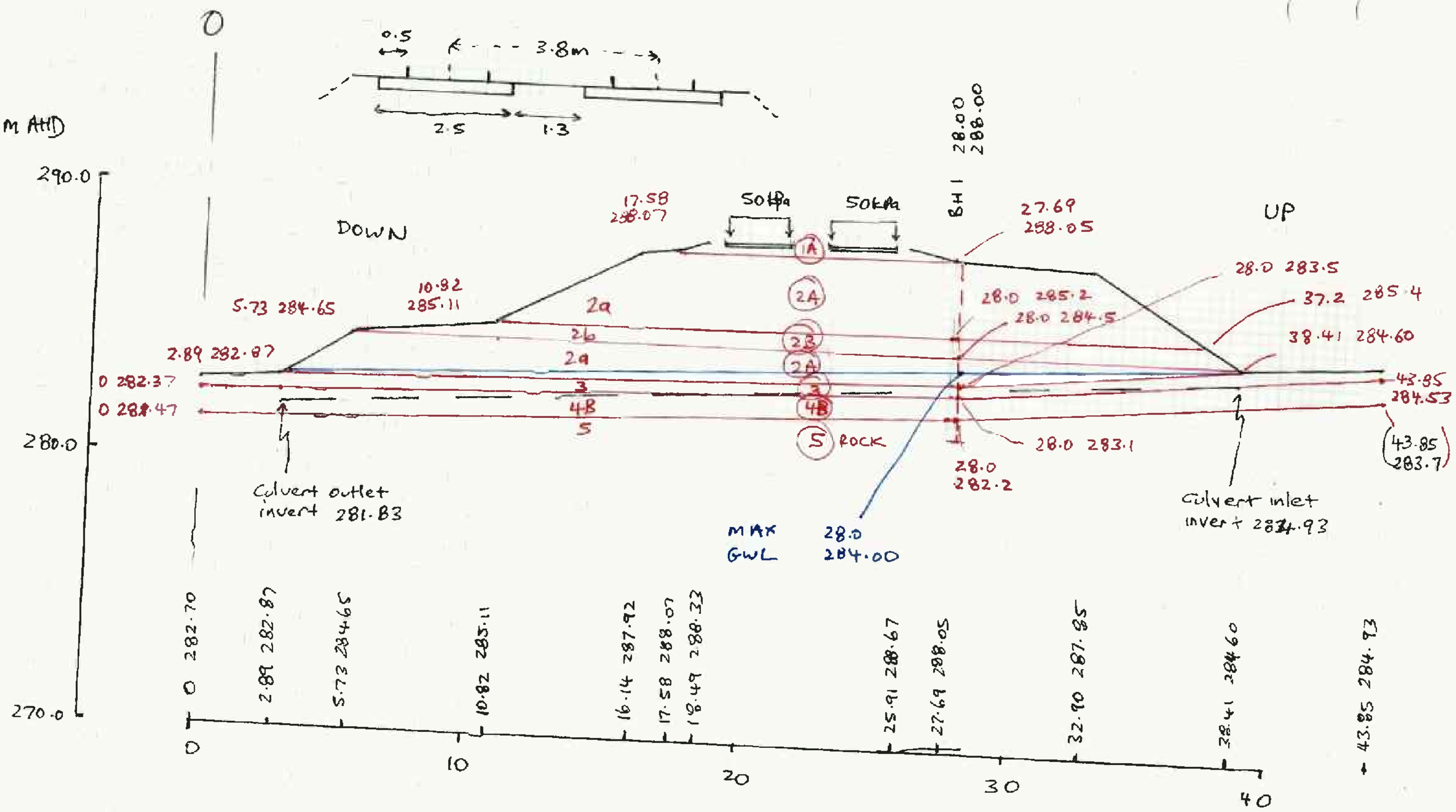
Appendix A:	Newcastle Geotechnical Material Parameters and Slope Sections
Appendix B:	Plaxis Reports
Appendix C:	Important Information

APPENDIX A

Newcastle Geotechnical Material Parameters and Sections

493 - Tahmoor South Project - Bargo

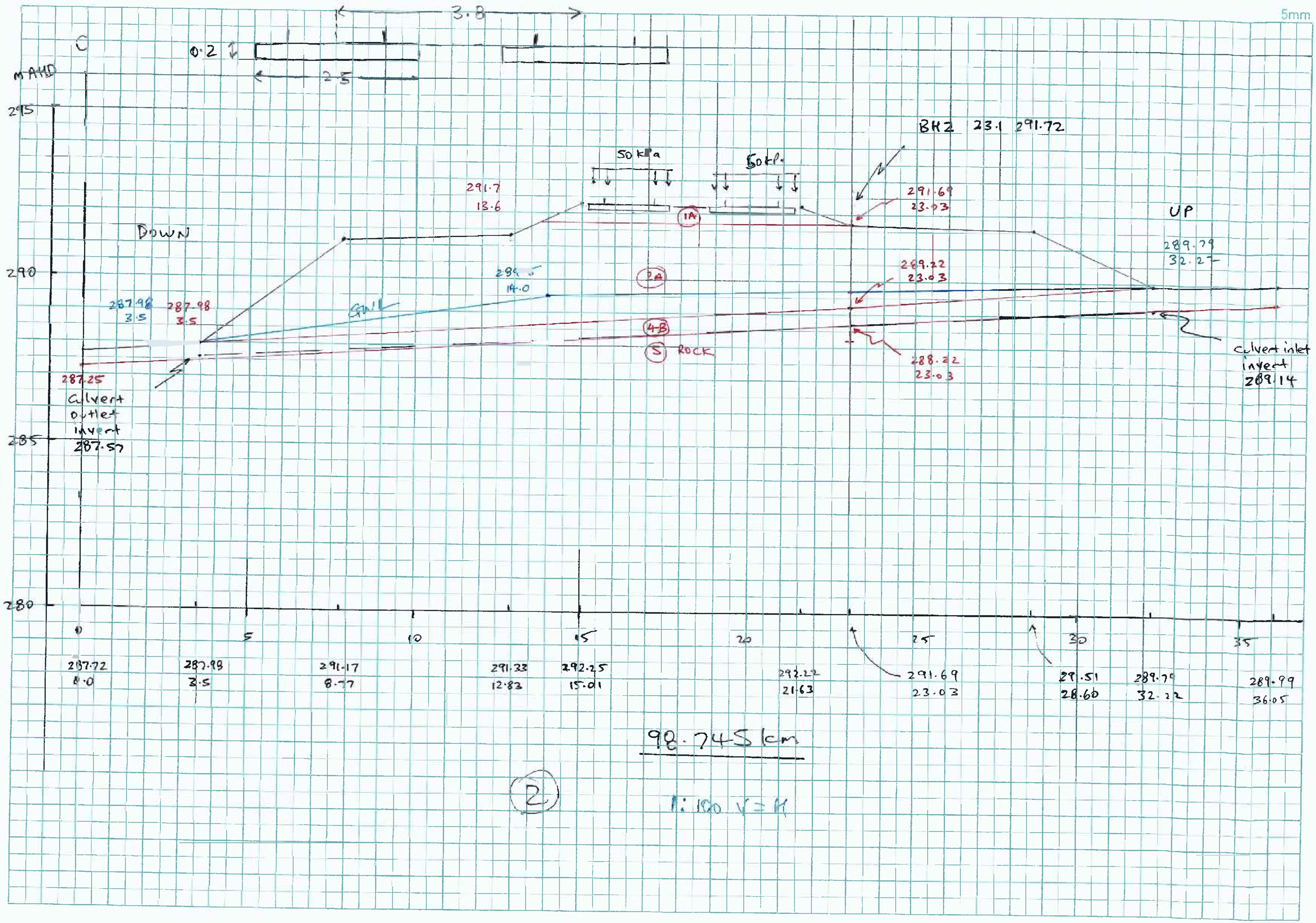
				Laboratory Results							Estimated Partametrs - TBC					
Unit	Origin	Material	SPT N Values	Atterberg Limit			PSD			Moisture content	Sat Unit Weight	Unsat Unit Weight	Cohesion	Angle Friction	E'	Poissons
				LL	PI	LS	Gravel	Sand	Fines		KN/m3	KN/m3	kPa	deg	MPa	v'
1A	Rail Formation	Ballast - highly fouled									20.5	20	0	40	50	0.25
1B		Capping / structural fill - Clayey Sandy Gravel Not in stability analysis									20.5	20	0	36	50	0.25
2A	Embankment Fill	Clay, Gravelly CLAY, Sandy Gravelly CLAY - medium plasticity, stiff to very stiff consistency, variable sand and gravel content, some weathered sandstone fragments	6 5 8 6 8 12 13 6 5 5 5 6 5 7	35 54 25 27 26 39 38	19 33 13 12 11 24 21	9.5 13 6.5 6.5 6.5 11.5 10	5 42 12 30	65 26 44 20	30 32 46 40	17.4 23.8 12 9.4 8.1 13.2 16 16.2 23.8	19	18	5	28	15	0.3
2B		Clayey SAND, Gravelly Clayey SAND, fine to medium grained, est 30% -40% medium plasticity clay, some weathered sandstone rock fragments	6 9 15	20	8	5	7 33	61 37	32 30	15.8 10.4	20	19	5	30	20	0.25
2C		Access road surfacing - Clayey GRAVEL, fouled ballast in a medium plasticity clay matrix Not in stability analysis									20.5	20	0	33	30	0.25
3	Alluvium / Slopewash	Clayey SAND, fine to medium grained, est 30% -40% medium plasticity clay, loose to medium dense									20	19	0	30	15	0.25
4A	Residual	Sandy CLAY, medium plasticity, stiff consistency becoming very stiff, some CLAY, medium to high plasticity, very stiff	9 4 8 12 15	26 67	12 44	7 15	1	38	31	23 24.7	19	18	5	25	15	0.3
4B		Clayey SAND, fine to medium grained, est 30% -40% medium plasticity clay, loose to medium dense					7 14	61 73	32 13	20.5	20	19	0	30	20	0.25
5	Rock	Sandstone, fine to medium grained extremely to highly weathered, estimated very low to low strength									24	23	20	35	80	0.25

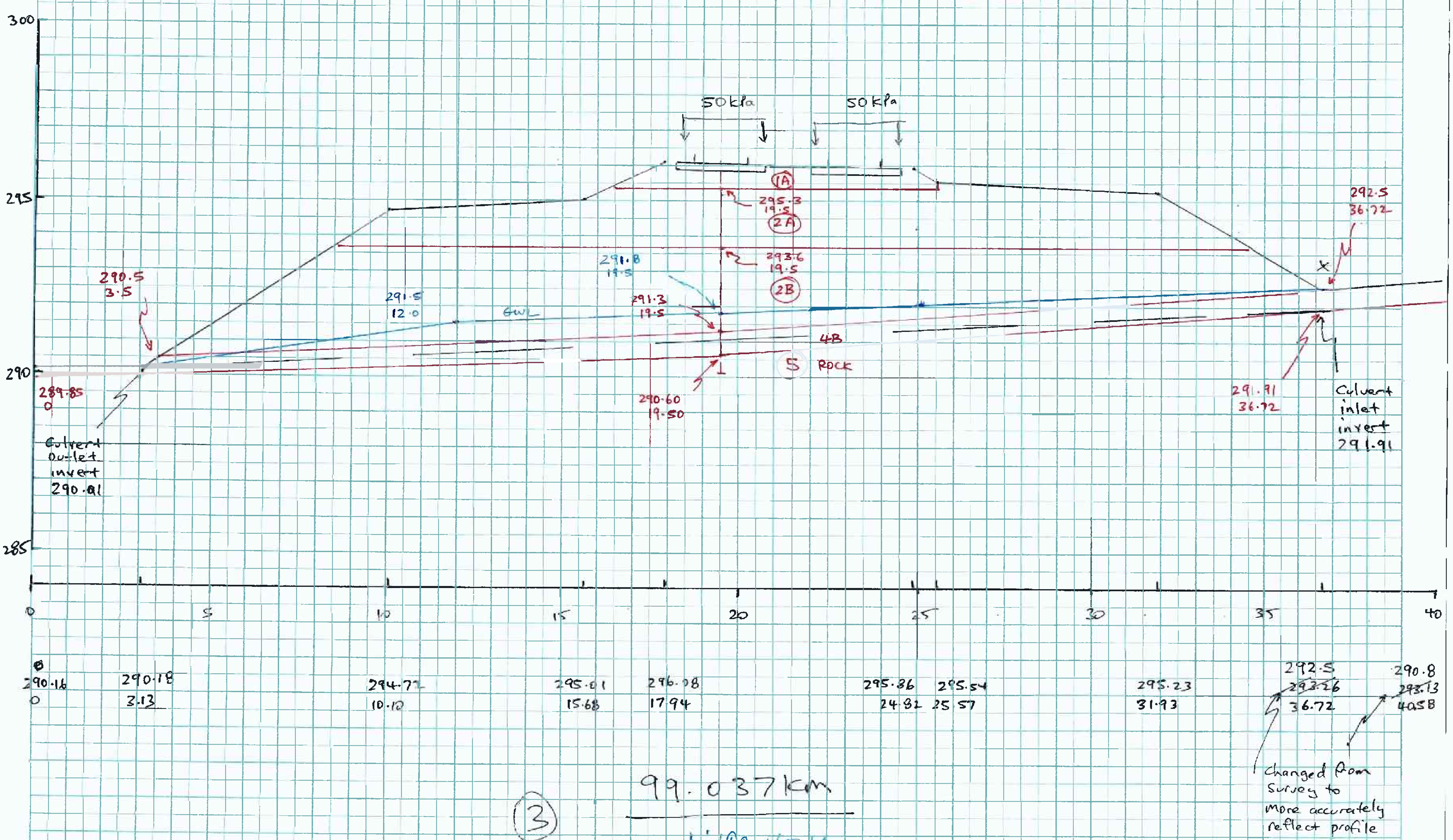


98.440 km

①

1:200 V=H


3.8
0.2
2.5
m AHD
295
290
285
280
DOWN
UP
BH2 23.1 291.72
50 kPa
50 kPa
291.7
13.6
291.69
23.03
289.79
32.27
14.0
1A
2A
4B
5
ROCK
CH
287.98
3.5
287.98
3.5
289.22
23.03
288.22
23.03
287.25
Culvert outlet invert 287.57
Culvert inlet invert 289.14
0
5
10
15
20
25
30
35
287.72
0.0
287.98
3.5
291.17
8.77
291.33
12.83
292.25
15.01
292.22
21.63
291.69
23.03
291.51
28.60
289.79
32.22
289.99
36.05
98.745 km
②
1:100 V=H
5mm

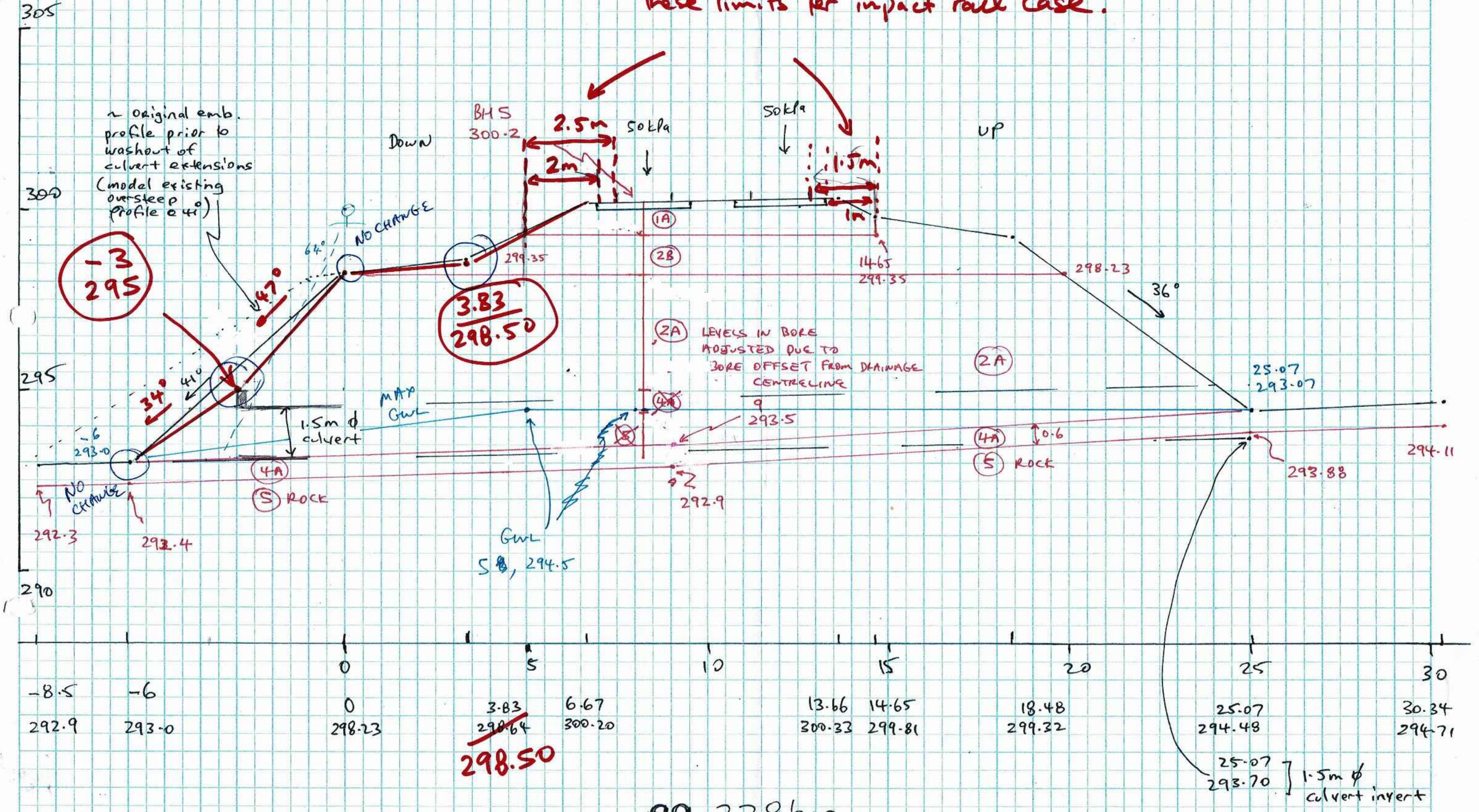


③

99.037km

1:100 V=H

Looking at slips beyond these limits for impact rail case.

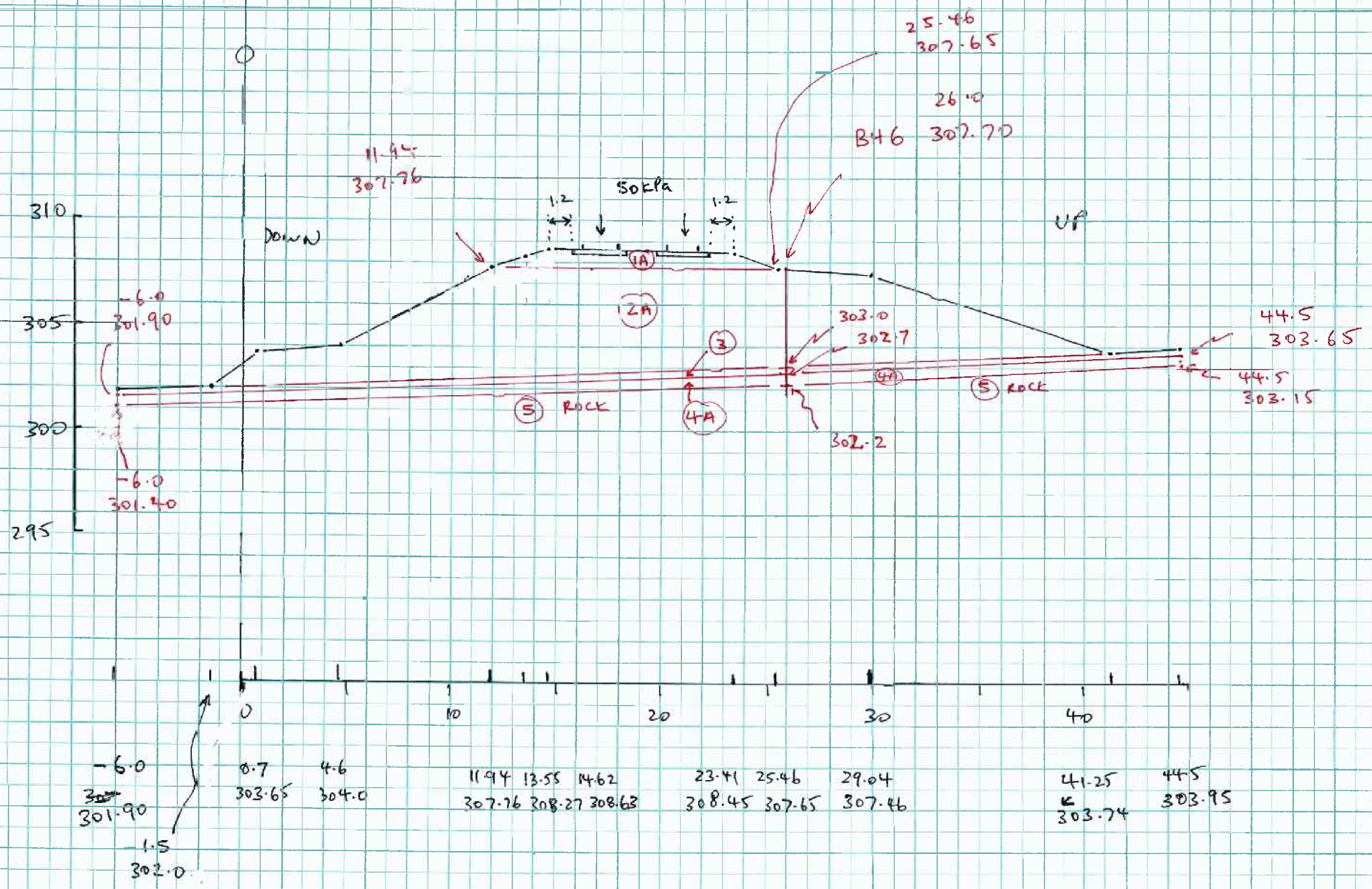


④

99.338km

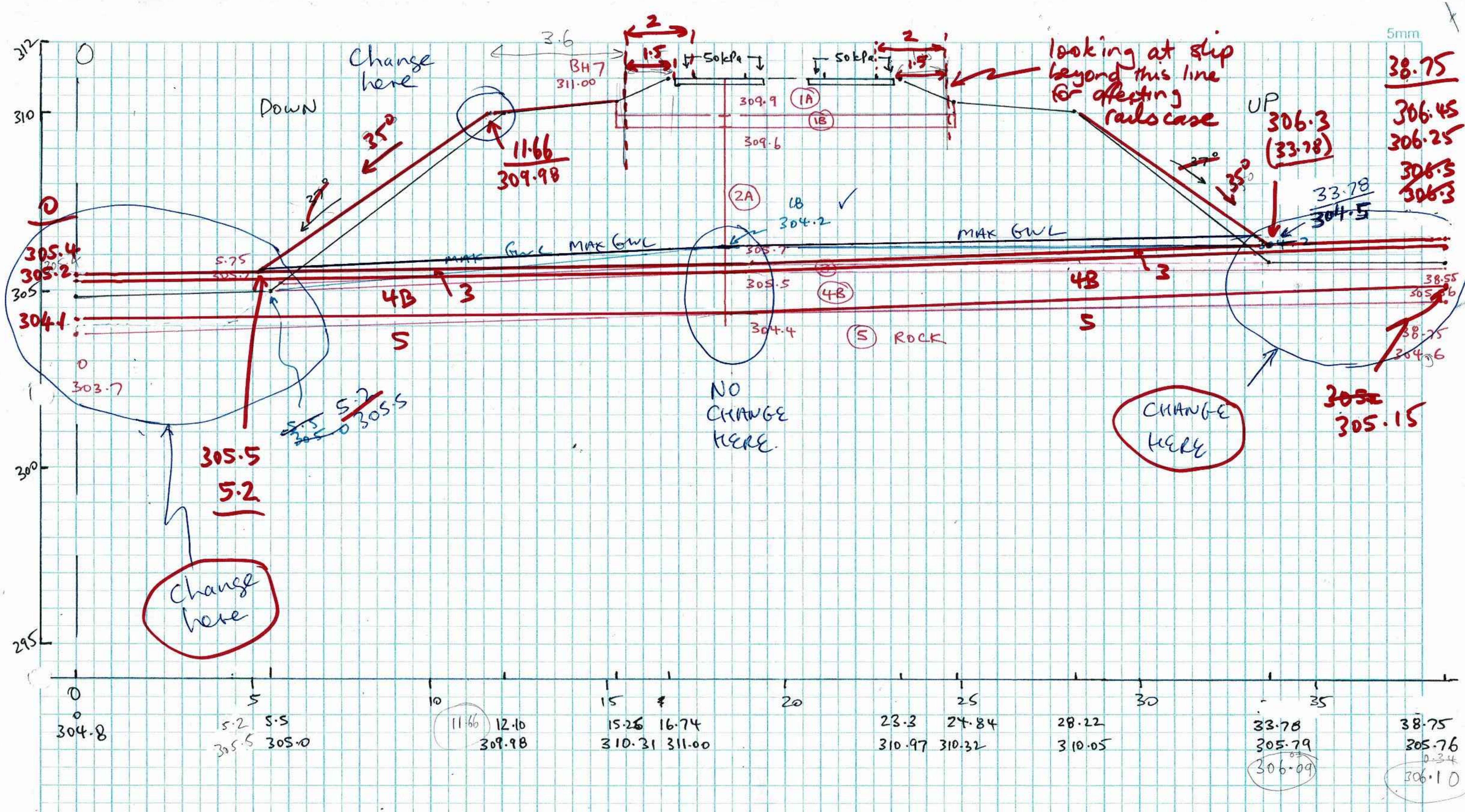
1:100 Y=H

Revised section Down following minor devegetation & closer mapping by MGD. – only minor change



⑤ 100.143km

1:200 V=H



37° 0.75 | 4.98
6.6

⑥ 100.427 km

1:100 V=H

Revised section MGD following devegetation/clearing inspection/mapping

4.26 | 0.766
3.96 | 37°
5.56
0.71 35°

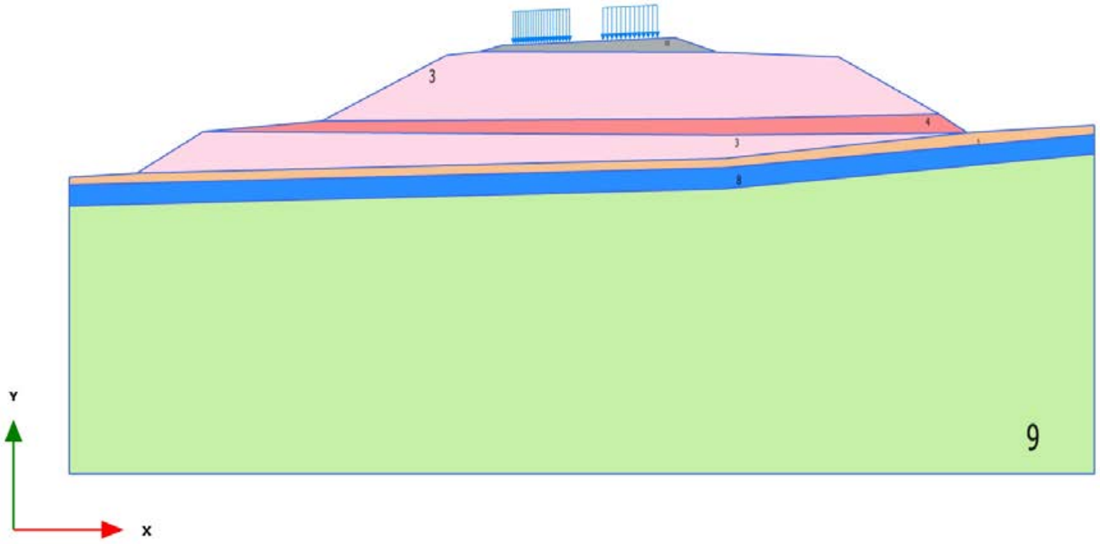
APPENDIX B

Plaxis Reports

P2607_Bargo_Section 1

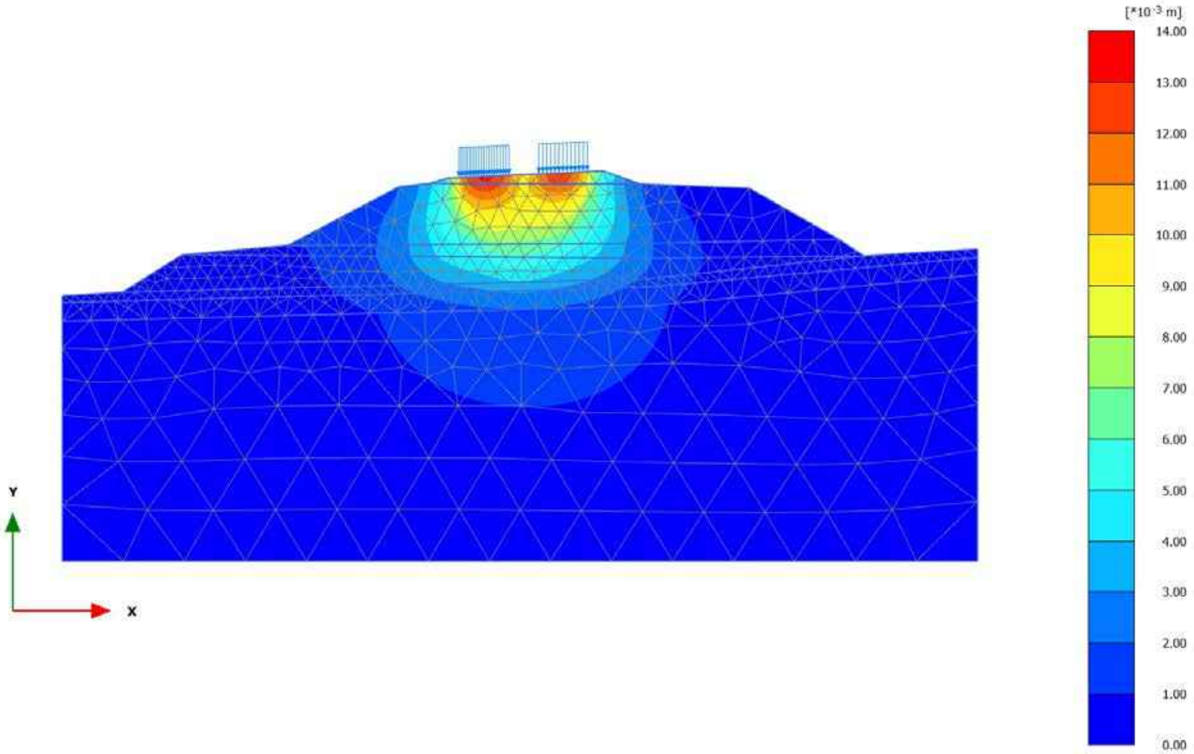
PLAXIS Report

1.1.1.1 Calculation results, Phase_4 [Phase_4] (4/37), Materials plot



Materials plot

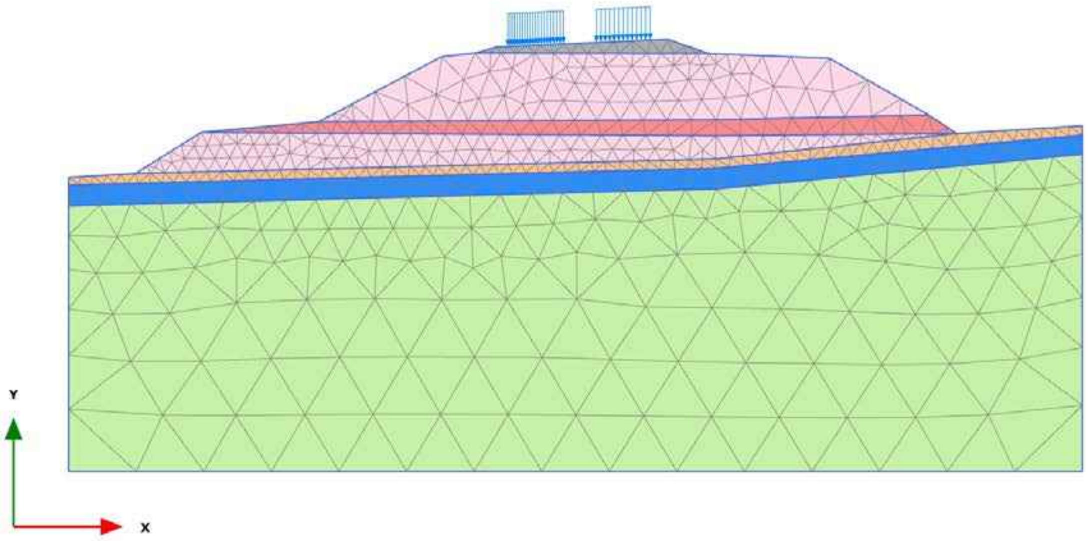
2.1.1.1.1 Calculation results, Phase_4 [Phase_4] (4/37), Total displacements |u|



Total displacements |u| (scaled up 100 times)

Maximum value = 0.01319 m (Element 1 at Node 3835)

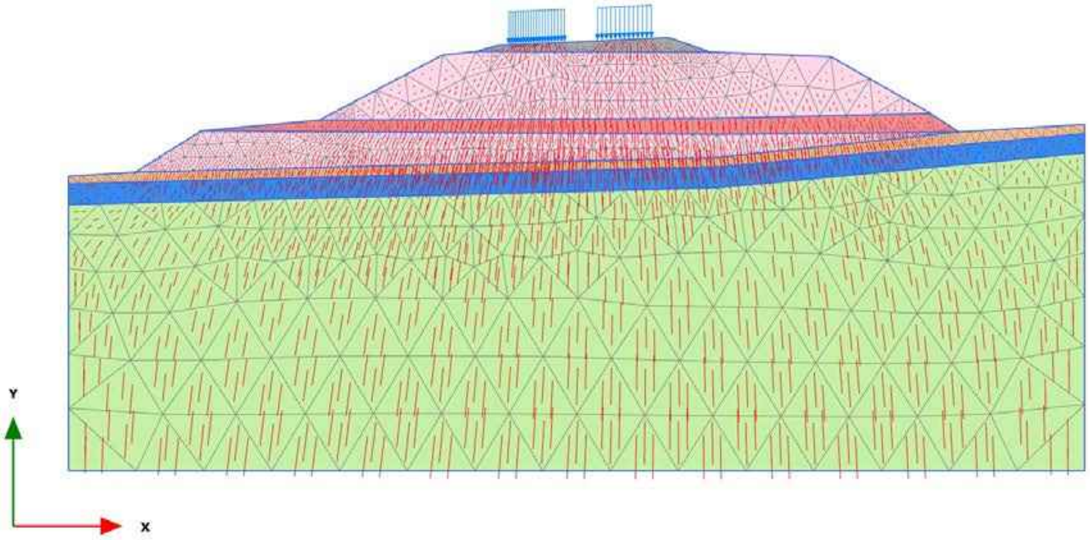
2.2.1.1.1 Calculation results, Phase_4 [Phase_4] (4/37), Excess pore pressures p_{excess}



Excess pore pressures p_{excess} (scaled up 1.00 times) (Pressure = negative)

Uniform value of 0.000 kN/m²

2.2.2.1.1 Calculation results, Phase_4 [Phase_4] (4/37), Principal total stress σ_1

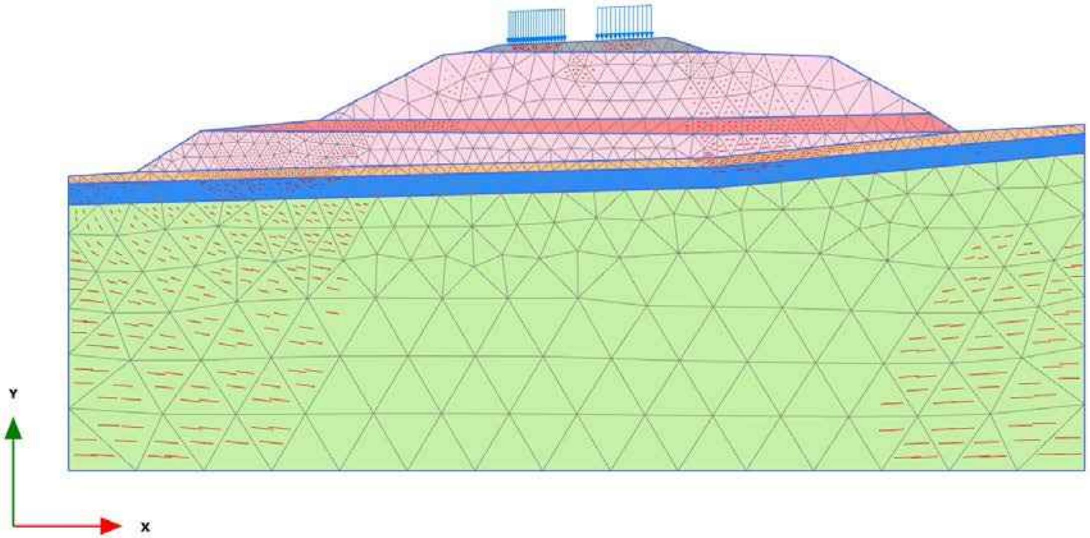


Principal total stress σ_1 (scaled up $5.00*10^{-3}$ times)

Maximum value = $-0.5551*10^{-15}$ kN/m² (Element 236 at Stress point 2823)

Minimum value = -399.6 kN/m² (Element 746 at Stress point 8949)

2.2.2.2.1 Calculation results, Phase_4 [Phase_4] (4/37), Principal total stress σ_2

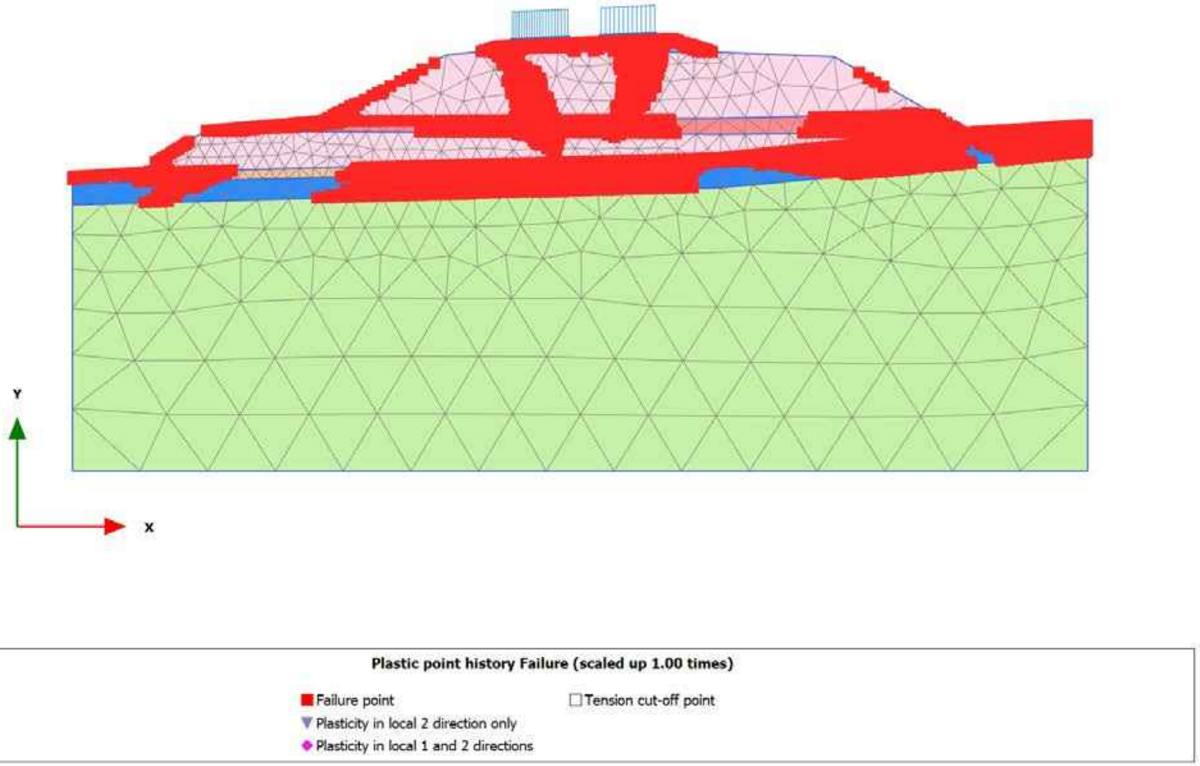


Principal total stress σ_2 (scaled up $5.00*10^{-3}$ times)

Maximum value = $-0.5551*10^{-15}$ kN/m² (Element 236 at Stress point 2823)

Minimum value = -241.0 kN/m² (Element 746 at Stress point 8950)

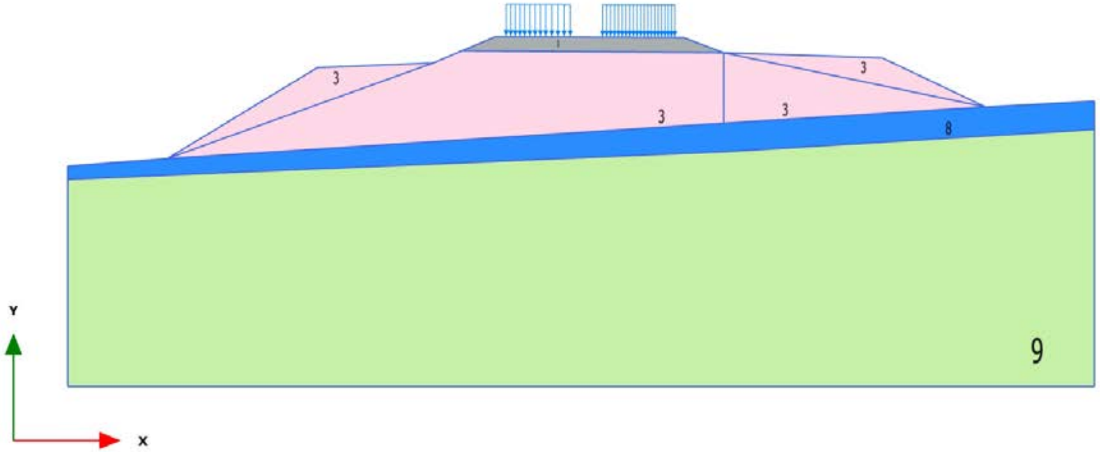
2.2.3.1.1 Calculation results, Phase_4 [Phase_4] (4/37), Plastic point history Failure



P2607_Bargo_Section 2

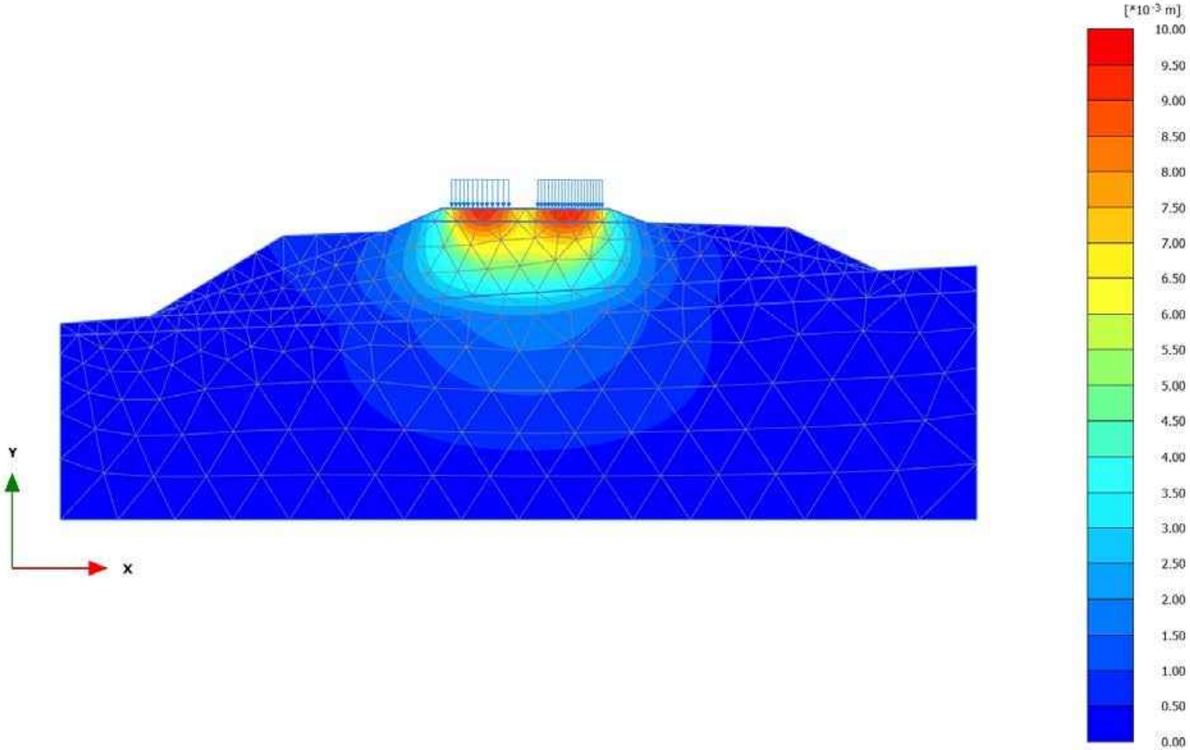
PLAXIS Report

1.1.1.1 Calculation results, Phase_4 [Phase_4] (4/22), Materials plot



Materials plot

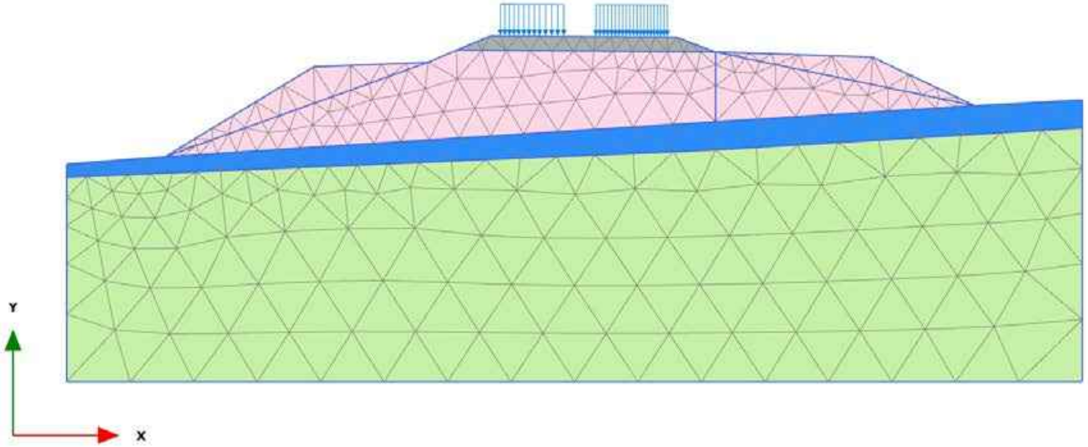
2.1.1.1.1 Calculation results, Phase_4 [Phase_4] (4/22), Total displacements |u|



Total displacements |u| (scaled up 100 times)

Maximum value = $9.531*10^{-3}$ m (Element 14 at Node 1327)

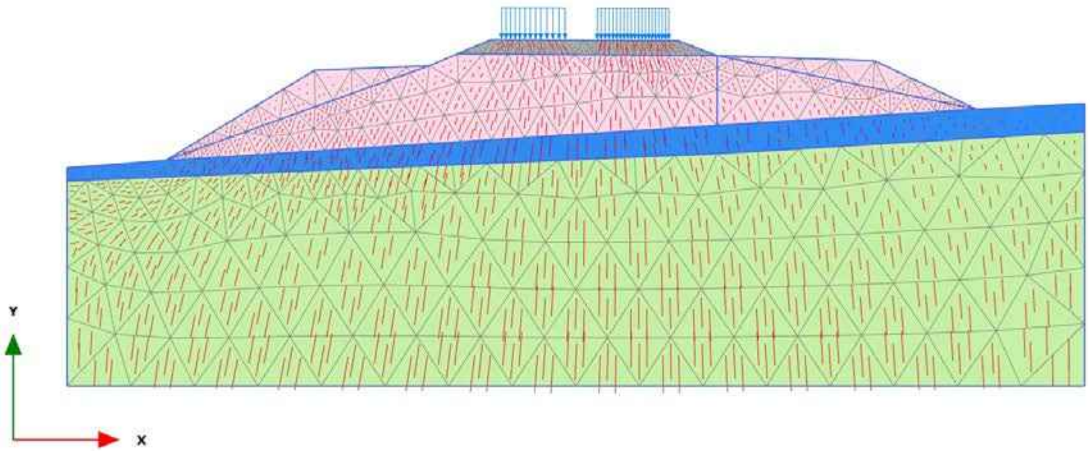
2.2.1.1.1 Calculation results, Phase_4 [Phase_4] (4/22), Excess pore pressures p_{excess}



Excess pore pressures p_{excess} (scaled up 1.00 times) (Pressure = negative)

Uniform value of 0.000 kN/m²

2.2.2.1.1 Calculation results, Phase_4 [Phase_4] (4/22), Principal total stress σ_1

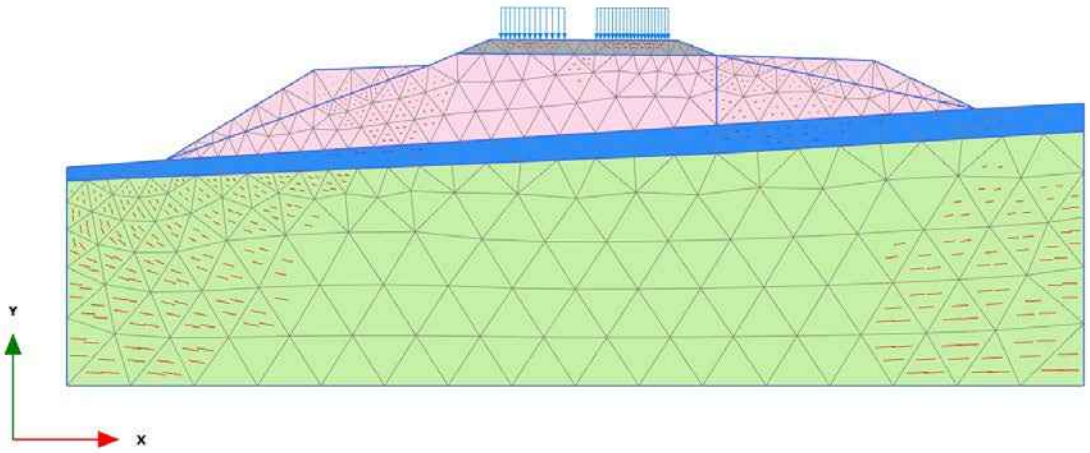


Principal total stress σ_1 (scaled up $5.00*10^{-3}$ times)

Maximum value = $3.553*10^{-15}$ kN/m^2 (Element 13 at Stress point 145)

Minimum value = -276.2 kN/m^2 (Element 306 at Stress point 3669)

2.2.2.2.1 Calculation results, Phase_4 [Phase_4] (4/22), Principal total stress σ_2

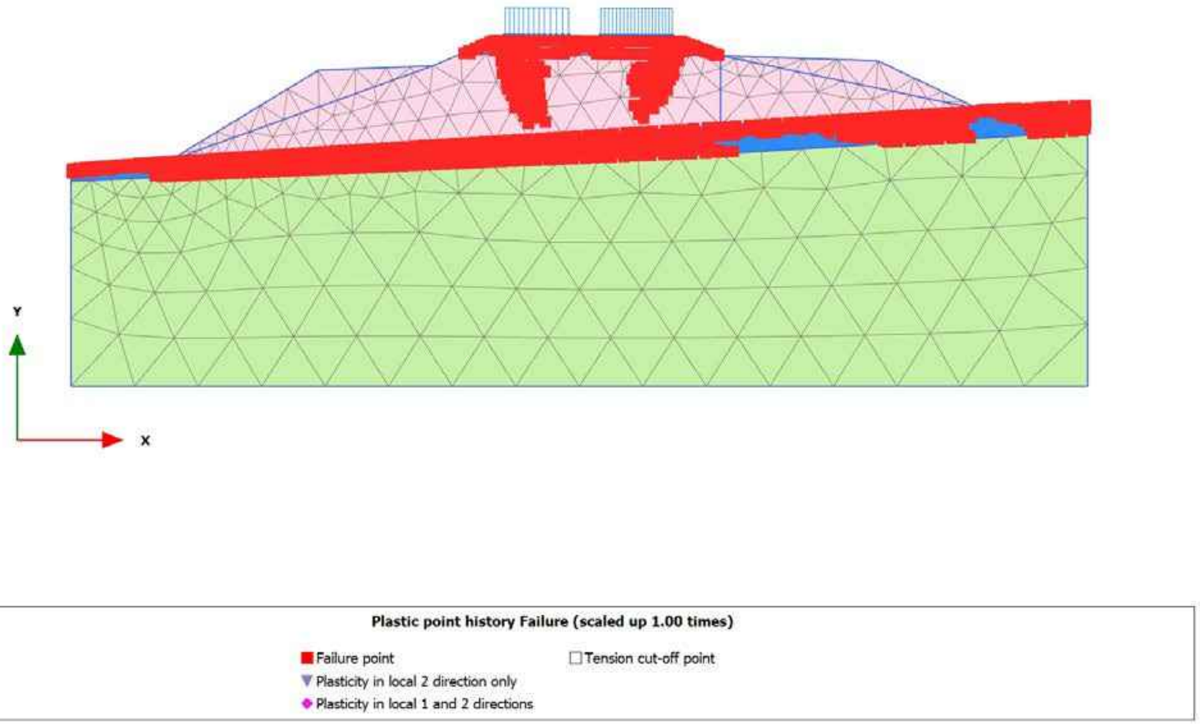


Principal total stress σ_2 (scaled up $5.00*10^{-3}$ times)

Maximum value = $3.553*10^{-15}$ kN/m² (Element 13 at Stress point 156)

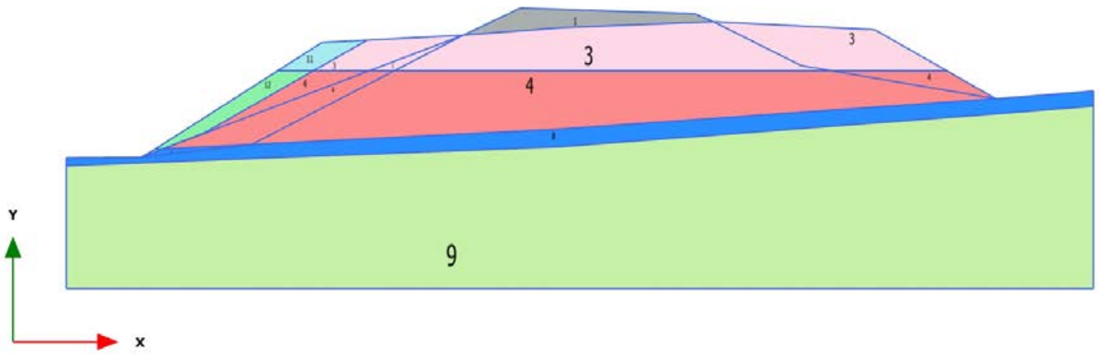
Minimum value = -166.4 kN/m² (Element 306 at Stress point 3670)

2.2.3.1.1 Calculation results, Phase_4 [Phase_4] (4/22), Plastic point history Failure



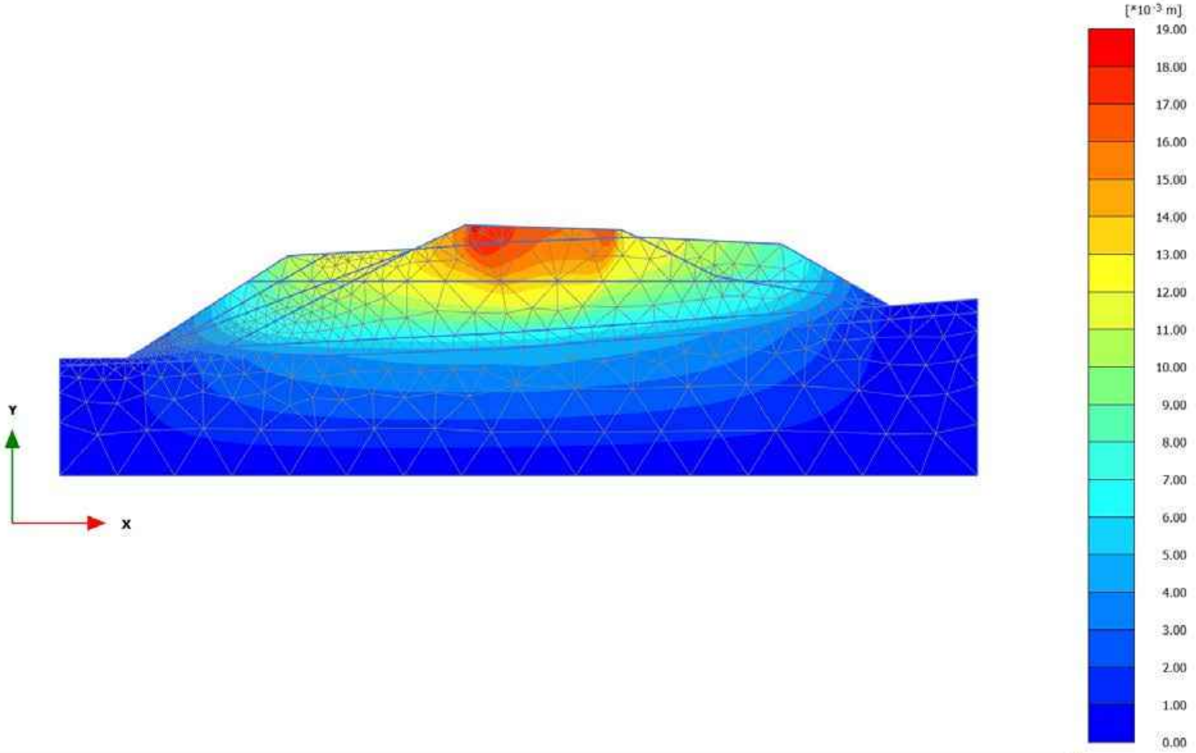
PLAXIS Report

1.1.1.1 Calculation results, Phase_6 [Phase_6] (6/66), Materials plot



Materials plot

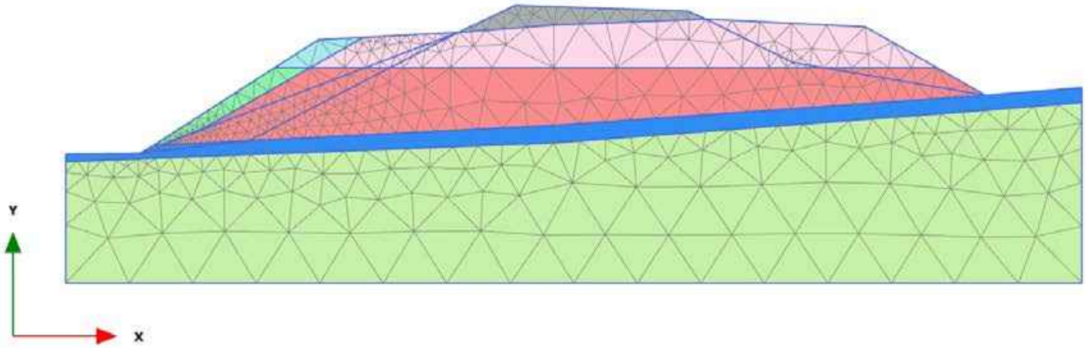
2.1.1.1.1 Calculation results, Phase_6 [Phase_6] (6/66), Total displacements |u|



Total displacements |u| (scaled up 50.0 times)

Maximum value = 0.01830 m (Element 31 at Node 4677)

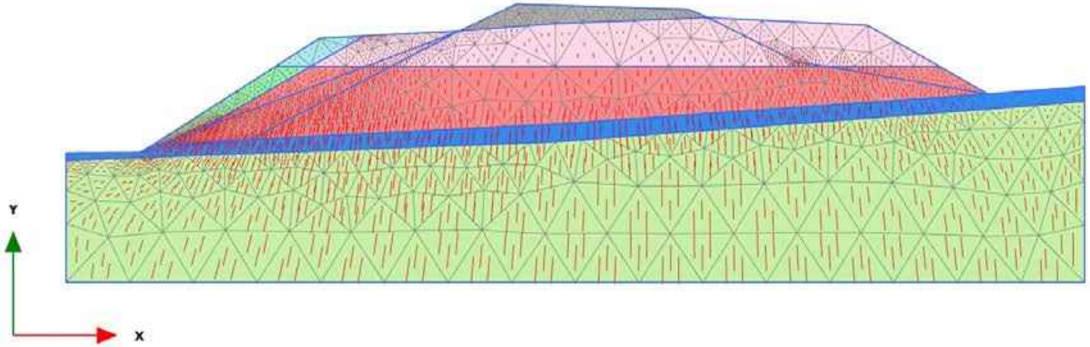
2.2.1.1.1 Calculation results, Phase_6 [Phase_6] (6/66), Excess pore pressures p_{excess}



Excess pore pressures p_{excess} (scaled up 1.00 times) (Pressure = negative)

Uniform value of 0.000 kN/m²

2.2.2.1.1 Calculation results, Phase_6 [Phase_6] (6/66), Principal total stress σ_1

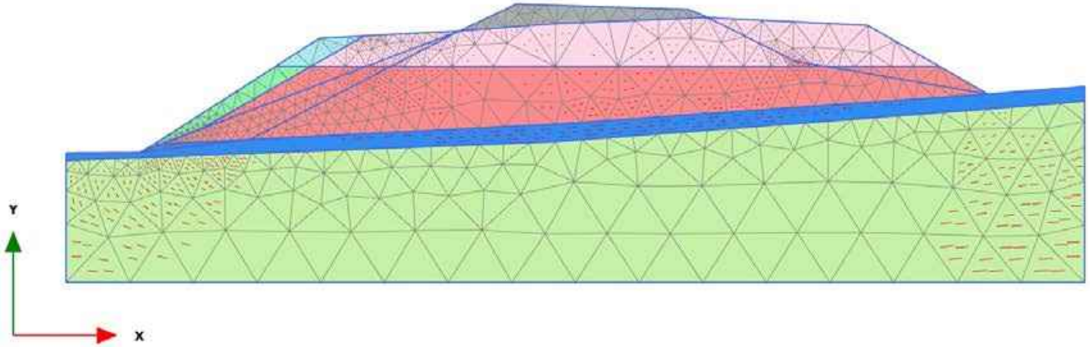


Principal total stress σ_1 (scaled up $5.00*10^{-3}$ times)

Maximum value = 0.000 kN/m² (Element 16 at Stress point 182)

Minimum value = -226.7 kN/m² (Element 746 at Stress point 8949)

2.2.2.2.1 Calculation results, Phase_6 [Phase_6] (6/66), Principal total stress σ_2

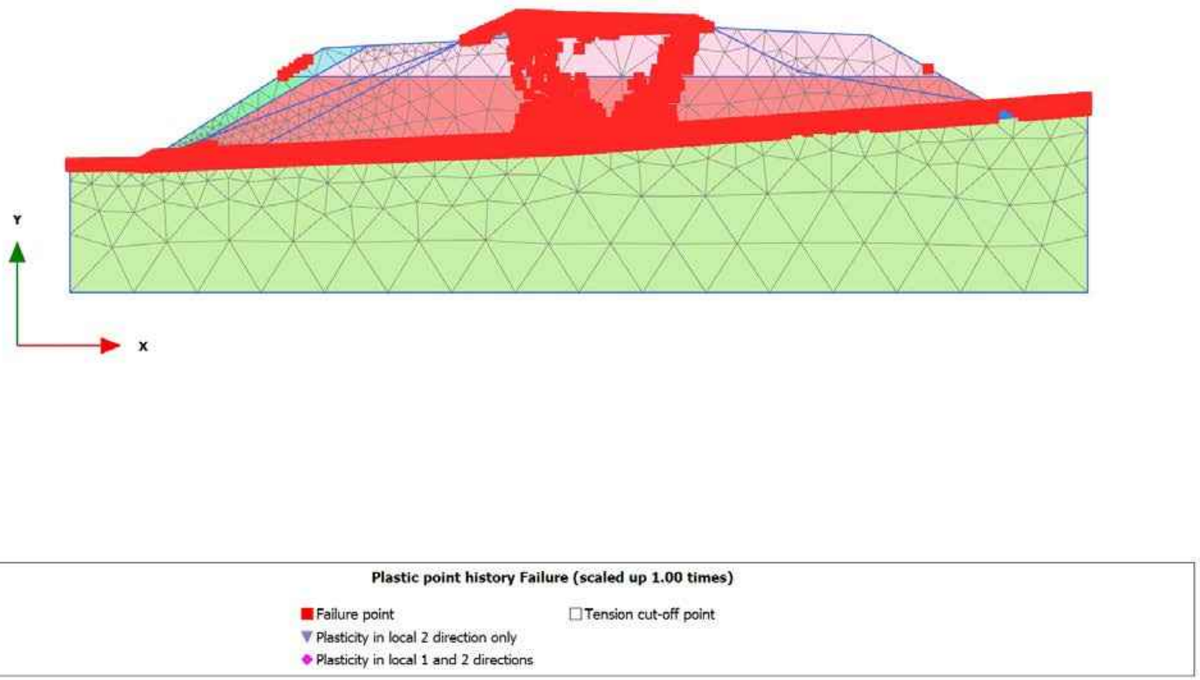


Principal total stress σ_2 (scaled up $5.00*10^{-3}$ times)

Maximum value = $0.05551*10^{-15}$ kN/m² (Element 16 at Stress point 182)

Minimum value = -129.8 kN/m² (Element 747 at Stress point 8961)

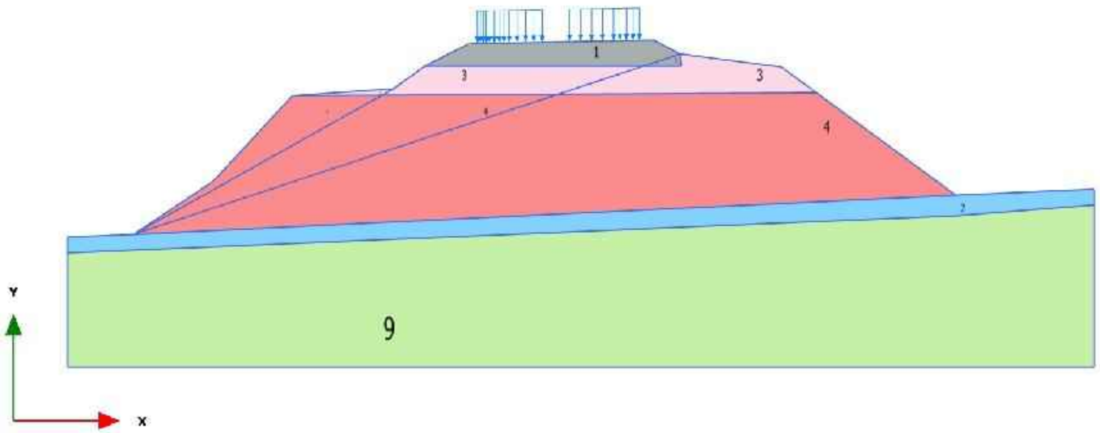
2.2.3.1.1 Calculation results, Phase_6 [Phase_6] (6/66), Plastic point history Failure



P2607_Bargo_Section 4

PLAXIS Report

1.1.1.1 Calculation results, Phase_3 [Phase_3] (3/16), Materials plot



Materials plot

1.1.2.1.1.1 Materials - Soil and interfaces - Mohr-Coulomb (1/3)

Identification number		1	2	3	4	5
Identification		P2607 - 1A	P2607 - 1B	P2607 - 2A	P2607 - 2B	P2607 - 2C
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		⬛	⬜	🟪	🟥	🟨
Comments						
γ_unsat	kN/m³	20.00	20.00	18.00	19.00	20.00
γ_sat	kN/m³	20.50	20.50	19.00	20.00	20.50
e_init		0.5000	0.5000	0.5000	0.5000	0.5000
n_init		0.3333	0.3333	0.3333	0.3333	0.3333
Identification number		1	2	3	4	5
Identification		P2607 - 1A	P2607 - 1B	P2607 - 2A	P2607 - 2B	P2607 - 2C
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		⬛	⬜	🟪	🟥	🟨
Comments						
E'_ref	kN/m²	50.00E3	50.00E3	15.00E3	20.00E3	30.00E3
ν (nu)		0.2500	0.2500	0.3000	0.2500	0.2500
Determination		ν-undrained definition	ν-undrained definition	ν-undrained definition	ν-undrained definition	ν-undrained definition
ν_u definition method		Direct	Direct	Direct	Direct	Direct
ν_u,equivalent (nu)		0.4950	0.4950	0.4950	0.4950	0.4950

Identification number		1	2	3	4	5
Skempton B		0.9833	0.9833	0.9783	0.9833	0.9833
K_w,ref/n	kN/m²	1.960E6	1.960E6	562.5E3	784.0E3	1.176E6
Identification number		1	2	3	4	5
Identification		P2607 - 1A	P2607 - 1B	P2607 - 2A	P2607 - 2B	P2607 - 2C
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		⬛	⬜	🟪	🟥	🟨
Comments						
Classification type		Standard	Standard	Standard	Standard	Standard
Soil class (Standard)		Coarse	Coarse	Coarse	Coarse	Coarse
< 2 µm	%	10.00	10.00	10.00	10.00	10.00
2 µm - 50 µm	%	13.00	13.00	13.00	13.00	13.00
50 µm - 2 mm	%	77.00	77.00	77.00	77.00	77.00
Identification number		1	2	3	4	5
Identification		P2607 - 1A	P2607 - 1B	P2607 - 2A	P2607 - 2B	P2607 - 2C
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		⬛	⬜	🟪	🟥	🟨
Comments						
c_s	kJ/t/K	0.000	0.000	0.000	0.000	0.000
λ_s	kW/m/K	0.000	0.000	0.000	0.000	0.000
ρ_s	t/m³	2.600	2.600	2.600	2.600	2.600
Thermal expansion type		Isotropic	Isotropic	Isotropic	Isotropic	Isotropic
α_sv	1/K	0.000	0.000	0.000	0.000	0.000

Identification number		1	2	3	4	5
Phase change		False	False	False	False	False
D_v	m²/day	0.000	0.000	0.000	0.000	0.000
f_Tv		0.000	0.000	0.000	0.000	0.000
Identification number		1	2	3	4	5
Identification		P2607 - 1A	P2607 - 1B	P2607 - 2A	P2607 - 2B	P2607 - 2C
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		⬛	⬜	🟪	🟥	🟨
Comments						
Stiffness determination		Derived	Derived	Derived	Derived	Derived
Strength determination		Manual	Manual	Manual	Manual	Manual
R_inter		0.6700	0.6700	0.6700	0.6700	0.6700
Consider gap closure		True	True	True	True	True
Cross permeability		Impermeable	Impermeable	Impermeable	Impermeable	Impermeable
Drainage conductivity, dk	m³/day/m	0.000	0.000	0.000	0.000	0.000
R_thermal	m² K/kW	0.000	0.000	0.000	0.000	0.000
Identification number		1	2	3	4	5
Identification		P2607 - 1A	P2607 - 1B	P2607 - 2A	P2607 - 2B	P2607 - 2C
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		⬛	⬜	🟪	🟥	🟨
Comments						
K_0 determination		Automatic	Automatic	Automatic	Automatic	Automatic
K_0,x		0.3572	0.4122	0.5305	0.5000	0.4554

Identification number	1	2	3	4	5
K_0,z	0.3572	0.4122	0.5305	0.5000	0.4554

1.1.2.1.1.2 Materials - Soil and interfaces - Mohr-Coulomb (2/3)

Identification number		6	7	8	9	10
Identification		P2607 - 3	P2607 - 4A	P2607 - 4B	P2607 - 5	P2607 - 1A FoS
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		🟧	🟦	🟦	🟩	⬛
Comments						
γ_unsat	kN/m³	19.00	18.00	19.00	23.00	20.00
γ_sat	kN/m³	20.00	19.00	20.00	24.00	20.50
e_init		0.5000	0.5000	0.5000	0.5000	0.5000
n_init		0.3333	0.3333	0.3333	0.3333	0.3333
Identification number		6	7	8	9	10
Identification		P2607 - 3	P2607 - 4A	P2607 - 4B	P2607 - 5	P2607 - 1A FoS
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		🟧	🟦	🟦	🟩	⬛
Comments						
E'_ref	kN/m²	15.00E3	15.00E3	20.00E3	80.00E3	50.00E3
ν (nu)		0.2500	0.3000	0.2500	0.2500	0.2500
Determination		ν-undrained definition	ν-undrained definition	ν-undrained definition	ν-undrained definition	ν-undrained definition
ν_u definition method		Direct	Direct	Direct	Direct	Direct
ν_u,equivalent (nu)		0.4950	0.4950	0.4950	0.4950	0.4950

Identification number		6	7	8	9	10
Skempton B		0.9833	0.9783	0.9833	0.9833	0.9833
K_w,ref/n	kN/m²	588.0E3	562.5E3	784.0E3	3.136E6	1.960E6
Identification number		6	7	8	9	10
Identification		P2607 - 3	P2607 - 4A	P2607 - 4B	P2607 - 5	P2607 - 1A FoS
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		🟧	🟦	🟦	🟩	⬜
Comments						
Classification type		Standard	Standard	Standard	Standard	Standard
Soil class (Standard)		Coarse	Coarse	Coarse	Coarse	Coarse
< 2 µm	%	10.00	10.00	10.00	10.00	10.00
2 µm - 50 µm	%	13.00	13.00	13.00	13.00	13.00
50 µm - 2 mm	%	77.00	77.00	77.00	77.00	77.00
Identification number		6	7	8	9	10
Identification		P2607 - 3	P2607 - 4A	P2607 - 4B	P2607 - 5	P2607 - 1A FoS
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		🟧	🟦	🟦	🟩	⬜
Comments						
c_s	kJ/t/K	0.000	0.000	0.000	0.000	0.000
λ_s	kW/m/K	0.000	0.000	0.000	0.000	0.000
ρ_s	t/m³	2.600	2.600	2.600	2.600	2.600
Thermal expansion type		Isotropic	Isotropic	Isotropic	Isotropic	Isotropic
α_sv	1/K	0.000	0.000	0.000	0.000	0.000

Identification number		6	7	8	9	10
Phase change		False	False	False	False	False
D_v	m²/day	0.000	0.000	0.000	0.000	0.000
f_Tv		0.000	0.000	0.000	0.000	0.000
Identification number		6	7	8	9	10
Identification		P2607 - 3	P2607 - 4A	P2607 - 4B	P2607 - 5	P2607 - 1A FoS
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		🟧	🟦	🟦	🟩	⬛
Comments						
Stiffness determination		Derived	Derived	Derived	Derived	Derived
Strength determination		Manual	Manual	Manual	Manual	Manual
R_inter		0.6700	0.6700	0.6700	0.6700	0.6700
Consider gap closure		True	True	True	True	True
Cross permeability		Impermeable	Impermeable	Impermeable	Impermeable	Impermeable
Drainage conductivity, dk	m³/day/m	0.000	0.000	0.000	0.000	0.000
R_thermal	m² K/kW	0.000	0.000	0.000	0.000	0.000
Identification number		6	7	8	9	10
Identification		P2607 - 3	P2607 - 4A	P2607 - 4B	P2607 - 5	P2607 - 1A FoS
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		🟧	🟦	🟦	🟩	⬛
Comments						
K_0 determination		Automatic	Automatic	Automatic	Automatic	Automatic
K_0,x		0.5000	0.5774	0.5000	0.4264	0.2929

Identification number	6	7	8	9	10
K_0,z	0.5000	0.5774	0.5000	0.4264	0.2929

1.1.2.1.1.3 Materials - Soil and interfaces - Mohr-Coulomb (3/3)

Identification number		11	12	13
Identification		P2607 - 2A - Shallow	P2607 - 2B - Shallow	P2607 - 4B - Shallow
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained
Colour		🟦	🟩	🟨
Comments				
γ_unsat	kN/m³	18.00	19.00	19.00
γ_sat	kN/m³	19.00	20.00	20.00
e_init		0.5000	0.5000	0.5000
n_init		0.3333	0.3333	0.3333

Identification number		11	12	13
Identification		P2607 - 2A - Shallow	P2607 - 2B - Shallow	P2607 - 4B - Shallow
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained
Colour		🟦	🟩	🟨
Comments				

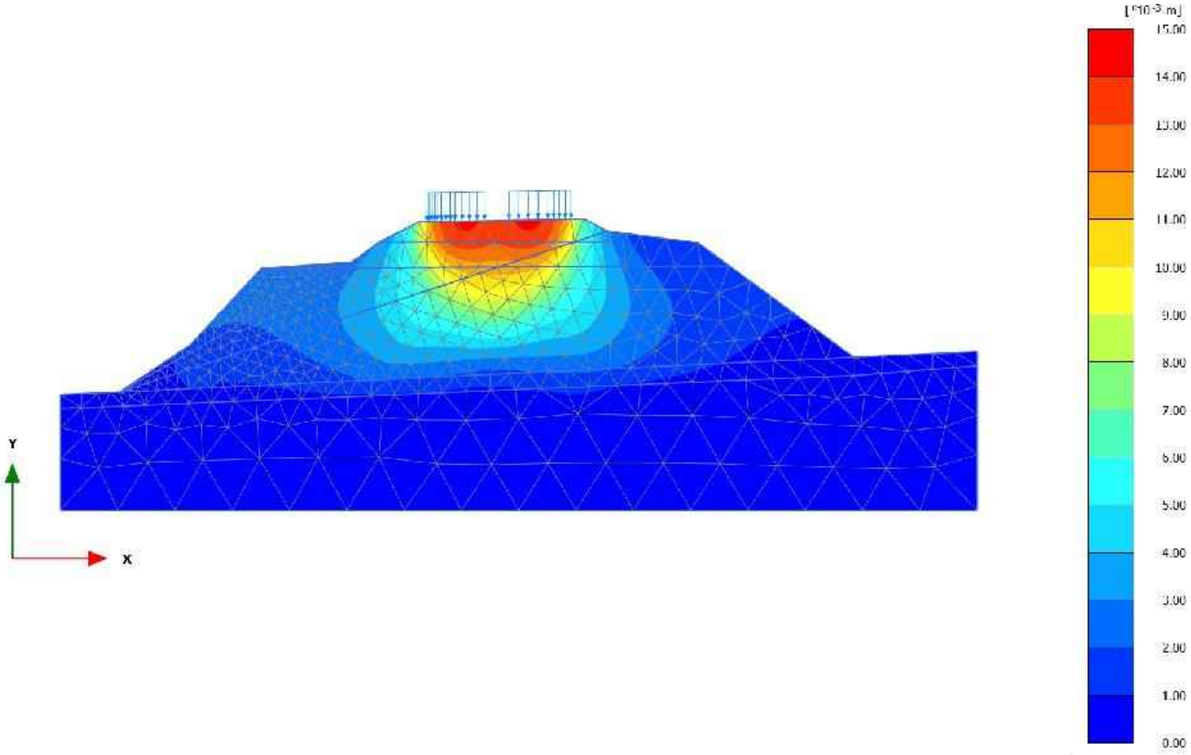
Identification number		11	12	13
E'_ref	kN/m²	15.00E3	20.00E3	20.00E3
ν (nu)		0.3000	0.2500	0.2500
Determination		ν-undrained definition	ν-undrained definition	ν-undrained definition
ν_u definition method		Direct	Direct	Direct
ν_u,equivalent (nu)		0.4950	0.4950	0.4950
Skempton B		0.9783	0.9833	0.9833
K_w,ref/n	kN/m²	562.5E3	784.0E3	784.0E3
Identification number		11	12	13
Identification		P2607 - 2A - Shallow	P2607 - 2B - Shallow	P2607 - 4B - Shallow
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained
Colour		🟦	🟩	🟨
Comments				
Classification type		Standard	Standard	Standard
Soil class (Standard)		Coarse	Coarse	Coarse
< 2 μm	%	10.00	10.00	10.00
2 μm - 50 μm	%	13.00	13.00	13.00
50 μm - 2 mm	%	77.00	77.00	77.00
Identification number		11	12	13

Identification number		11	12	13
Identification		P2607 - 2A - Shallow	P2607 - 2B - Shallow	P2607 - 4B - Shallow
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained
Colour		🟦	🟩	🟨
Comments				
c_s	kJ/t/K	0.000	0.000	0.000
λ_s	kW/m/K	0.000	0.000	0.000
ρ_s	t/m^3	2.600	2.600	2.600
Thermal expansion type		Isotropic	Isotropic	Isotropic
α_sv	1/K	0.000	0.000	0.000
Phase change		False	False	False
D_v	m^2/day	0.000	0.000	0.000
f_Tv		0.000	0.000	0.000

Identification number		11	12	13
Identification		P2607 - 2A - Shallow	P2607 - 2B - Shallow	P2607 - 4B - Shallow
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained
Colour		🟦	🟩	🟨
Comments				

Identification number		11	12	13
Stiffness determination		Derived	Derived	Derived
Strength determination		Manual	Manual	Manual
R_inter		0.6700	0.6700	0.6700
Consider gap closure		True	True	True
Cross permeability		Impermeable	Impermeable	Impermeable
Drainage conductivity, dk	m³/day/m	0.000	0.000	0.000
R_thermal	m² K/kW	0.000	0.000	0.000
Identification number		11	12	13
Identification		P2607 - 2A - Shallow	P2607 - 2B - Shallow	P2607 - 4B - Shallow
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained
Colour		🟦	🟩	🟨
Comments				
K_0 determination		Automatic	Automatic	Automatic
K_0,x		0.4264	0.4264	0.4264
K_0,z		0.4264	0.4264	0.4264

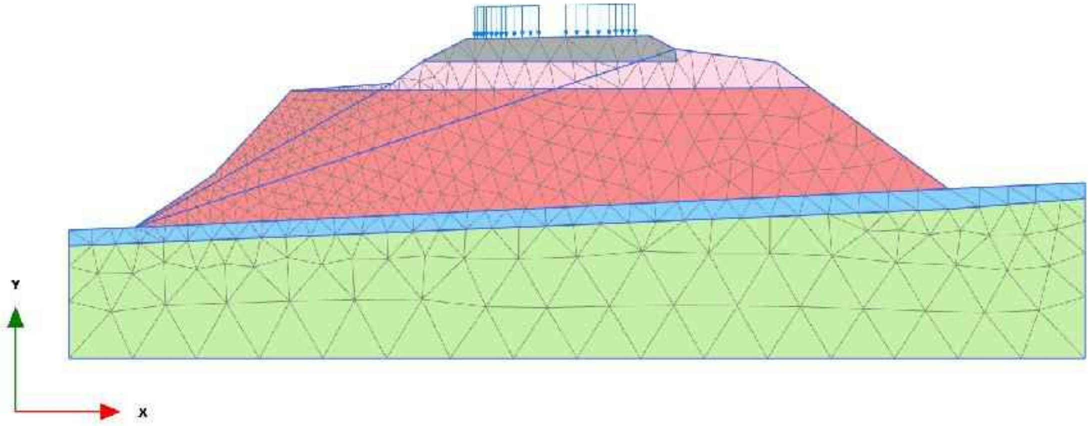
2.1.1.1.1 Calculation results, Phase_3 [Phase_3] (3/16), Total displacements |u|



Total displacements |u| (scaled up 50.0 times)

Maximum value = 0.01433 m (Element 1 at Node 1846)

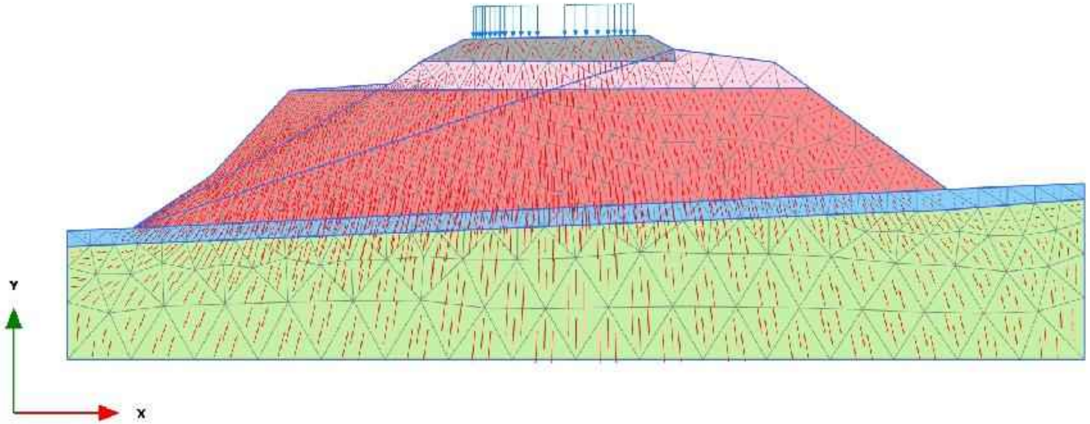
2.2.1.1.1 Calculation results, Phase_3 [Phase_3] (3/16), Excess pore pressures p_{excess}



Excess pore pressures p_{excess} (scaled up 1.00 times) (Pressure = negative)

Uniform value of 0.000 kN/m²

2.2.2.1.1 Calculation results, Phase_3 [Phase_3] (3/16), Principal total stress σ_1

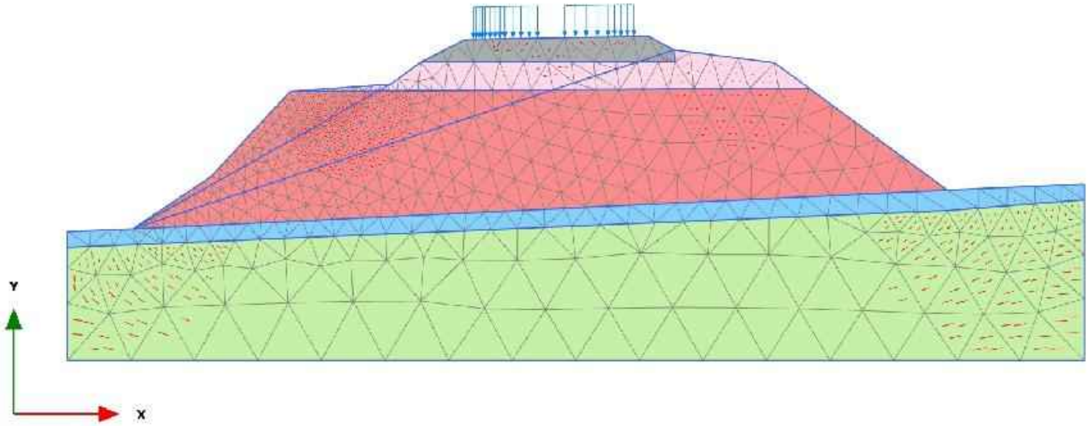


Principal total stress σ_1 (scaled up $5.00*10^{-3}$ times)

Maximum value = 0.000 kN/m² (Element 18 at Stress point 206)

Minimum value = -255.0 kN/m² (Element 717 at Stress point 8601)

2.2.2.2.1 Calculation results, Phase_3 [Phase_3] (3/16), Principal total stress σ_2

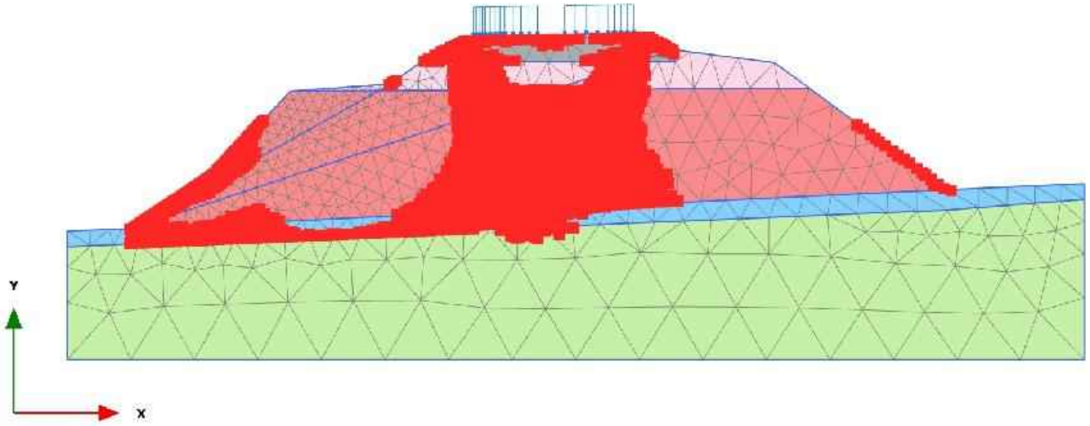


Principal total stress σ_2 (scaled up $5.00*10^{-3}$ times)

Maximum value = $0.4441*10^{-15}$ kN/m² (Element 18 at Stress point 206)

Minimum value = -134.5 kN/m² (Element 717 at Stress point 8601)

2.2.3.1.1 Calculation results, Phase_3 [Phase_3] (3/16), Plastic point history Failure



Plastic point history Failure (scaled up 1.00 times)

🟥 Failure point

▼ Plasticity in local 2 direction only

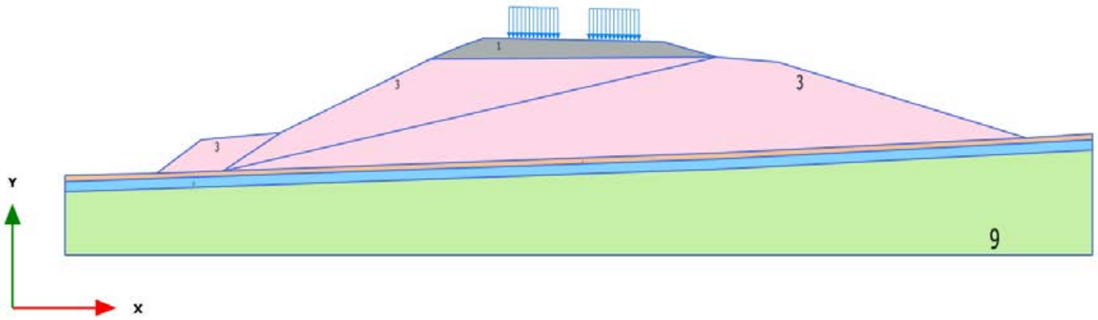
◆ Plasticity in local 1 and 2 directions

⌶ Tension cut-off point

P2607_Bargo_Section 5

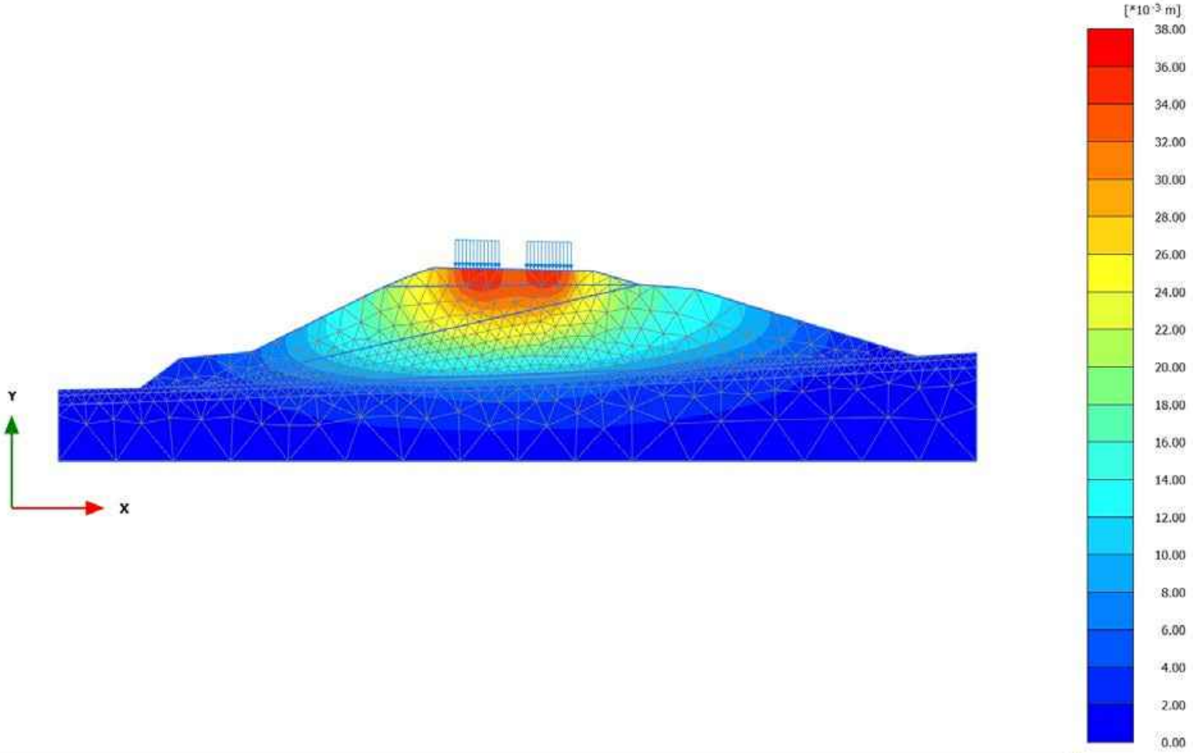
PLAXIS Report

1.1.1.1 Calculation results, Phase_3 [Phase_3] (3/73), Materials plot



Materials plot

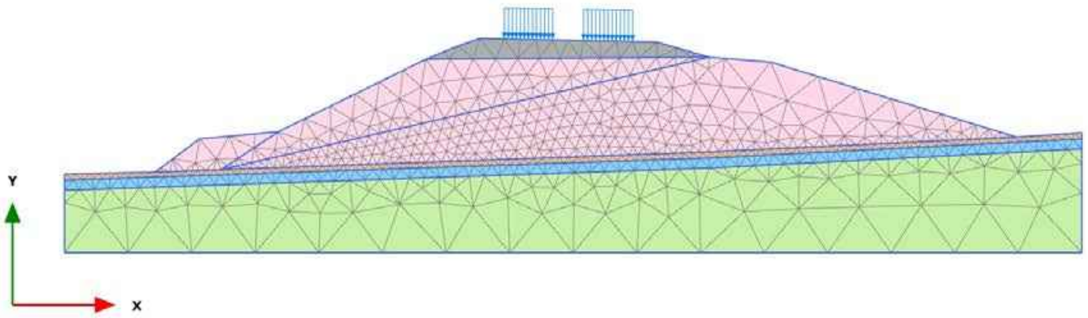
2.1.1.1.1 Calculation results, Phase_3 [Phase_3] (3/73), Total displacements |u|



Total displacements |u| (scaled up 50.0 times)

Maximum value = 0.03608 m (Element 19 at Node 9619)

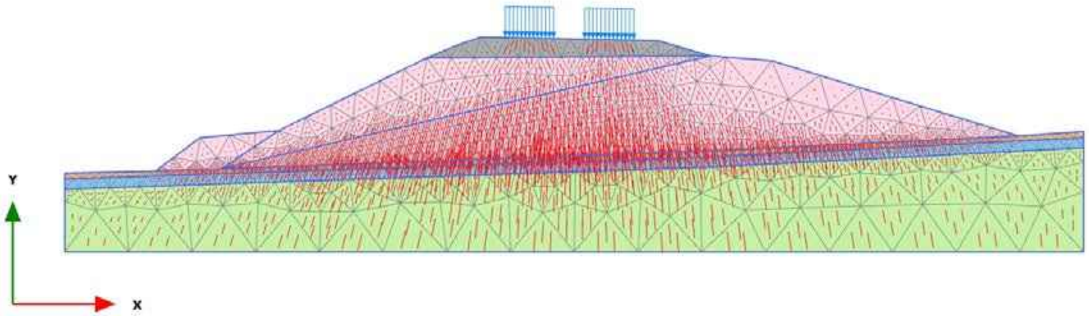
2.2.1.1.1 Calculation results, Phase_3 [Phase_3] (3/73), Excess pore pressures p_{excess}



Excess pore pressures p_{excess} (scaled up 1.00 times) (Pressure = negative)

Uniform value of 0.000 kN/m²

2.2.2.1.1 Calculation results, Phase_3 [Phase_3] (3/73), Principal total stress σ_1

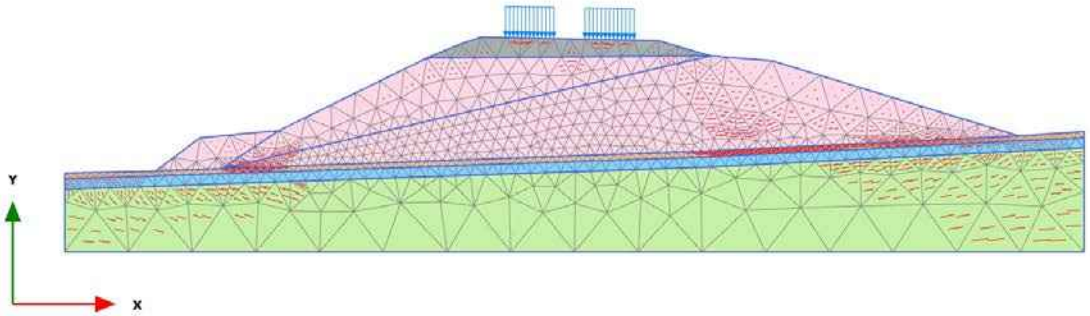


Principal total stress σ_1 (scaled up $5.00*10^{-3}$ times)

Maximum value = $0.7772*10^{-15}$ kN/m² (Element 6 at Stress point 62)

Minimum value = -222.8 kN/m² (Element 1072 at Stress point 12854)

2.2.2.2.1 Calculation results, Phase_3 [Phase_3] (3/73), Principal total stress σ_2

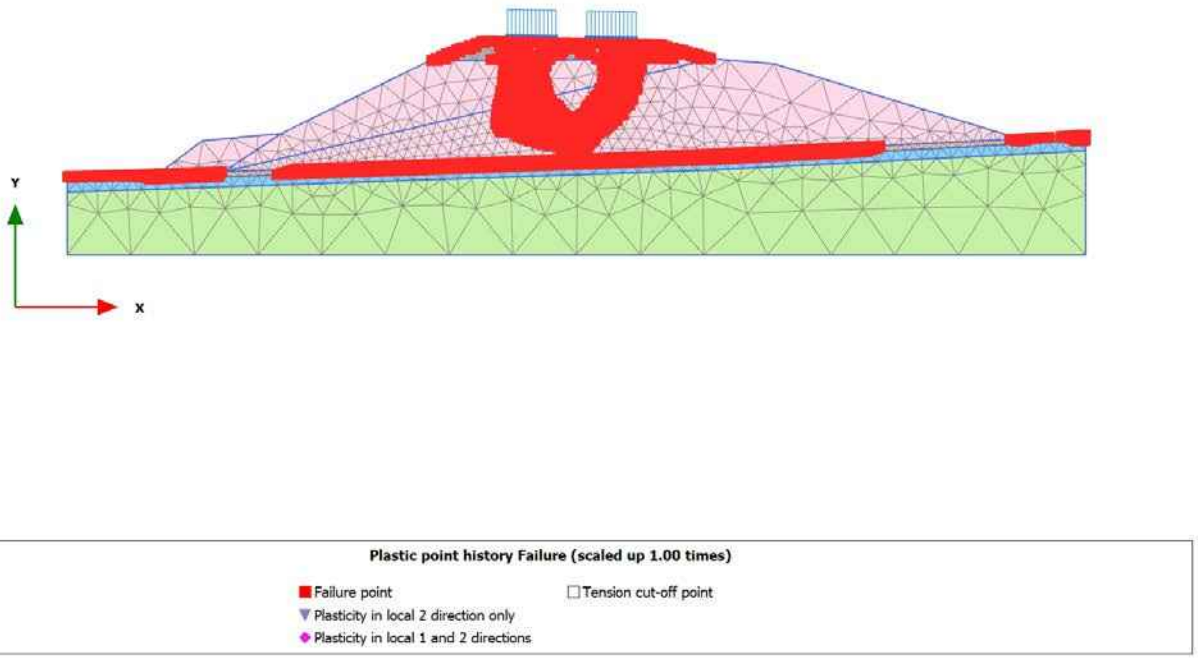


Principal total stress σ_2 (scaled up 0.0100 times)

Maximum value = $0.2498*10^{-15}$ kN/m² (Element 24 at Stress point 277)

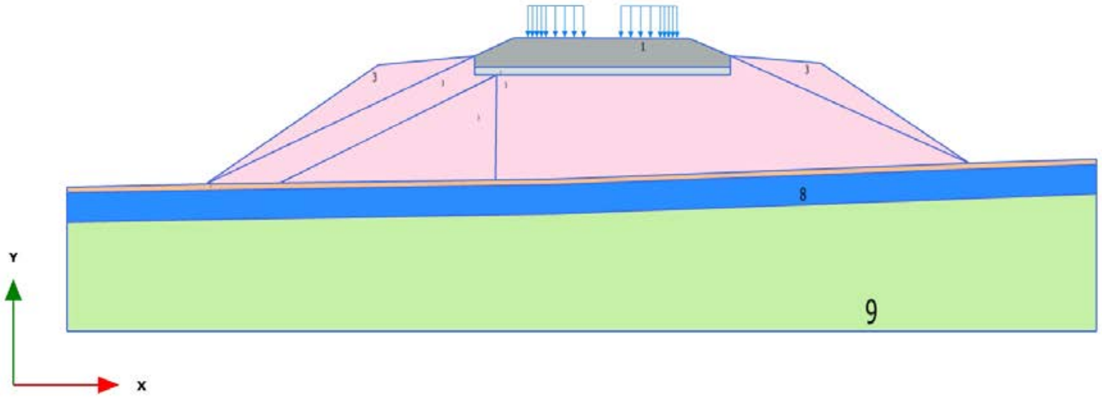
Minimum value = -114.9 kN/m² (Element 1072 at Stress point 12861)

2.2.3.1.1 Calculation results, Phase_3 [Phase_3] (3/73), Plastic point history Failure



PLAXIS Report

1.1.1.1 Calculation results, Phase_2 [Phase_2] (2/9), Materials plot



Materials plot

1.1.2.1.1.1 Materials - Soil and interfaces - Mohr-Coulomb (1/3)

Identification number		1	2	3	4	5
Identification		P2607 - 1A	P2607 - 1B	P2607 - 2A	P2607 - 2B	P2607 - 2C
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		⬛	⬜	🟥	🟥	🟨
Comments						
γ_unsat	kN/m³	20.00	20.00	18.00	19.00	20.00
γ_sat	kN/m³	20.50	20.50	19.00	20.00	20.50
e_init		0.5000	0.5000	0.5000	0.5000	0.5000
n_init		0.3333	0.3333	0.3333	0.3333	0.3333
Identification number		1	2	3	4	5
Identification		P2607 - 1A	P2607 - 1B	P2607 - 2A	P2607 - 2B	P2607 - 2C
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		⬛	⬜	🟥	🟥	🟨
Comments						
E'_ref	kN/m²	50.00E3	50.00E3	15.00E3	20.00E3	30.00E3
ν (nu)		0.2500	0.2500	0.3000	0.2500	0.2500
Determination		ν-undrained definition	ν-undrained definition	ν-undrained definition	ν-undrained definition	ν-undrained definition
ν_u definition method		Direct	Direct	Direct	Direct	Direct
ν_u,equivalent (nu)		0.4950	0.4950	0.4950	0.4950	0.4950

Identification number		1	2	3	4	5
Skempton B		0.9833	0.9833	0.9783	0.9833	0.9833
K_w,ref/n	kN/m²	1.960E6	1.960E6	562.5E3	784.0E3	1.176E6
Identification number		1	2	3	4	5
Identification		P2607 - 1A	P2607 - 1B	P2607 - 2A	P2607 - 2B	P2607 - 2C
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		■	■	■	■	■
Comments						
Classification type		Standard	Standard	Standard	Standard	Standard
Soil class (Standard)		Coarse	Coarse	Coarse	Coarse	Coarse
< 2 µm	%	10.00	10.00	10.00	10.00	10.00
2 µm - 50 µm	%	13.00	13.00	13.00	13.00	13.00
50 µm - 2 mm	%	77.00	77.00	77.00	77.00	77.00
Identification number		1	2	3	4	5
Identification		P2607 - 1A	P2607 - 1B	P2607 - 2A	P2607 - 2B	P2607 - 2C
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		■	■	■	■	■
Comments						
c_s	kJ/t/K	0.000	0.000	0.000	0.000	0.000
λ_s	kW/m/K	0.000	0.000	0.000	0.000	0.000
ρ_s	t/m³	2.600	2.600	2.600	2.600	2.600
Thermal expansion type		Isotropic	Isotropic	Isotropic	Isotropic	Isotropic
α_sv	1/K	0.000	0.000	0.000	0.000	0.000

Identification number		1	2	3	4	5
Phase change		False	False	False	False	False
D_v	m²/day	0.000	0.000	0.000	0.000	0.000
f_Tv		0.000	0.000	0.000	0.000	0.000
Identification number		1	2	3	4	5
Identification		P2607 - 1A	P2607 - 1B	P2607 - 2A	P2607 - 2B	P2607 - 2C
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		⬛	⬜	🟥	🟥	🟨
Comments						
Stiffness determination		Derived	Derived	Derived	Derived	Derived
Strength determination		Manual	Manual	Manual	Manual	Manual
R_inter		0.6700	0.6700	0.6700	0.6700	0.6700
Consider gap closure		True	True	True	True	True
Cross permeability		Impermeable	Impermeable	Impermeable	Impermeable	Impermeable
Drainage conductivity, dk	m³/day/m	0.000	0.000	0.000	0.000	0.000
R_thermal	m² K/kW	0.000	0.000	0.000	0.000	0.000
Identification number		1	2	3	4	5
Identification		P2607 - 1A	P2607 - 1B	P2607 - 2A	P2607 - 2B	P2607 - 2C
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		⬛	⬜	🟥	🟥	🟨
Comments						
K_0 determination		Automatic	Automatic	Automatic	Automatic	Automatic
K_0,x		0.3843	0.4122	0.5305	0.4701	0.4554

Identification number	1	2	3	4	5
K_0,z	0.3843	0.4122	0.5305	0.4701	0.4554

1.1.2.1.1.2 Materials - Soil and interfaces - Mohr-Coulomb (2/3)

Identification number		6	7	8	9	10
Identification		P2607 - 3	P2607 - 4A	P2607 - 4B	P2607 - 5	P2607 - 1A FoS
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		🟧	🟦	🟦	🟩	◼
Comments						
γ_unsat	kN/m³	19.00	18.00	19.00	23.00	20.00
γ_sat	kN/m³	20.00	19.00	20.00	24.00	20.50
e_init		0.5000	0.5000	0.5000	0.5000	0.5000
n_init		0.3333	0.3333	0.3333	0.3333	0.3333
Identification number		6	7	8	9	10
Identification		P2607 - 3	P2607 - 4A	P2607 - 4B	P2607 - 5	P2607 - 1A FoS
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		🟧	🟦	🟦	🟩	◼
Comments						
E'_ref	kN/m²	15.00E3	15.00E3	20.00E3	80.00E3	50.00E3
ν (nu)		0.2500	0.3000	0.2500	0.2500	0.2500
Determination		ν-undrained definition	ν-undrained definition	ν-undrained definition	ν-undrained definition	ν-undrained definition
ν_u definition method		Direct	Direct	Direct	Direct	Direct
ν_u,equivalent (nu)		0.4950	0.4950	0.4950	0.4950	0.4950

Identification number		6	7	8	9	10
Skempton B		0.9833	0.9783	0.9833	0.9833	0.9833
K_w,ref/n	kN/m²	588.0E3	562.5E3	784.0E3	3.136E6	1.960E6
Identification number		6	7	8	9	10
Identification		P2607 - 3	P2607 - 4A	P2607 - 4B	P2607 - 5	P2607 - 1A FoS
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		🟧	🟦	🟦	🟩	◼
Comments						
Classification type		Standard	Standard	Standard	Standard	Standard
Soil class (Standard)		Coarse	Coarse	Coarse	Coarse	Coarse
< 2 µm	%	10.00	10.00	10.00	10.00	10.00
2 µm - 50 µm	%	13.00	13.00	13.00	13.00	13.00
50 µm - 2 mm	%	77.00	77.00	77.00	77.00	77.00
Identification number		6	7	8	9	10
Identification		P2607 - 3	P2607 - 4A	P2607 - 4B	P2607 - 5	P2607 - 1A FoS
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		🟧	🟦	🟦	🟩	◼
Comments						
c_s	kJ/t/K	0.000	0.000	0.000	0.000	0.000
λ_s	kW/m/K	0.000	0.000	0.000	0.000	0.000
ρ_s	t/m³	2.600	2.600	2.600	2.600	2.600
Thermal expansion type		Isotropic	Isotropic	Isotropic	Isotropic	Isotropic
α_sv	1/K	0.000	0.000	0.000	0.000	0.000

Identification number		6	7	8	9	10
Phase change		False	False	False	False	False
D_v	m²/day	0.000	0.000	0.000	0.000	0.000
f_Tv		0.000	0.000	0.000	0.000	0.000
Identification number		6	7	8	9	10
Identification		P2607 - 3	P2607 - 4A	P2607 - 4B	P2607 - 5	P2607 - 1A FoS
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		🟧	🟦	🟦	🟩	⬛
Comments						
Stiffness determination		Derived	Derived	Derived	Derived	Derived
Strength determination		Manual	Manual	Manual	Manual	Manual
R_inter		0.6700	0.6700	0.6700	0.6700	0.6700
Consider gap closure		True	True	True	True	True
Cross permeability		Impermeable	Impermeable	Impermeable	Impermeable	Impermeable
Drainage conductivity, dk	m³/day/m	0.000	0.000	0.000	0.000	0.000
R_thermal	m² K/kW	0.000	0.000	0.000	0.000	0.000
Identification number		6	7	8	9	10
Identification		P2607 - 3	P2607 - 4A	P2607 - 4B	P2607 - 5	P2607 - 1A FoS
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained	Drained	Drained
Colour		🟧	🟦	🟦	🟩	⬛
Comments						
K_0 determination		Automatic	Automatic	Automatic	Automatic	Automatic
K_0,x		0.5000	0.5774	0.5000	0.4264	0.3572

Identification number	6	7	8	9	10
K_0,z	0.5000	0.5774	0.5000	0.4264	0.3572

1.1.2.1.1.3 Materials - Soil and interfaces - Mohr-Coulomb (3/3)

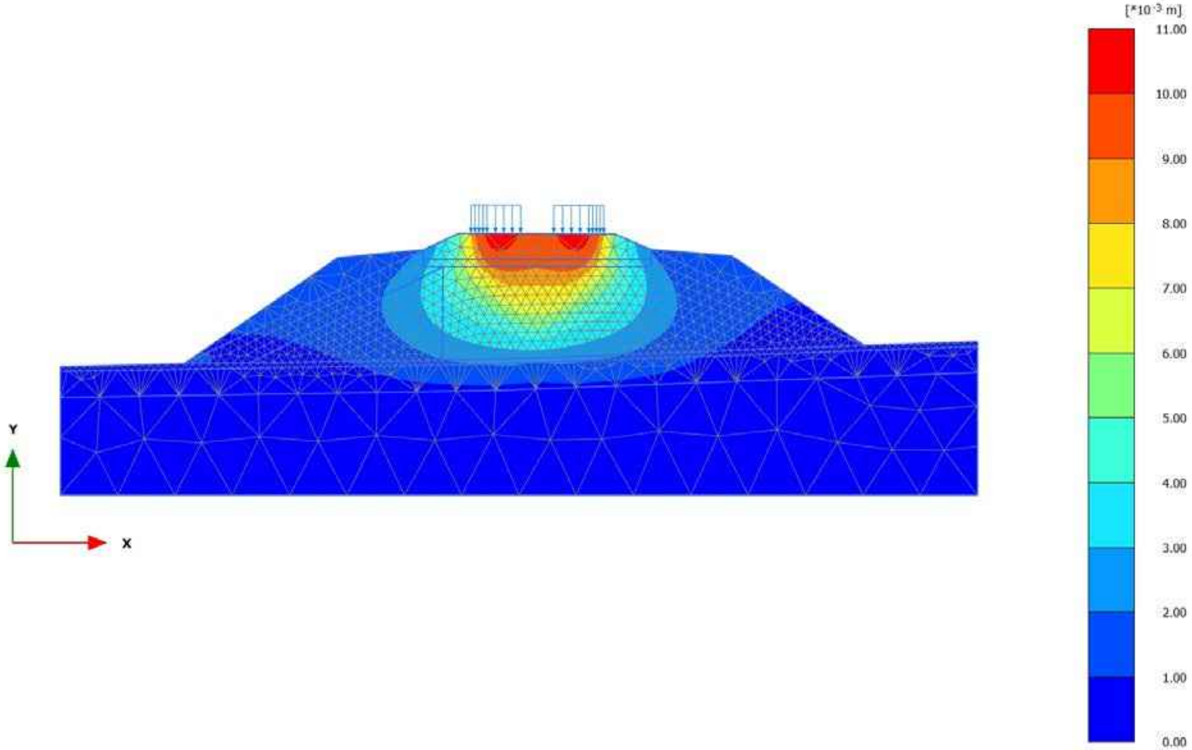
Identification number		11	12	13
Identification		P2607 - 2A - Shallow	P2607 - 2B - Shallow	P2607 - 4B - Shallow
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained
Colour		🟦	🟩	🟨
Comments				
γ_unsat	kN/m^3	18.00	19.00	19.00
γ_sat	kN/m^3	19.00	20.00	20.00
e_init		0.5000	0.5000	0.5000
n_init		0.3333	0.3333	0.3333
Identification number		11	12	13
Identification		P2607 - 2A - Shallow	P2607 - 2B - Shallow	P2607 - 4B - Shallow
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained
Colour		🟦	🟩	🟨
Comments				

Identification number		11	12	13
E'_ref	kN/m²	15.00E3	20.00E3	20.00E3
ν (nu)		0.3000	0.2500	0.2500
Determination		ν-undrained definition	ν-undrained definition	ν-undrained definition
ν_u definition method		Direct	Direct	Direct
ν_u,equivalent (nu)		0.4950	0.4950	0.4950
Skempton B		0.9783	0.9833	0.9833
K_w,ref/n	kN/m²	562.5E3	784.0E3	784.0E3
Identification number		11	12	13
Identification		P2607 - 2A - Shallow	P2607 - 2B - Shallow	P2607 - 4B - Shallow
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained
Colour		🟦	🟩	🟨
Comments				
Classification type		Standard	Standard	Standard
Soil class (Standard)		Coarse	Coarse	Coarse
< 2 μm	%	10.00	10.00	10.00
2 μm - 50 μm	%	13.00	13.00	13.00
50 μm - 2 mm	%	77.00	77.00	77.00
Identification number		11	12	13

Identification number		11	12	13
Identification		P2607 - 2A - Shallow	P2607 - 2B - Shallow	P2607 - 4B - Shallow
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained
Colour		🟦	🟩	🟨
Comments				
c_s	kJ/t/K	0.000	0.000	0.000
λ_s	kW/m/K	0.000	0.000	0.000
ρ_s	t/m³	2.600	2.600	2.600
Thermal expansion type		Isotropic	Isotropic	Isotropic
α_sv	1/K	0.000	0.000	0.000
Phase change		False	False	False
D_v	m²/day	0.000	0.000	0.000
f_Tv		0.000	0.000	0.000
Identification number		11	12	13
Identification		P2607 - 2A - Shallow	P2607 - 2B - Shallow	P2607 - 4B - Shallow
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained
Colour		🟦	🟩	🟨
Comments				

Identification number		11	12	13
Stiffness determination		Derived	Derived	Derived
Strength determination		Manual	Manual	Manual
R_inter		0.6700	0.6700	0.6700
Consider gap closure		True	True	True
Cross permeability		Impermeable	Impermeable	Impermeable
Drainage conductivity, dk	m^3/day/m	0.000	0.000	0.000
R_thermal	m^2 K/kW	0.000	0.000	0.000
Identification number		11	12	13
Identification		P2607 - 2A - Shallow	P2607 - 2B - Shallow	P2607 - 4B - Shallow
Soil model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Drainage type		Drained	Drained	Drained
Colour		🟦	🟩	🟨
Comments				
K_0 determination		Automatic	Automatic	Automatic
K_0,x		0.3572	0.4264	0.4264
K_0,z		0.3572	0.4264	0.4264

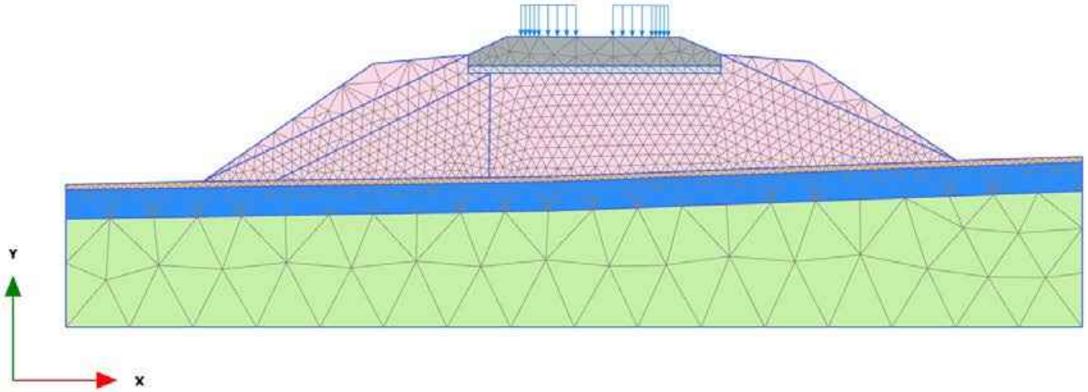
2.1.1.1.1 Calculation results, Phase_2 [Phase_2] (2/9), Total displacements |u|



Total displacements |u| (scaled up 100 times)

Maximum value = 0.01055 m (Element 3 at Node 10325)

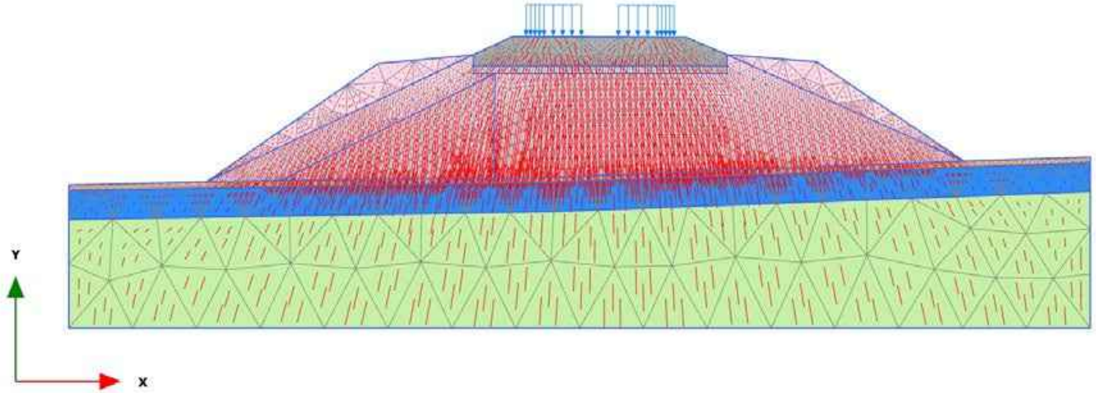
2.2.1.1.1 Calculation results, Phase_2 [Phase_2] (2/9), Excess pore pressures p_{excess}



Excess pore pressures p_{excess} (scaled up 1.00 times) (Pressure = negative)

Uniform value of 0.000 kN/m²

2.2.2.1.1 Calculation results, Phase_2 [Phase_2] (2/9), Principal total stress σ_1

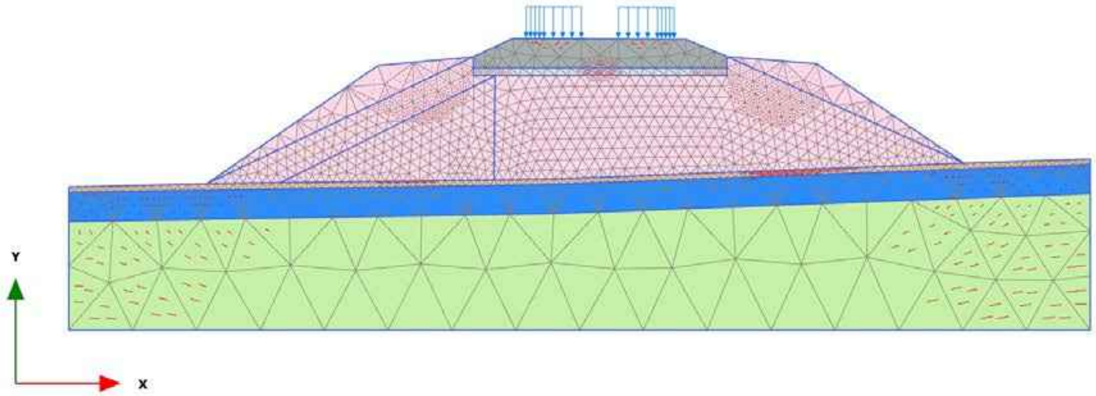


Principal total stress σ_1 (scaled up $5.00*10^{-3}$ times)

Maximum value = $3.553*10^{-15}$ kN/m² (Element 32 at Stress point 373)

Minimum value = -228.6 kN/m² (Element 1661 at Stress point 19930)

2.2.2.2.1 Calculation results, Phase_2 [Phase_2] (2/9), Principal total stress σ_2

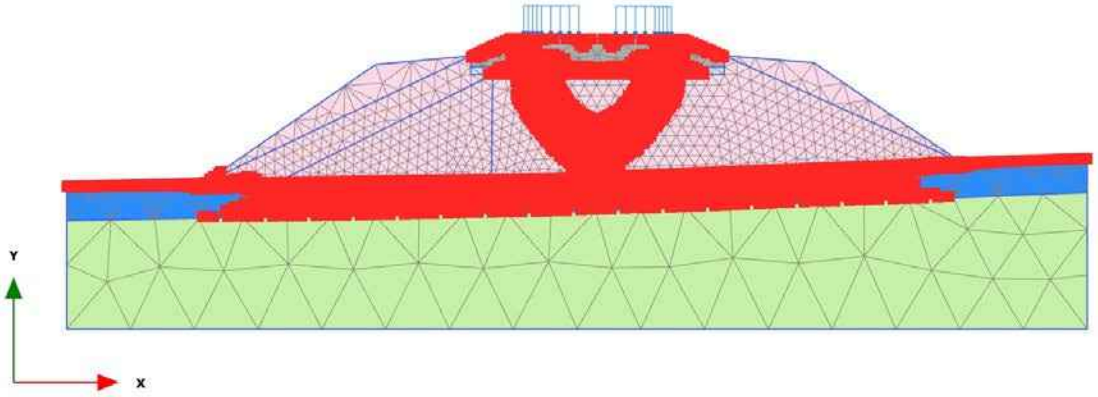


Principal total stress σ_2 (scaled up $5.00*10^{-3}$ times)

Maximum value = 0.000 kN/m² (Element 32 at Stress point 379)

Minimum value = -123.0 kN/m² (Element 1661 at Stress point 19929)

2.2.3.1.1 Calculation results, Phase_2 [Phase_2] (2/9), Plastic point history Failure



Plastic point history Failure (scaled up 1.00 times)

🟥 Failure point
☐ Tension cut-off point
▼ Plasticity in local 2 direction only
◆ Plasticity in local 1 and 2 directions

APPENDIX C

Important Information

morrow

Important Information

This Document has been provided by Morrow Geotechnics Pty Ltd subject to the following limitations:

This Document has been prepared for the particular purpose outlined in Morrow Geotechnics’ proposal and no responsibility is accepted for the use of this Document, in whole or in part, in other contexts or for any other purpose.

The scope and the period of Morrow Geotechnics’ Services are as described in Morrow Geotechnics’ proposal, and are subject to restrictions and limitations. Morrow Geotechnics did not perform a complete assessment of all possible conditions or circumstances that may exist at the site referenced in the Document. The scope of services may have been limited by such factors as time, budget, site access or other site conditions. If a service is not expressly indicated, do not assume it has been provided. If a matter is not addressed, do not assume that any determination has been made by Morrow Geotechnics in regards to it. Any advice given within this document is limited to geotechnical considerations only. Other constraints particular to the project, including but not limited to architectural, environment, heritage and planning matters may apply and should be assessed independently of this advice.

Conditions may exist which were undetectable given the limited nature of the enquiry Morrow Geotechnics was retained to undertake with respect to the site. Variations in conditions may occur between investigatory locations, and there may be special conditions pertaining to the site which have not been revealed by the investigation and which have not therefore been taken into account in the Document. Accordingly, additional studies and actions may be required. No geotechnical investigation can provide a full understanding of all possible subsurface details and anomalies at a site.

In addition, it is recognised that the passage of time affects the information and assessment provided in this Document. Morrow Geotechnics’ opinions are based upon information that existed at the time of the production of the Document. It is understood that the Services provided allowed Morrow Geotechnics to form no more than an opinion of the actual conditions of the site at the time the site was visited and cannot be used to assess the effect of any subsequent changes in the quality of the site, or its surroundings, or any laws or regulations.

Any assessments made in this Document are based on the conditions indicated from published sources and the investigation described. No warranty is included, either express or implied, that the actual conditions will conform exactly to the assessments contained in this Document.

Where data supplied by the client or other external sources, including previous site investigation data, have been used, it has been assumed that the information is correct unless otherwise stated. No responsibility is accepted by Morrow Geotechnics for incomplete or inaccurate data supplied by others.

Where ground conditions encountered at the site differ significantly from those anticipated in the report, either due to natural variability of subsurface conditions or construction activities, it is a condition of the report that Morrow Geotechnics be notified of any variations and be provided with an opportunity to review the recommendations of this report.

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Appendix E

Newcastle Geotech Reports

Inclinometer installation report 498-6 Sept 2022

Downside culvert remediation 99.035km & 99.338km 493-4 Apr 2022

Newcastle Geotech

7/4/2022
Our ref 493-4

Simec Mining
Tahmoor Coking Coal Operations
Remembrance Driveway
Tahmoor NSW 2573

Attention: Ross Barber / Kevin Golledge

RE: GEOTECHNICAL SCOPE OF WORK

DOWNSIDE CULVERT 99.035KM AND 99.384KM REMEDIATION OPTIONS

TAHMOOR SOUTH PROJECT – BARGO

As requested Newcastle Geotech Pty Ltd undertook inspection of downside culverts at Bargo on 28/4/2022 to assess scope of works for remediation at:

- 99.035km where there is a piping hole / void in the downside access associated with a broken roof section in the 0.9m diameter reinforced concrete pipe (RCP) culvert extension resulting in wash in and collapse of the 3.8m deep fill cover to the surface.
- 99.384km where a narrow downside access road and very steep fill batter slope occurs above the original 1.5m diameter brick arch culvert outlet and wingwalls. The original 1.2m diameter RCP culvert pipe extension and overlying fill at this location has previously failed presumably under a peak flow / food event resulting in a very steep fill batter / scarp below the access road.

Culvert 99.035km

The existing piping hole in the downside has widened from approximately 1m diameter in August 2021 to 2.3m diameter on 28 March 2022 where the hole was observed choked off at 2m depth. A cover of 3.8m over the open RCP extension was previously observed. Details are shown on attached Drawing 99.035.

The piping hole is about 4m from the ballast toe and as such is not currently constraining access. The key issue is that further collapse of the hole may potentially result in culvert blockage during a rainfall event resulting in potential impoundment of water along the upside embankment. As such rectification is recommended.

Key issues in rectification are:

- Excavation up to 4m to 5m depth and establishment of temporary stable batters to facilitate access for inspection and repair. Allowance for maximum stepped or profiled batter gradient of 45 degrees can be allowed for with provision for geotechnical assessment prior to personnel entering excavation. Alternatively a trench shoring shield would be the preferred approach.
- The scope of rectification by concrete patching, grouting, headwall dowel installation (or combination of) or pipe section replacement will only become apparent once the joint and extent of RCP damage is exposed.
- The treatment methodology adopted to ensure a tight permanent seal is maintained between the pipe extension and original brick headwall.

Culvert 99.384km

The downside culvert originally incorporated extension pipes and a fill batter (1.5H:1V) presumably constructed as part of downside batter widening works undertaken for access purposes, the same as constructed at other nearby culverts. Refer to Drawing 99.384 for details.

At some stage it is appears that flood damage has occurred with blow out of the RCP culvert extension pipes and slumping of the batter slope above the original headwall. The underlying reason for the failure at this location appears to be the undersized 1.2m diameter RCP extension joined to the 1.5m diameter brick arch culvert and the skewed alignment of the culvert and tight configuration of the brick wingwalls that is likely to have precluded a tight fit between the pipe extension and headwall.

The failure has resulted in a narrow (3.3m) access road between the ballast toe and embankment crest with a very steep fill embankment slope / slip scarp up to estimated 45 degrees down to the culvert headwall. This steep bank is expected to have marginal stability based on the steep profile for the fill materials. Potential loading from construction plant during the Tahmoor South Project establishment works would increase the risk of slump type instability along the roadway. It is noted that evidence of recent batter instability can be noted in the dense vegetation on the city side of the culvert, possibly associated with the March 2022 rainfall event.

It is highlighted that dense vegetation along the bank limits measurement and it is recommended that clearing and detailed survey be undertaken to provide further information for assessment and design.

In its present state the steep bank and narrow roadway presents a risk to the project in terms of potential loss of downside access and potential for vehicle drive off over the steep bank. As such remedial works are recommended with options presented on Drawing 99.384 comprising:

- Option 1 - Installing standard armco ballast retainer wall along the ballast shoulder to increase the width of the access road to approximately 4m with an armco barrier set back about 0.5m from the crest of the steep embankment to address drive off risk. Compliance with ARTC standards for ballast wall offset to be confirmed. It is highlighted that this option does not address the risk of slope instability associated with slumping of the over steep batter above the culvert headwall but addresses the risk of drive off.
- Option 2 - Re-establishment of the original culvert extension and batter profile by use of imported rockfill battered at 1V:1.5H with a 1m increase in embankment crest width. This option addresses the risk of instability associated with the over-steep batter by providing a rockfill buttress. The main constraints with this option are initial infill of the pond / open water area by rip rap materials encapsulated in geotextile and establishing a tight connection between the pipe extension and headwall due to the tight wingwall configuration - potentially requiring dowels into the headwall and shotcrete or similar grouted collar.
- Option 3 - Construction of piled retaining wall support at the crest of the over steep batter with deep piles potentially up to 8m in length and ground anchors to provide tie back support. This option has been discounted based on cost and practicality.
- Option 4 – Construction of retaining wall support along the toe of ballast and lowering of the access road level. This has been discounted due to the presence of Telstra and rail signal cabling under the access road.

It is noted that the above options are conceptual only and will need to be confirmed based on detail survey and design.

Mark Delaney

Mark Delaney
Principal Engineering Geologist

Attachments - Drawings 99.035 and 99.384

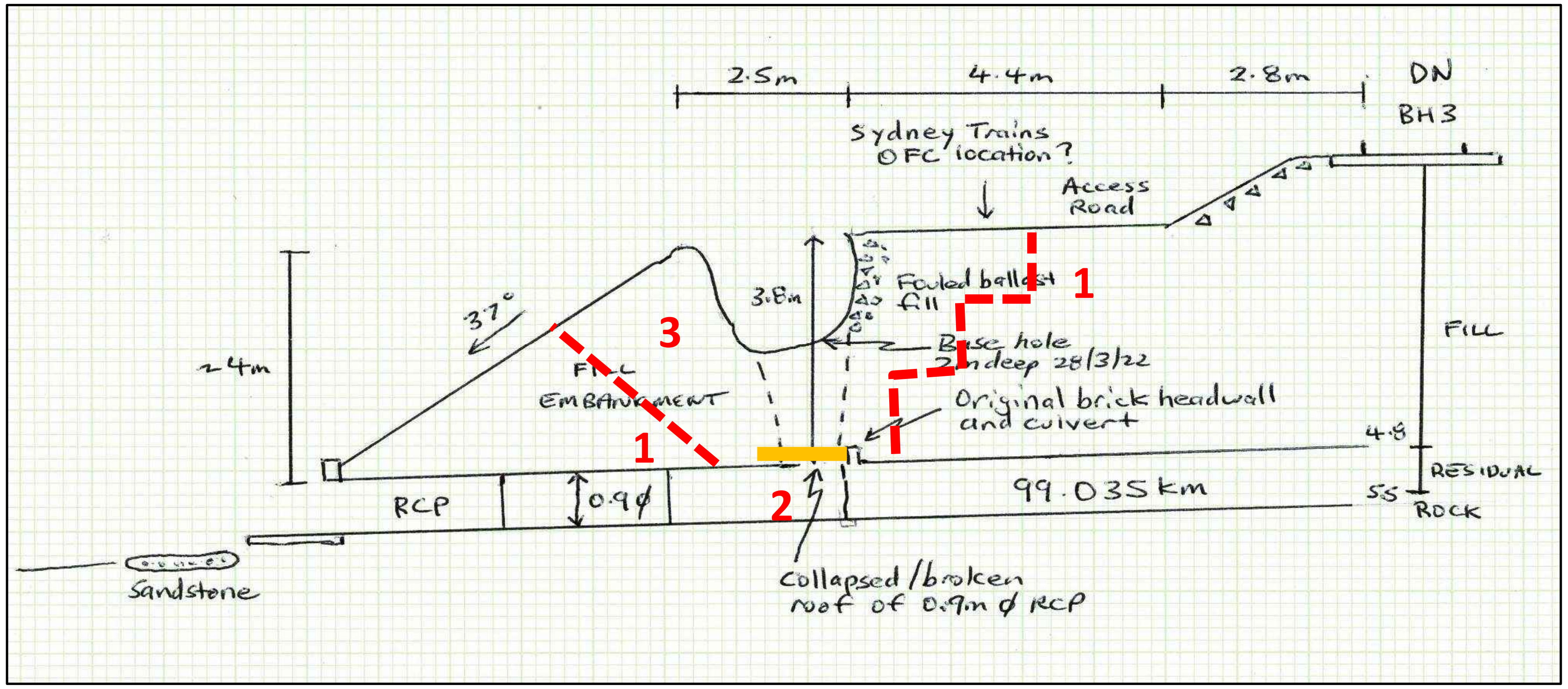
Collapsed culvert extension roof August 2021.
Note tree growing in fill.

Sinkhole 1m diameter August 2021.
Sinkhole now 2.3m diameter

Bunded off sinkhole at crest of fill embankment
4m from ballast toe 28 march 2022

SCOPE OF REMEDIAL WORK

1. Excavate fill materials (fouled ballast, mine spoil (coarse washery reject) and other and stockpile for reuse. Maximum temporary excavation profile 1V:1H (45deg) in battered or stepped profile.
   Geotechnical assessment of excavation stability and support requirements prior to personnel entering excavation. Altenatively support excavation by trench shoring shield.
2. Expose open pipe section and joint between 0.9m dia RCP and original brick headwall. The scope of rectification by concrete patching, grouting, headwall dowel installation (or combination of) or pipe section replacement will only become apparent once the joint and extent of RCP damage is exposed.
   The treatment methodology adopted to ensure a tight permanent seal is maintained between the pipe extension and original brick headwall.
3. Backfill with excavated spoil (where suitable) placed in layers and compacted by vibrating plate or roller head on excavator or backhoe.



Scale

Revision

Scale	As shown
Drawn by	MGD
Approved by	MGD
Date	7-Apr-22
Original size	A3

Newcastle Geotech Pty Ltd
ABN 55 140 203 247
0428 689 509

Client:	Simec Mining - Tahmoor Coking Coal Operations		
Project:	Tahmoor South - Bargo		
Location:	Main Southern Rail - Downside Culvert 99.035km		
Title:	Sketch Section, Photographs and Remedial Concept		
Job Number:	493	Drawing No:	99.035

Narrow (3.3m) access between ballast toe and steep bank
28/03/2022

Very steep bank down to ponding water where
original batter slope was before washout 28/3/2022

Washed out 1.8m diameter and 2.45m long RCP extension
20m downstream, presumably others further down 28/3/2022

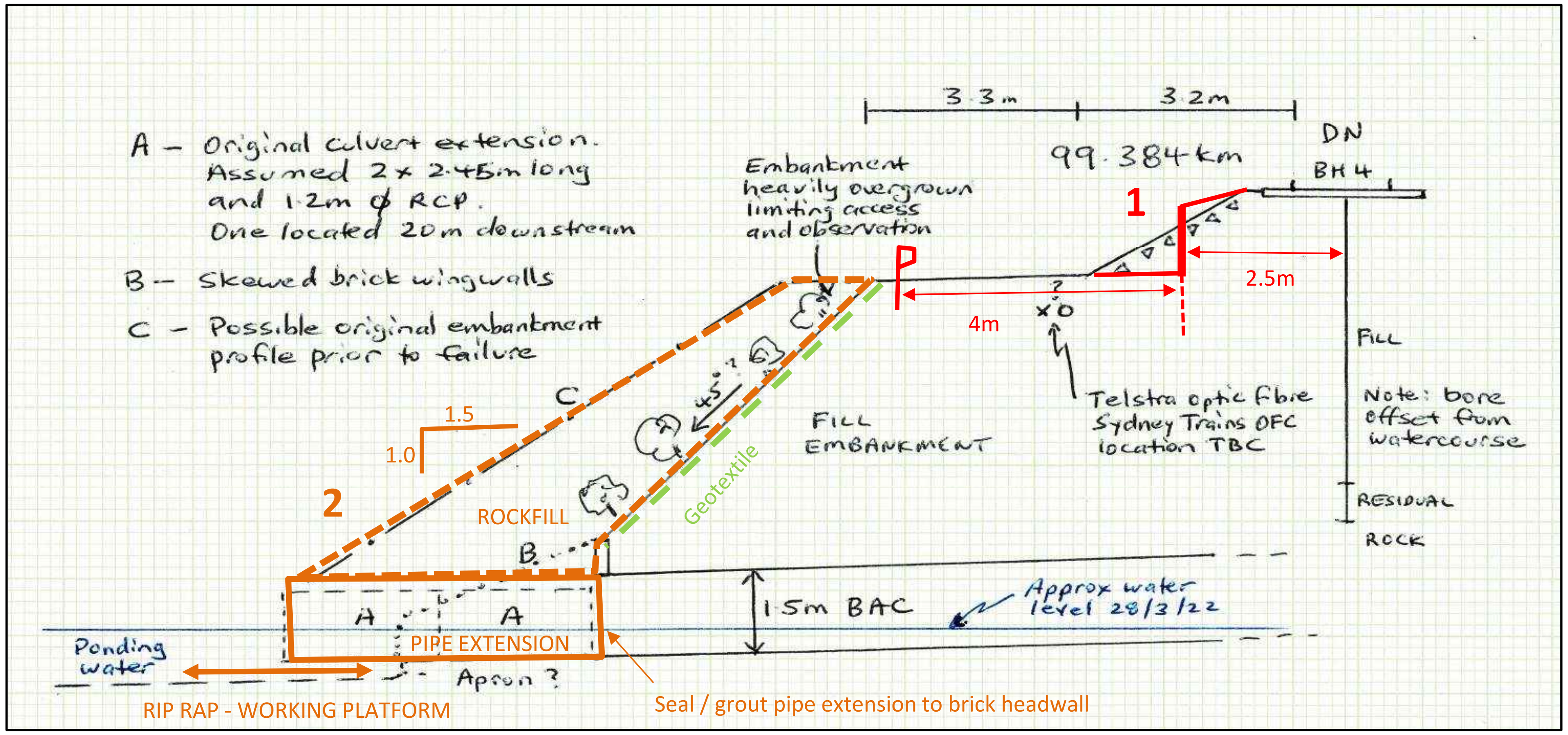
1.5m dia brick arch culvert outlet with tight join between
wingwalls and culvert restricting ability to tightly
join / seal extension pipe against headwall.

SCOPE OF REMEDIAL WORK - OPTION 1

Increase access width by installing standard armco ballast retainer wall in ballast shoulder approximately 1m high.
Wall offset of 2.5m from rail centreline will create access width of approximately 4m with armco barrier set back about 0.5m from crest of steep embankment.
Compliance with ARTC standards for wall offset to be confirmed.
Note - this option does not address the risk of instability associated with the oversteep batter but addresses drive off risk.

SCOPE OF REMEDIAL WORK - OPTION 3

Construction of piled retaining wall support at crest of oversteep batter with deep piles (up to 8m?) and ground anchors.
Option discounted based on cost and practicality.



SCOPE OF REMEDIAL WORK - OPTION 2

Note options conceptual only - to be confirmed by survey and design

Re-establishment of original culvert extension and batter profile by use of imported rockfill battered at 1V:1.5H and 1m increase in embankment crest
Main constraints are initial infill of pond / open water area by rip rap materials encapsulated in geotextile and establishing tight connection between p
extension and headwall due to the tight wingwall configuration - potentially requiring dowels into the headwall and shotcrete or similar grouted collar.
This option addresses the risk of instability associated with the over-steep batter by providing a rockfill buttress.

Scale		Scale	As shown
		Drawn by	MGD
Revision		Approved by	MGD
		Date	7-Apr-22
		Original size	A3

Newcastle Geotech

Newcastle Geotech Pty Ltd
ABN 55 140 203 247
0428 689 509

Client:	Simec Mining - Tahmoor Coking Coal Operations		
Project:	Tahmoor South - Bargo		
Location:	Main Southern Rail - Downside Culvert 99.384km		
Title:	Sketch Section, Photographs and Remedial Concept		
Job Number:	493	Drawing No:	99.384

Newcastle
Geotech

28/9/2022
Our ref 493-6

Simec Mining
Tahmoor Coking Coal Operations
Remembrance Driveway
Tahmoor NSW 2573

Attention: Ross Barber / Kevin Golledge

RE: TAHMOOR SOUTH PROJECT – MAIN SOUTHERN RAIL - BARGO
GEOTECHNICAL INVESTIGATION AND INCLINOMETER INSTALLATION
UPSIDE ACCESS ROAD / EMBANKMENT – 99.333KM

1 INTRODUCTION

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 south of the existing Tahmoor Mine. Extraction of longwalls S1A to S6A is proposed to commence in late October 2022 with extraction towards the northwest from the southeast end.

A risk assessment on potential impacts on the ARTC's Main Southern Railway Line associated with Tahmoor South Longwalls LW1A - LW6A was undertaken in September 2021 by HMS Consultants Australia Pty Ltd. In relation to rail fill embankments the assessment noted the following controls to be adopted:

- Geotechnical assessment of embankment ground conditions and stability analysis to establish baseline conditions (predominantly completed and to be issued shortly).
- Install instrumentation as determined by assessment.

As part of the Management Plan for the Main Southern Railway being developed by MSEC, installation of an inclinometer has been recommended for the fill embankment that extends from 99.230km to 99.500km.

This report presents the factual results of the geotechnical investigation and inclinometer installation in the upside access road at 99.333km. The upside access road was selected for installation due to the presence of a Telstra Optic Fibre cable along the downside access road.

The inclinometer has been installed to monitor any lateral deformation of the fill embankment relative to the underlying rock that may develop as part of LW S1A to S6A mining by providing downhole horizontal displacement data. The inclinometer data will supplement existing survey monitoring at 20m spacing along the embankment crest and toe together with rail stress and temperature gauges.

2 INCLINOMETER INSTALLATION

Setout of the borehole and inclinometer location involved clearance and mark out of the rail signal cable that runs down the centre of the upside access road. Clearance was undertaken by Ted Johansen (Signal Support Services).

Drilling and inclinometer installation was performed by BG Drilling Pty Ltd between 3rd and 4th September 2002 during a rail possession with finalisation of the upper grout annulus and concrete cover by BG Drilling Pty Ltd on 28th September 2020 under rail protection.

Newcastle Geotech's role in the installation as undertaken by a Principal Engineering Geologist was to:

- Direct the drilling and inclinometer installation.
- Log the soil and rock profile and photograph the drill core.
- Undertake point load strength testing on core.

Borehole Inclo1 was advanced by a Hanjin DB20 tracked drilling rig by:

- 100mm diameter continuous flight augers in the soil profile.
- 114mm diameter HQ casing reamed to rock level at 6.35m.
- Diamond drill bit HQ3 size coring from 6.35m to 15.2m with a 96mm diameter hole.

Difficulty in auger drilling was encountered through gravelly fill below about 1.5m to 2m depth that presumably contains sandstone cobbles and boulders. The hole had to be repositioned four times due to the augers being deflected off alignment by rocks in the fill with one auger shearing off and left down the hole.

The borehole logs and core photos are attached. Point load (Is50) strength testing of the rock core was undertaken onsite during the drilling to assess the rock strength with results presented on the borehole logs and attached.

Upon completion of the borehole the hole was flushed with clean water and the inclinometer casing was installed to a depth of 15.1m. The inclinometer casing consisted of HMA rifled casing in 3m lengths (nominal diameter 70mm OD and 58.5mm ID). The casing was provided by Geotechnical Systems Australia. The casing was installed and grouted in accordance with supplier's specification.

The annulus between the casing and the borehole was fully grouted from base upwards using a 20mm diameter grout pipe, grout mixer and pump. The grout mix comprised cement and about 10% bentonite. A significant loss of grout was encountered in the bottom up grouting process at about 2m depth associated with the presence of rock fill and possible voids. Re-establishment to the site by BG Drilling was undertaken on 28th September 2020 to complete the grouting and install a 150mm diameter steel road box cover cemented at the ground surface.

The 'A' direction of the inclinometer casing was oriented parallel to the axis of LW S1A to S6A in a southeast to northeast alignment at 317° MGA (304° magnetic) with the 'B' direction orientated perpendicular. The set out of the orientation was undertaken by hand held compass.

Survey pick up of the inclinometer cover to be undertaken by SRS during the next survey works.

 Drilling of borehole 3/9/2022	 Completion of inclinometer grouting 28/9/2022.

3 GROUND CONDITIONS

The profile encountered in the borehole Inclo1 was consistent with previous boreholes drilled as part of the embankment investigation works. The profile is detailed on the attached bore log and can be summarised as:

- Fill – comprising layers of Sandy Gravelly CLAY and Sandy Clayey GRAVEL with medium plasticity clay and fine to coarse gravel and cobble sized sandstone rock fragments ranging from weak and friable to competent rock with possibly some sandstone boulders present. Fill generally in a moist state becoming moist to wet at base, to 5.4m depth over
- Residual soil weathered insitu from underlying bedrock – comprising Sandy CLAY / Clayey SAND, medium plasticity clay and fine to coarse sand, wet, to 6m depth over
- Sandstone Bedrock – extremely to highly weathered and estimated low strength to 6.5m over moderately weathered and estimated medium strength sandstone.

The sandstone rock is interpreted to comprise the Triassic Age Hawkesbury Sandstone.

The rock mass structure is dominated by sub-horizontal (0° to 10°) bedding partings with other defects comprising cross bedding up to 20° and minor thin clay and crush seams at 10° to 25°. Defects are generally widely spaced in the order of 1m.

No evidence of shearing, faulting or brecciation was observed in the core.

Groundwater was encountered at about 5.4m depth.

4 INCLINOMETER MONITORING

Monitoring of the inclinometer is to be undertaken by Lynton Surveys on a frequency to be nominated in the MSEC Management Plan. This will comprise as a first step baseline survey with two lots of readings to be undertaken in October 2022.

Access for inclinometer monitoring is via the upside rail corridor access track from 99km with inclinometer monitoring to be undertaken under rail protection.

For and on behalf of Newcastle Geotech Pty Ltd

Mark Delaney

Mark Delaney

Principal Engineering Geologist

Attached

Borehole Log Inclo1

Core photographs Detailed costing

Point Load Test Results

Geotechnical Log - Borehole

Newcastle Geotech

Borehole Inclo 1

Sheet 1 of 4

Client	**Simec (Tahmoor Coal)**	Job No.	*493*
Project	**Tahmoor South Project - Inclinometer Installation**	Date	3-4 September 2024
Location	**Main Southern Rail**	Logged by	*MGD*
Borehole Location	**99.333km Up Access Road**	Checked by	*MGD*

Equipment type & model: Hanjin DB20 Tracked Drill Rig - BG Drilling Borehole diameter (mm): 100 Borehole inclination(deg): 90

R.L surface: Access road approw 1m below top of rail MGA Co-ordinates: 276746 E 6206302 N

Method	Sample Test	Ground-water	Geotechnical Unit	USC	Depth (m)		Material soil name, plasticity or particle size, colour, secondary and minor components	Moisture status	Consistency Density	Origin, Structure, Observation Test results
Auger 100mm and washbore 90mm drilling			2C	GC		0.1	**Clayey Sandy GRAVEL**- rail ballast, grey	D		Access Road-fouled ballast
			2A	CI	0.5 1.0		**Sandy Gravelly CLAY -** medium plasticity, grey / brow and red, fine to coarse sand, fine to coarse subrounded gravel (sandstone rock fragments)	D-M M > Wp		Embankment FILL
			2B	GC	1.5	1.5	**Sandy Clayey GRAVEL -**fine to coarse gravel and cobble sized sandstone rock fragments, subangular, weathered and competent, in a sandy clay matrix, orange, brown and grey	M		
			2A	CI	2.0	2	**Sandy Gravelly CLAY**- as above	M > Wp		
			2B	GC	2.5	2.5	**Sandy Clayey GRAVEL -**as above	M		
			2A	CI	3.0 3.5 4.0	3	**Sandy Gravelly CLAY**- as above	M > Wp		
			2B	GC	4.5 5.0	4.3 5	**Sandy Clayey GRAVEL -**as above	M		Embankment FILL

Method		**Samples / Tests**	
HA	Hand auger	U_{50}	Undisturbed tube (50mm)
AD	Auger drilling	SPT	Standard pentration test
WB	Washbore	pp	Pocket penetrometer
NMLC	Rock coring	D	Disturbed sample
NQ HQ	Wireline coring	E	Environmental sample
S	Sonic drilling	GWS	Groundwater sample

Moisture		**Groundwater**	
D	dry	Groundwater level (at time of excavtion)	▼
M	moist		
W	wet	Inflow / seepage	►
Wp	plastic limit		
LL	liquid limit		
OMC	optimum moisture content (std)		

Consistency		**Density**	
VS	very soft	VL	very loose
S	soft	L	loose
F	firm	MD	medium dense
St	stiff	D	dense
Vst	very stiff	VD	very dense
H	hard		

Geotechnical Log - Borehole

Borehole **Inclo 1**

Sheet 2 of 4

Client	**Simec (Tahmoor Coal)**	Job No.	*493*
Project	**Tahmoor South Project - Inclinometer Installation**	Date	3-4 September 2024
Location	**Main Southern Rail**	Logged by	*MGD*
Borehole Location	**99.333km Up Access Road**	Checked by	*MGD*

Equipment type & model: Hanjin DB20 Tracked Drill Rig - BG Drilling Borehole diameter (mm): 100 Borehole inclination(deg): 90

R.L surface: Access road approw 1m below top of rail MGA Co-ordinates: 276746 E 6206302 N

Method	**S**ample Test	Ground-water	Geotechnical Unit	USC	Depth (m)		**Material** soil name, plasticity or particle size, colour, secondary and minor components	Moisture status	Consistency Density	Origin, Structure, Observation Test results
Auger and washbore drilling			2B	GC		5.4	**Sandy Clayey GRAVEL -**fine to coarse gravel and cobble sized sandstone rock fragments, subangular, weathered and competent, in a sandy clay matrix, orange, brown and grey	M - W		Embankment FILL
			4B	SC-CI	5.5	6	**Sandy CLAY / Clayey SAND**- fine to coarse sand, medium plasticity clay,, yellow /brown	W		RESIDUAL
			5		6.0	6.35	**SANDSTONE** medium grained, yellow / brown	M		ROCK Extremely to highly weatherd, low strength
					6.5		End non-cored bore at 6.35m Refer to sheets 3 and 4 for cored bore			
					7.0					
					7.5					
					8.0					
					8.5					
					9.0					
					9.5					
					10.0					

Method		**Samples / Tests**		**Moisture**		**Groundwater**		**Consistency**		**Density**	
HA	Hand auger	U_{50}	Undisturbed tube (50mm)	D	dry	Groundwater level	▼	VS	very soft	VL	very loose
AD	Auger drilling	SPT	Standard pentration test	M	moist	(at time of excavtion)		S	soft	L	loose
WB	Washbore	pp	Pocket penetrometer	W	wet	Inflow / seepage	►	F	firm	MD	medium dense
NMLC	Rock coring	D	Disturbed sample	Wp	plastic limit			St	stiff	D	dense
NQ HQ	Wireline coring	E	Environmental sample	LL	liquid limit			Vst	very stiff	VD	very dense
S	Sonic drilling	GWS	Groundwater sample	OMC	optimum moisture content (std)			H	hard		

Geotechnical Log - Cored Borehole

Borehole Inclo 1

Sheet 3 of 4

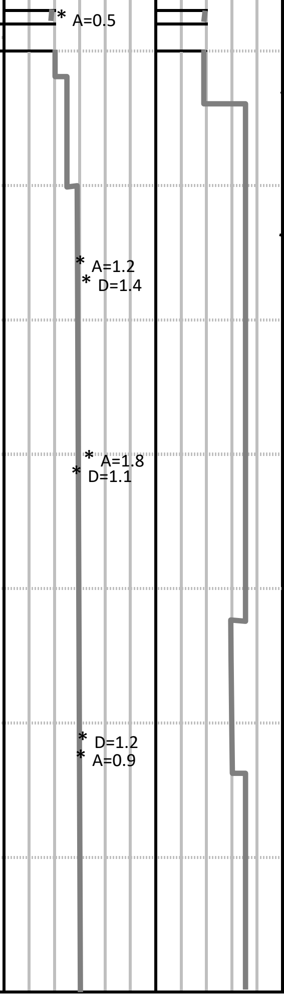
Newcastle Geotech

Client	**Simec (Tahmoor Coal)**	Job No	7/05/1901
Project	**Tahmoor South Project - Inclinometer Installation**	Date	3-4 September 2024
Location	**Main Southern Rail**	Logged by	MGD
Borehole Location	**99.333km Up Access Road**	Checked by	MGD

Equipment type & model: Hanjin DB20 Tracked Drill Rig - BG Drilling   Borehole diameter (mm): 90   Borehole inclination(deg): 90

R.L surface: Access road approw 1m below top of rail   MGA Co-ordinates: 276746 E 6206302 N

Drilling	Water	Sample / Test	Reduced Level	Depth (m)	Geotechnical Unit	DESCRIPTION - ROCK TYPE Grain size, colour, structure, minor components, durability / alteration	WEATHERING	DEFECT DESCRIPTION Defect type, inclination (deg), surface shape, surface roughness, coating
Auger drilling then HQ casing to 6.35m				5.5 6.0 6.35		Start HQ coring at 6.35m		
HQ 100% recovery	100% water return			6.35		**SANDSTONE** as below	HW	
				6.5 6.53		**NO CORE** 6.38m - 6.53m (EW seam?)		
				7.0 7.5 8.0 8.5		**SANDSTONE** medium grained with some coarse sand and trace of fine subrounded gravel, quartzose, white light grey and orange / brown, with some orange / brown iron stained cross bedding at 5° to 20° NO CORE 6.38m - 6.53m (EW seam?)	MW	6.54 Clay seam 0° 10mm 6.7 Crush seam 25° 5-15mm thick 7.2 bedding parting 15° planar rough clean 7.3 Handling break 7.73 Handling break 8.4 Handling break 8.62 bedding parting 5° planar rough clay veneer
				8.7 9.0		**SANDSTONE** medium grained light brown, massive		9.17 Clay seam 5° -10° 15mm
HQ				9.5 10.0				



Weathering		Strength		Defect Type		Surface Shape		Surace Roughness		Defect Coating	
RS	Residual	VL	Very low	PT	Parting	Pl	Planar	VR	Very rough	Cl	Clean
EW	Extremely	L	Low	J	Joint	Cu	Curved	R	Rough	St	Stained
HW	Highly	M	Medium	SZ	Shear zone	U	Undulating	S	Smooth	Vn	Veneer
MW	Moderately	H	High	SS	Shear seam	Sd	Stepped	Sl	Slickensided	Co	Coating
SW	Slightly	VH	Very High	CS	Crushed seam	Ir	Irregular	P	Polised	Fe	Iron oxide
Fr	Fresh	EH	Extremely High	IS	Infilled seam					Qz	Quartz
				ES	Extremely weathered seam					Ca	Calcite

Point load strength Index $I_{(50)}$ A=axial D= diametrical

Geotechnical Log - Cored Borehole

Newcastle Geotech

Borehole **Inclo 1** Sheet 4 of 4

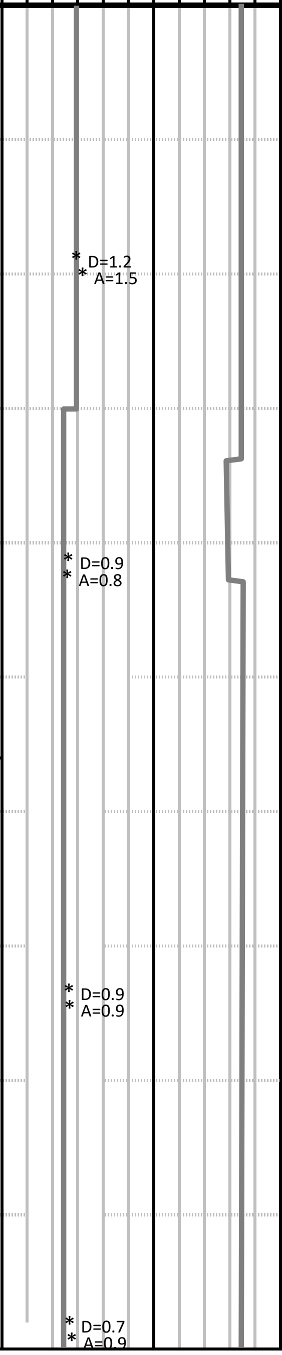
Client	**Simec (Tahmoor Coal)**	Job No	7/05/1901
Project	**Tahmoor South Project - Inclinometer Installation**	Date	3-4 September 2024
Location	**Main Southern Rail**	Logged by	MGD
Borehole Location	**99.333km Up Access Road**	Checked by	MGD

Equipment type & model: Hanjin DB20 Tracked Drill Rig - BG Drilling Borehole diameter (mm): 90 Borehole inclination(deg): 90

R.L surface: Access road approw 1m below top of rail MGA Co-ordinates: 276746 E 6206302 N

Drilling	Water	Sample / Test	Reduced Level	Depth (m)	Geotechnical Unit	DESCRIPTION - ROCK TYPE Grain size, colour, structure, minor components, durability / alteration	WEATHERING	DEFECT DESCRIPTION Defect type, inclination (deg), surface shape, surface roughness, coating
HQ 100% recovery	100% water return					**SANDSTONE** medium grained quartzose, light grey / brown with some red brown staining along moderately developed cross bedding at 10˚ to 20˚	MW	
				10.5				10.63 bedding parting 20° planar rough clean
				11.0				
				11.5				11.7 bedding parting 5° planar rough clean
				12.0				12.23 bedding parting 20° planar rough clean
HQ 100% recovery	100% water return			12.4		**SANDSTONE** fine to medium grained light white grey, siltstone laminations black, undulose, 5-20˚, 1-2mm		
				12.5				
				12.65		**SANDSTONE** medium grained with some coarse sand and trace fine subrounded gravel, quartzose, white mottled orange / brown, massive	MW-SW	
				13.0				
				13.5				
				14.0				14.0 bedding parting 10° planar rough clay veneer
				14.5				11.7 bedding parting 5° planar rough clean
				15.0		End bore at 15.2m		

ESTIMATED STRENGTH: VL L M H VH EH — DEFECT SPACING (mm): 30 100 300 1000 3000



Weathering		Strength		Defect Type		Surface Shape		Surace Roughness		Defect Coating	
RS	Residual	VL	Very low	PT	Parting	Pl	Planar	VR	Very rough	Cl	Clean
EW	Extremely	L	Low	J	Joint	Cu	Curved	R	Rough	St	Stained
HW	Highly	M	Medium	SZ	Shear zone	U	Undulating	S	Smooth	Vn	Veneer
MW	Moderately	H	High	SS	Shear seam	Sd	Stepped	Sl	Slickensided	Co	Coating
SW	Slightly	VH	Very High	CS	Crushed seam	Ir	Irregular	P	Polised	Fe	Iron oxide
Fr	Fresh	EH	Extremely High	IS	Infilled seam					Qz	Quartz
				ES	Extremely weathered seam					Ca	Calcite

Point load strength Index $I_{(50)}$ A=axial D= diametrical

Borehole Inclo 1 - 6.35m to 15.25m

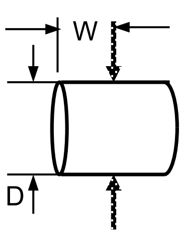
Newcastle Geotech

		Project No.	493
Client:		Date:	4/09/2022
Project:		Tested by:	MGD
Location:		Data checked:	MGD

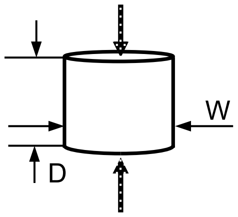
Test Machine:	Test Locality: Site	Core Size: HQ 63mm

Bore	Depth (m)	Moisture Condition	Test Type	W (mm)	D (mm)	Load kN (P)	Failure Type	Point Load Strength Index $Is_{(50)}$ (MPa)	Strength Classification
Incinometer 1									
	6.37	M	A	63	32	0.50	1	0.19	Low
	7.27	M	D	90	63	5.50	1	1.39	Medium-high
	7.25	M	A	63	38	3.70	1	1.21	Medium-high
	8.05	M	D	370	63	4.40	1	1.11	Medium-high
	8.03	M	A	63	44	6.40	1	1.81	High
	9.05	M	D	150	63	4.60	1	1.16	Medium-high
	9.03	M	A	63	34	2.40	1	0.88	Medium
	10.94	M	D	360	63	4.70	1	1.18	Medium-high
	10.97	M	A	63	48	5.60	1	1.45	High
	12.07	M	D	200	63	3.50	1	0.88	Medium
	12.05	M	A	63	34	2.30	1	0.84	Medium
	13.78	M	D	270	63	3.40	1	0.86	Medium
	13.95	M	A	63	53	3.70	1	0.87	Medium
	15.20	M	D	200	63	2.70	1	0.68	Medium
	15.22	M	A	63	33	2.40	1	0.91	Medium-high

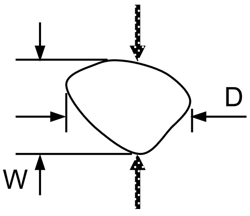
TEST TYPE :



W/D > 0.5
DIAMETRAL



D/W = 0.3 - 1.0
AXIAL (A)



D/W = 0.3 - 1.0
IRREGULAR LUMP

MOISTURE CONDITION :
Field (F), Saturated (S), Dry (D)

FAILURE TYPE :
1. Fracture through fabric of specimen oblique to bedding, not influenced by weak
2. Fracture along bedding.
3. Fracture influenced by pre-existing joint plane (J), microfracture (M), vein (V),
4. Chip or partial fracture.

NOTES For specimens tested parallel to plane of weakness $D_e^2 = D^2$
For specimens tested perpendicular to plane of weakness $D_e^2 = 4WD/\pi$