Department of Planning, Housing and Infrastructure

Our ref: SSI-9687-PA-274

Nicola Fraser
Post Approvals
Snowy Hydro Limited
By email

02/02/2026

Subject: Snowy 2.0 - Main Works – TBM4 Subsidence Management Plan

Dear Ms Fraser

I refer to the Snowy 2.0 - Main Works - TBM4 Subsidence Management Plan (Revision C dated 12 December 2025), submitted in accordance with Condition 64(b), Schedule 3 of the approval for the Snowy 2.0 Main Works (SSI-9687).

I note the Subsidence Management Plan:

- has been prepared in consultation with the NSW National Parks and Wildlife Service; and
- contains the information required by the conditions of approval.

The Department has carefully reviewed the document and is satisfied that it meets the requirements of the relevant conditions in approval SSI-9687.

You are reminded that if there are any inconsistencies between the Subsidence Management Plan and the conditions of approval, the conditions prevail.

Please ensure you make the document publicly available on the project website at the earliest convenience.

If you wish to discuss the matter further, please contact Anthony Ko on (02 8217 2022) or at anthony.ko@planning.nsw.gov.au.

Yours sincerely

Nicole Brewer
Director
Energy Assessments

As nominee of the Planning Secretary

# Snowy 2.0 Main Works
# TBM4 - Subsidence Management Plan

Version: Rev C - update  to DPHI incorporating comments and close out of NPWS

Date: 12 December 2025

| | Name | Title |
|---|---|---|
| **Prepared By:** | V.Chathuranga<br>N.Chapman | Senior Underground Engineer - Snowy 2.0<br>Tunnel Engineer - Snowy 2.0 |
| **Reviewed By:** | Ben Chapman<br>Damiano Frontini | Lead Tunnel Engineer<br>Geotechnical Lead |
| **Approved By:** | Damon Miller | General Manager Engineering and Quality |

# Contents

# Abbreviations

| Acronym | Definition |
|---|---|
| CSSI | Critical State Significant Infrastructure |
| EIS | Environmental Impact Statement |
| EPB | Earth Pressure Balance |
| FGJV | Future Generation Joint Venture |
| HDD | Horizontal Directional Drilling |
| HRT | Head Race tunnel |
| LPFZ | Long Plain Fault Zone |
| NEM | National Electricity Market |
| RtS | Response to Submissions (Report) |
| SHL | Snowy Hydro Limited |
| SSI | State Significant Infrastructure |
| TBM | Tunnel Boring Machine |
| TARP | Trigger Action Response Plan |

# Introduction

## 1.1. Project Description

Snowy Hydro Limited (SHL) is constructing a pumped hydro-electric expansion of the Snowy Mountains Hydro-electric Scheme (Snowy Scheme), 'Snowy 2.0'. Snowy 2.0 is being built by the delivery of two projects: Exploratory Works and Snowy 2.0 Main Works.

Snowy 2.0 is a pumped hydro-electric project that will link the existing Tantangara and Talbingo reservoirs through a series of new underground tunnels and a hydro-electric power station. Most of the project's facilities will be built underground, with approximately 27 kilometres of concrete-lined tunnels constructed to link the two reservoirs and a further 20 kilometres of tunnels required to support the facility. Intake and outlet structures will be built at both Tantangara and Talbingo Reservoirs.

Snowy 2.0 will increase the generation capacity of the Snowy Scheme by an additional 2,200 MW, and at full capacity will provide approximately 350,000 MWh of large-scale energy storage to the National Electricity Market (NEM).

The Contractor, Future Generation Joint Venture, a consortium of WeBuild, Clough and Lane, have been engaged by SHL to deliver both Stage 2 of the Exploratory Works and key elements of the Snowy 2.0 Main Works. This Subsidence Management Plan has been prepared as part of the Snowy 2.0 Main Works.

## 1.2. Project Approval

On 7 March 2018, the NSW Minister for Planning declared Snowy 2.0 to be State Significant Infrastructure (SSI) and Critical State Significant Infrastructure (CSSI) under the *Environmental Planning and Assessment Act 1979 (*EP&A Act).

An Environmental Impact Statement (EIS) for the second stage of Snowy 2.0, the *Main Works Environmental Impact Statement*, was submitted to the Department of Planning and Environment in September 2019 and publicly displayed between 26 September 2019 and 6 November 2019. A total of 222 submissions including from government agencies, special interest groups and the general public were received. In February 2020, the Response to Submissions Report (RtS) was issued to DPIE to address the public and agency submissions (Snowy 2.0 Main Works - Preferred Infrastructure Report and Response to Submissions).

Following consideration of the Main Works EIS and RtS, approval was granted by the Minister for Planning and Public Spaces on 20 May 2020, through the Planning Instrument - SSI9687. Further to the Infrastructure Approval, the Main Works RtS includes Revised Environmental Management Measures (REMMs) to be implemented as part of the Main Works Project.

A Commonwealth Referral (EPBC 2018/8322) was prepared and lodged with the Commonwealth Department of Agriculture, Water and Environment (DAWE) under the *Environmental Protection and Commonwealth Conservation Act 1999* (EPBC Act). The Commonwealth Minister determined on 5 December 2018 that Snowy 2.0 Main Works is a 'controlled action' under the EPBC Act.

On 27 January 2022, a modification to CSSI-9687 was granted (Mod 1) to include horizontal directional drilling (HDD) to establish water and electricity services between Lobbs Hole and Marica areas of the Project.

On 29 November 2023, a second modification to CSSI-9687 was granted (Mod 2) to undertake sinkhole rectification works near the adit portal at Tantangara, inclusive of geotechnical investigations and remediation.

On 16 December 2024, a third modification to CSSI-9687 was granted (Mod 3) to permit the construction of an additional adit (Marica Adit) and launching a fourth Tunnel Boring Machine (TBM4) at Marica West to facilitate excavation of a section of the Headrace Tunnel (HRT) through the Long Plain Fault Zone (LPFZ).

## 1.3. Purpose and Objectives of this Plan

The purpose of this Subsidence Management Plan is to address the construction and environmental management requirements detailed in:

- the Infrastructure Approval (SSI 9687) issued for Snowy 2.0 Main Works on 20 May 2020;
- the Infrastructure Approval (SSI 9208) issued for Snowy 2.0 Exploratory Works on 7 February 2019 and modified on 2 December 2019 and 27 March 2020;
- the Main Works Snowy 2.0 - Environmental Impact Statement (2019)
- the Main Works Snowy 2.0 - Preferred Infrastructure Report and Response to Submissions (2020) including:
    - REMMS within Appendix C
- the Main Works for Snowy 2.0 - Modification 1 Assessment Report
- the Main Works for Snowy 2.0 - Modification 2 Assessment Report
- the Main Works for Snowy 2.0 - Modification 3 Assessment Report

The objective of this Management Plan is to provide structure and process for managing the potential risk of subsidence associated with TBM 4, through nomination of the following:

- Trigger Action Response Plan (TARP)- refer Attachment 2;
- Survey and Monitoring Plan; and
- Management and reporting commitment.

## 1.4. Scope of Plan

This Management Plan details the proposed monitoring and controls for the area of the Headrace Tunnel and Marica Adit which are less than 100 m depth below the surface (cover). The scope of this Management Plan is specifically focused on the areas of less than 100m cover as this is considered the area with a potential risk of subsidence, as described in the Modification Application.

This plan identifies how ground movement, both surface and sub-surface will be identified and measured until the tunnel obtains sufficient surface cover, whereby at that stage negligible surface settlement is expected to occur. Both surface and in-tunnel monitoring activities are considered.

As outlined in Section 5, surface monitoring will be limited to the areas where the tunnel cover is less than 100 meters. However, in-tunnel monitoring will be continued along the entire tunnel length in accordance with the design requirements to ensure continuous assessment of tunnel stability.

## 1.5. Relationships with other key Project Plans

This Subsidence Management Plan is based on the approved Modification 2 Subsidence Management Plan and developed to be complementary and consistent with the following key project documents:

- S2-CIV-CT-HAD-REP-6410 MA01B.1 - Marica Adit Tunnel - Geomechanical Report
- S2-CIV-CT-HAD-REP-6501.A - Marica Adit Segmental Lining - Technical Report
- S2-CIV-HT-HTU-REP-6001 HT02C.2 - Long Plain Fault Zone - Technical Report
- Snowy 2.0 Main Works - Modification 2 , Appendix C Water Assessment , August 2023
- S2-FGJV-ENV-DPE-LET-0032_A_HRT Subsidence Update September 2023
- Snowy 2.0 Environmental Management Plans including the Water Management Plan (S2-FGJV-ENV-PLN-0010) and Groundwater Management Plan (S2-FGJV-ENV-PLN-0012).

In addition to the above, this Plan is intended to function in conjunction with the following existing project documentation:

- Design Drawings, Reports and Specifications
- Project Geotechnical Instrumentation and Monitoring Plan

- Construction Method Statements
- Inspection and Test Plans.

## 1.6. Plan Preparation

In accordance with Schedule 3, Condition 64(b), the Subsidence Management Plan has been prepared by Snowy 2.0 Tunnel Engineer, Nick Chapman and Senior Underground Engineer, Vikum Chathuranga under direction and supervision by suitably qualified experts from the Snowy 2.0 delivery team, Ben Chapman, SHL Lead Tunnel Engineer and Damiano Frontini, Geotechnical Lead from FGJV. The Plan has been approved by SHL General Manager Engineering and Quality, Damon Miller.

## 1.7. Consultation

In accordance with Schedule 3, Condition 64 of the Planning Instrument, this Subsidence Management Plan has been prepared in consultation with NSW National Parks and Wildlife Service (NPWS). This Plan has been based on the Subsidence Management Plan developed and approved for Modification 2.

**Table 1.7 Consultation undertaken for this Plan**

| Date | Consultation | Outcomes |
|---|---|---|
| 3 April 2025 | SHL and NPWS met to discuss the possibility of monitoring equipment needing to be placed outside the approved boundary. | To update the Plan to include notification to NPWS to prompt an environmental assessment and one off authorisation noting the temporary nature. |
| 16 May 2025 | SHL issued Subsidence Management Plan to NPWS for comment | SHL closed out NPWS list of comments. |
| 7 October 2025 | DPIE provided comments and a request for further information from SHL. | SHL in collaboration with Future Generation updated the document to address the RFI |
| 5 December 2025 | SHL issued the updated document to NPWS for their review, specifically the changes made to the document. | Request to include May 2025 consultation and provide Attachment 4 which was addressed. |

As part of the Independent Environmental Audit as required under Schedule 3, Condition 66, consultation will also be required with the relevant agencies, specifically NPWS and DPHI.

# 2. Environmental Requirements

Key environmental legislation relevant to this Plan include:

- *Environmental Planning and Assessment Act 1979* (EP&A Act)
- *National Parks and Wildlife Act 1974* (NPW Act)
- *Biodiversity Conservation Act 1994* (BC Act)
- *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act)

## 2.1. NSW Conditions of Approval

Table 2-1 details the applicable Conditions from the Main Works Infrastructure Approval (SSI 9687) which relate to the Subsidence Management Plan including where each condition is addressed within the Plan.

**Table 2-1 Main Works Condition of Approval relevant to the Subsidence Management Plan**

| Condition | Requirement | Addressed |
|---|---|---|
| Schedule 3, Condition 63 | The Proponent must ensure that any project related subsidence impacts do not cause greater than negligible environmental consequences on the National Park Estate, including but not limited to water, biodiversity and heritage values. | This Plan |
| Schedule 3, Condition 64 | Prior to recommencing tunnelling using tunnel boring machine Florence as described in MOD 2 or commencing tunnelling for the Marica west adit as described in MOD 3, the Proponent must prepare a Subsidence Management Plan in respect of the tunnelling works by tunnel boring machine Florence and the Marica west adit, to the satisfaction of the Planning Secretary and in consultation with NPWS. This plan must: | This Plan |
| | (a) be prepared by a suitably qualified geotechnical expert; | Section 1.6 |
| | (b) include detailed measures and controls that would be implemented to ensure performance measure in condition 63 is met; | Section 4 and 5<br>Attachment 2 |
| | (c) include a detailed description of subsidence monitoring prior to tunnelling recommencing and ongoing monitoring at surface or within the tunnel; | Section 4 |
| | (d) include a risk assessment and trigger action response plan (TARP) to identify and manage settlement risk; and | Section 5<br>Attachment 2 |
| | (e) include a contingency plan and adaptive management process. | Section 5.1<br>Attachment 2 |
| Schedule 3, Condition 65 | The Proponent must implement the Subsidence Management Plan as approved by the Planning Secretary | This Plan |
| Schedule 3, Condition 66 | Within 6 months of the recommencement of the tunnelling works by tunnel boring machine Florence or commencing tunnelling for the Marica west adit as described in MOD 3, unless otherwise agreed by the Planning Secretary, and at any other time requested by the Planning Secretary, the Proponent must commission and pay the full cost of an Independent Environmental Audit of the Subsidence Management Plan described in condition 64. This audit must: | Section 6.3 |
| | (a) be conducted by a suitably qualified, experienced and independent team of experts, including a lead auditor, whose appointment has been endorsed by the Planning Secretary; | Section 6.3 |
| | (b) include consultation with the relevant agencies; | Section 1.7<br>Section 6.3 |
| | (c) assess the environmental performance of the development and whether it is complying with the requirements in conditions 63 and 64; | Section 6.4 |

| | | |
|---|---|---|
| | (d) review the adequacy of the approved strategies, plans or programs for the development; and | Section 6.4 |
| | (e) recommend appropriate measures or actions to improve the environmental performance of the development, and/or any approved strategies, plans or programs. | Section 6.4 |
| Schedule 3, Condition 67 | Within 12 weeks of commissioning the audit required in condition 66, unless the Planning Secretary agrees otherwise, the Proponent must submit the following via the Major Projects Portal: | Section 6.4 |
| | (a) a copy of the audit report; | Section 6.4 |
| | (b) its response to the recommendations in the audit report; and | Section 6.4 |
| | (c) a copy of the proposed audit action plan to address the recommendations. | Section 6.4 |
| Schedule 3, Condition 68 | The Proponent must implement any approved audit action plan for the development. | Section 6.4 |

## 2.2. Revised Environmental Management Measures

Table 2-2 details the applicable environmental management measures from the Main Works Infrastructure Approval (SSI 9687) Revised Environmental Management Measure (REMMs) which relate to the Subsidence Management Plan including where each measure is addressed within the Plan.

**Table 2-2 Relevant Revised Environmental Management Measures**

| Impact | Ref # | Revised Environmental Management Measure | Where addressed |
|---|---|---|---|
| Groundwater | | | |
| Groundwater inflow /drawdown | WM06 | The groundwater model developed for Snowy 2.0 Main Works will be validated and, if necessary, recalibrated to new groundwater monitoring data as the monitoring record increases throughout construction.<br><br>It is recommended that assessment of the monitoring record and groundwater affecting activities, along with model updates, be undertaken at least annually throughout construction and into operation until it is evident that the update frequency can be reduced | Groundwater Management Plan |
| Groundwater modelling | WM07 | Where discrete high flow features are intercepted, pre-grouting and secondary grouting from the TBM may be undertaken to enable tunnel construction | Groundwater Management Plan |

## 2.3. Environment Protection Licence

Table 2-3 details the conditions applicable to the Project's Environmental Protection Licence (EPL) (21266) which relate to the Subsidence Management Plan including where each condition is addressed within the Plan.

**Table 2-3 Environmental Protection Licence applicable conditions**

| Condition no. | Condition | Where addressed |
|---|---|---|
| **R2 Notifications of environmental harm** | R2.1 Notifications must be made by telephoning the Environment Line service on 131 555. | This Plan and the Project's Environmental Management Plan's<br><br>Section 6.5 of this Plan. |
| | R2.2 The licensee must provide written details of the notification to the EPA within 7 days of the day on which they become aware of the incident. | Section 6.5 of this Plan. |

## 2.4. Commonwealth Approval

Table 2-4 details the applicable conditions of the Commonwealth EPBC Referral related to the Subsidence Management Plan including where each condition is addressed within the Plan.

**Table 2-4 Commonwealth EPBC Act Approval conditions relevant to subsidence**

| Condition | Requirement | Where Addressed |
|---|---|---|
| Condition 34 | The approval holder must notify the Department in writing of any incident as soon as practicable after becoming aware of the incident and no later than two business days. The notification must specify: | Section 6.5 |
| | (a) a short description of the incident; and | Section 6.5 |
| | (b) the location (including co-ordinates), date, and time of the incident. In the event the exact information cannot be provided, provide the best information available. | Section 6.5 |
| Condition 35 | The approval holder must provide to the Department in writing the details of any incident or noncompliance with the conditions or commitments made in plans within 10 business days after becoming aware of the incident or non-compliance, specifying: | Section 6.5 |
| | (a) any condition that is or may be in breach; | Section 6.5 |
| | (b) any corrective action or investigation which the approval holder has already taken or intends to take in the immediate future; | Section 6.5 |
| | (c) the potential impacts of the incident or non-compliance on protected matters; | Section 6.5 |
| | (d) the method and timing of any remedial action that will be undertaken by the approval holder. | Section 6.5 |

## 2.5. NPWS Licence and Lease

In 2018, SHL established an Agreement for Lease with NPWS. In order to carry out the works in accordance with the relevant Snowy 2.0 Main Works and approved management plans, a Construction Lease (CL) and Works Access Licence (WAL) were established with NPWS.

In consultation with NPWS in the preparedness of this Plan, a one-off authorisation under the *National Parks and Wildlife Regulation 2019* may be permitted should temporary monitoring equipment be required outside the current NPWS lease boundary for the purpose of monitoring subsidence.

Similarly, SHL will undertake a Conservation Risk Assessment and submit to NPWS for approval prior to this activity occurring in accordance with Clauses 2.107 and 2.20 of the Transport and Infrastructure State Environmental Planning Policy (SEPP) 2021.

# 3. Marica Adit and Headrace Tunnel Construction Approach

The tunnels within the scope of this Management Plan, comprising the Marica Adit and downstream sections of the Headrace Tunnel, will all be excavated using a new purpose built TBM, designated TBM4.

TBM4 is a sophisticated Earth Pressure Balance (EPB) shield TBM, which has the capability to apply an active face pressure during excavation, primarily for the purpose of controlling geotechnical stability within varying ground conditions ranging from soft, soil-like material to hard volcanic rock. However, this capability also allows for the enhanced control of ground subsidence above the tunnel alignment.

The EPB shield functions by turning excavated material into a soil paste that is used as a pliable, plastic excavation support medium. This makes it possible to balance the pressure conditions at the tunnel face, avoid uncontrolled inflow of soil into the machine and create the conditions for tunnelling with minimal settlement. A screw conveyor transports the excavated material from the base of the excavation chamber onto a belt conveyor, where it is transported out of the tunnel. The interaction between the screw conveyor's throughput and the TBM's advance rate ensures that the support pressure of the soil paste can be controlled precisely.

The TBM4 excavation drive will commence with the construction of the 1,400m long Marica Adit, which will connect the surface Marica Adit Portal with the Headrace Tunnel alignment. The TBM4 drive will then continue eastward to construct downstream sections of the Headrace Tunnel, between HRT Ch. 17+365 and approximately HRT Ch. 15+400. This section of the Headrace Tunnel encompasses a complex regional geological feature known as the "Long Plain Fault", which presents geotechnical challenges for tunnel construction. TBM4 has been engineered with particular consideration to navigating and overcoming the highly demanding ground conditions anticipated within this critical stretch of the Headrace Tunnel. However, as this entire tunnel section has more than 300m of ground cover, it is considered to have a negligible risk of surface subsidence. Moreover, the capabilities of TBM4, although primarily required for the excavation of the Long Plain Fault Zone, make the TBM highly capable at controlling ground subsidence within shallow cover sections of the Marica Adit.

The completion of the TBM4 drive will coincide with the intersection with the westward heading TBM3 drive, which is currently constructing the majority of the Headrace Tunnel from the Tantangara Intake.

# 4. Subsidence Instrumentation and Monitoring

## 4.1. Subsidence Monitoring Approach

The general approach to subsidence instrumentation and monitoring comprises the following steps:

1. Prediction of ground subsidence due to the proposed tunnelling activities, followed by the planning and installation of instrumentation and monitoring systems;
2. Monitoring, review and interpretation during construction;
3. Response to suit the observed performance.

These steps define the framework of this Plan and in general, reflect the process adopted for the design and construction of the Snowy 2.0 tunnels as defined in the specific project documentation. This Plan draws on the detailed information from this supporting documentation where necessary.

Given the Snowy 2.0 tunnels are predominantly located deep beneath the ground surface, a focus on in-tunnel instrumentation and monitoring has typically been adopted. This reflects the low risk of surface subsidence, but also the timeliness and effectiveness of in-tunnel systems with respect to monitoring and responding.

However, for areas of the Headrace Tunnel and Marica Adit that are less than 100m in depth below surface level, where there is a potential risk of subsidence, ground surface instrumentation and monitoring subsystems have also been adopted. These subsystems supplement and complement the existing in-tunnel systems.

The following sections describe the main parts of the subsidence monitoring approach, in line with the above.

## 4.2. Subsidence Prediction And Impact Assessment

As a key component of this Plan, assessments have been undertaken to predict the structural performance of the tunnel support system, and the corresponding tunnel and ground surface deformations which may occur during construction. Using these predictions, potential impacts on surrounding areas and the environment have then been assessed. The assessments rely on inputs from the following:

- The project Geotechnical Investigation Program, which was undertaken to gain an understanding of the ground conditions within which the tunnels will be constructed
- The tunnel design process, which aims to enable:
    - Safe construction
    - Safe and functional operation
    - Management of project risks and minimisation of environmental impacts
- Planning for an approach to construction, involving methodologies, sequences of works and risk mitigation and control measures which are compatible with the project and design requirements (and vice versa).

Applying the above, subsidence predictions have been undertaken based on a Gaussian distribution using the method proposed by Mair et al (1993), which is a standard industry accepted approach. In this method, the excavation of a tunnel provides an opening into which the surrounding ground can deform. The movement of the ground into the opening can be related to the concept of ‘loss of ground’, where the convergence of the ground surrounding the tunnel after excavation is related to the ‘volume loss’ at the surface.

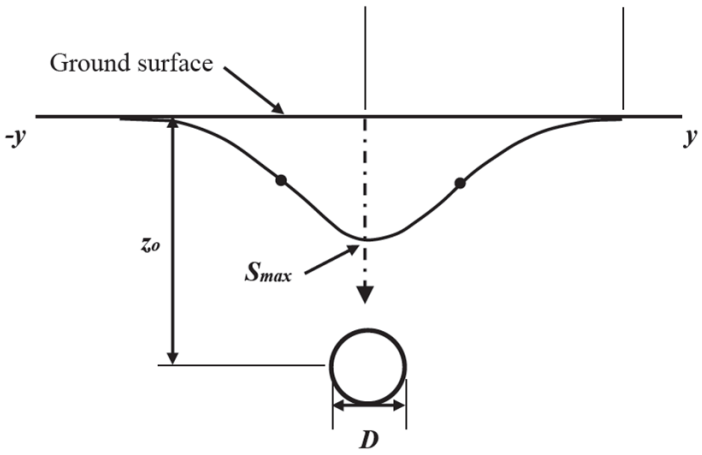


**Figure 1. Cross Section of predicted subsidence during tunnelling**

The volume loss parameter provides an assessment of the amount of tunnel convergence that may manifest as surface settlement. The volume loss parameter represents the change in excavated area due to convergence, compared with the original excavated volume of the tunnel, and is generally expressed as a percentage.

The volume loss is dependent on the geological conditions and the tunnel excavation methodology. Depending on the material that the tunnel passes through, the volume loss at the tunnel can be less than, equal to or greater than the volume of the settlement trough observed at the surface. Other factors controlling the magnitude of settlement include the size of the tunnel cross-section and the depth to the centreline of the tunnel.

The maximum settlement due to tunnelling is calculated using the following equation:

$$S_{\max} = \frac{0.31 V_L D^2}{K z_0}$$

Where:

*$S_{max}$ = maximum settlement at the tunnel centreline*

*$V_L$ = volume loss*

*D = equivalent diameter of a tunnel*

*K = trough width parameter*

*$Z_o$ = depth from ground surface to tunnel axis.*

Assessments have been conducted to identify the possible range of volume loss for the Marica Adit and Headrace Tunnel. This was done by considering actual settlement data during past tunnelling activities and back calculating the actual volume loss. The TBM in the Adit is expected to be predominantly excavated in rock, however with possible very localised sections of poorer material. Two cases were used to evaluate the maximum potential settlement, the first considering a credible lower bound design case and assuming the material to be excavated is soil with no cohesion. This case has been used to develop the monitoring triggers A second case has been assessed considering likely encountered conditions assuming the material to be excavated is weak rock, however this is used for reference only due to the lower predicted impacts. These worked examples have been provided in Attachment 1.

Based on the subsidence prediction assessment conducted, a maximum ground subsidence of 21 mm may occur close to the Marica Adit Portal, where the ground cover is only 35m. However, this is assuming the credible lower bound design case of “Granular And Non-Cohesive Material”. When a more likely scenario of “Weak Rock” is assumed with a conservative Volume Loss, it is predicted that a maximum subsidence of 2.5 mm at the surface may occur close to the Adit Portal.

At CH 0+200 the TBM will reach the projection of the EIS boundary, where the TBM will have a depth of 60 m to surface.Beyond this point it is considered that the risk of subsidence is low and there will be negligible surface settlement. To be conservative, further assessments were extended to the location at which the tunnel reaches 100m overburden.

Once the TBM is at 100 m depth, the predicted settlement is less than 10 mm , which is negligible This depth of cover will be reached at Ch. 0+400, and from that point forward the tunnel cover does not reduce to less than 100m for the remainder of the tunnel drive.

#### 4.2.1. The Extent of Ground Subsidence Monitoring

The Marica Adit will be excavated within the Boraig Formation (BRG) up to approximately Ch. 0+487, after which the remaining section of the Marica Adit, along with the Headrace Tunnel section, will be excavated in the Ravine Beds East Formation (RBE). Upon advancing approximately 1,400m, TBM4 will intersect the Headrace Tunnel alignment. The Headrace Tunnel section designated for excavation by TBM4 extends from HRT Ch. 17+365 to approximately HRT Ch. 15+400, encompassing the most challenging section of the Long Plain Fault Zone, which spans 815m.

Based on the results of subsidence prediction assessments for the TBM4 alignment, tunnel sections with more than 100m of ground cover are considered to have negligible risk of surface subsidence. The only tunnel stretch with a ground cover of less than 100m is located in the Marica Adit, between Ch. 0+000 and Ch. 0+400. Consequently, this section (0+000 to Ch. 0+400) is the only part of the TBM4 alignment designated for Surface Subsidence Monitoring, under this Subsidence Management Plan.

Surface monitoring will be actively undertaken in the first 200m of tunnel to CH0+200 which lies within the EIS boundary. If during the tunnelling activities, the monitoring exceeds the Action trigger level, the surface monitoring boundary will be extended to cover a further 200 m to CH0+400 of tunnel at which point 100 m overburden will be achieved.

As such the Surface Subsidence Monitoring has been split into two sections for the ease of access and the difference in instrumentation used;

1) Surface Subsidence Monitoring within EIS boundary (Ch. 0+000 to Ch. 0+200)
2) Surface Subsidence Monitoring outside EIS boundary (Ch. 0+200 to Ch. 0+400), if required

Consultation with NSW Archaeology (November 2025) confirms there are no known heritage values within the zones of potential impact.

## 4.3. Subsidence instrumentation and monitoring

To observe and control surface settlement (subsidence), it will be necessary to monitor the actual ground response to tunnelling. The prediction assumptions (i.e. VL and K) will be confirmed or adjusted (this is also called “calibration of the model”). In parallel, the survey records will be used as part of a Trigger, Action and Response Plan (TARP), designed to manage and control the risk of impacts on the ground surface and surrounds.

The monitoring of potential subsidence will be identified through two methods;

1) monitoring of tunnelling operations and equipment
2) monitoring of the surface using ground based survey

The “as built gaussian curve” recorded on site will be used to confirm/amend the assumption reported in chapter 4.2. The results will also be used to confirm/amend the required monitoring extension that, from the empirical analysis, is not predicted to be required once the tunnel will be at depth of 60m.

The approach to monitoring will focus on in-tunnel methods, with surface methods supplementing in certain areas. Both the surface and in-tunnel instrumentation and monitoring systems are described as follows.

### 4.3.1. In Tunnel Monitoring for Subsidence

As mentioned above, the volume loss is dependent on both the geological conditions and the tunnelling methodology. To control the volume loss due to excavation, monitoring inside the tunnel will also be required.

During tunnelling, the amount of sub-surface excavated material tends to lead to localised ground movement inward towards the tunnel. The first phase is volume loss due to stress relief ahead of the tunnel shield whereby the second phase occurs due to radial ground movement around the tunnel.

Along the TBM4 alignment, for the calculation of the maximum settlement (Smax), the TBM is assumed to be operating in ‘closed’ or ‘EPB’ mode. In principle, closed face tunnelling involves continuous face support, in order to reduce ground deformation.

In ‘EPB mode’ the control of the face extrusion will be guaranteed by the exerted EPB pressure on the excavated face, and radial movement of the excavated tunnel profile is controlled by the TBM shield and pressurized backfill grout injected in to the annulus between the excavated profile and the installed support.

In addition to the existing geological information, 2 No. 150m long probe holes will be drilled from the portal before launching the TBM, parallel to the tunnel alignment. From 150m onwards, additional sets of probe holes will be drilled from the TBM in order to assess the ground conditions in front of the tunnel excavation face. Upon completion of the Geological Assessment, the face pressure applied by TBM4 will be adjusted to suit the encountered conditions

In stable ground, where the TBM will be operated in ‘Semi-closed mode’ with minimal face pressure the ground deformation is expected to be minimal in the TBM advance time frame.

The structural monitoring of the installed support is also a key parameter concerning ground movement, and therefore tunnel convergence (closure) and lining stresses will also be monitored. In-tunnel convergence monitoring will involve survey targets installed on the tunnel segments after installation while lining stresses will be monitored using strain gauges cast into the tunnel segments.

Over-excavations will affect, in an unfavourable way, the Volume Loss and as a consequence the settlement at the surface. The control of the extracted volume from the TBM is the key parameter to avoid over-excavation leading to surface subsidence.

The volume of material being produced during TBM operations is measured through the conveyor system which is continuously recorded during TBM excavation. This value is monitored and controlled by the TBM operator with a guidance sheet showing the muck tonnage/ required for a given length of mining. Any breach in the muck tonnage by +10% at every 600 mm during the first 400m of tunnel excavation will activate the TARP.

In Tunnel Convergence monitoring will be undertaken daily until the distance between the excavation face and the convergence array is greater than 30 m. Between 30 m and 60 m, the frequency of monitoring will be twice weekly. When the distance between the excavation face and the convergence array is greater than 60 m, the frequency of monitoring will be weekly, until tunnel excavation is complete.

Strain gauges readings are undertaken with an automated logging system every 6 hours until 3 sets of stabilized readings are achieved.

### 4.3.2. Surface Subsidence Monitoring Within EIS Boundary

To record the "As-built gaussian curve" along the surface, the area inside the EIS boundary will be monitored using tilt sensors checked via 1D levelling observations. Moreover, for the first meter of the tunnel, where there is an unobstructed line of sight to the installed level and tilt targets, an automated total station will be set up to monitor these targets in an almost continuous manner, in order to improve the calibration of the Gaussian curve. The tilt monitors will be installed on spikes that can be removed at the completion of the subsidence monitoring program.

Settlement sections will be installed inside the EIS boundary and an initial baseline will be established with daily readings no less than 7 days before any mining takes place. This base line will be used as a comparison for future readings to trigger any breach of threshold activating the TARP.

This settlement is expected to occur shortly after the installation of the marks. To mitigate this effect, before mining, two monitoring runs will need to be in agreement within a tolerance of 2 mm to establish the baseline. Settlement in a gaussian distribution, as detailed above is then expected.

The tilt sensors are highly sensitive and linked over radio. This will allow the alignment to be monitored remotely, in real time, with minimal impact to the surface. An example of the array and its connectivity is shown in Figure 2. The tilt sensors will be installed to target the predicted point of inflection of the gaussian curve.

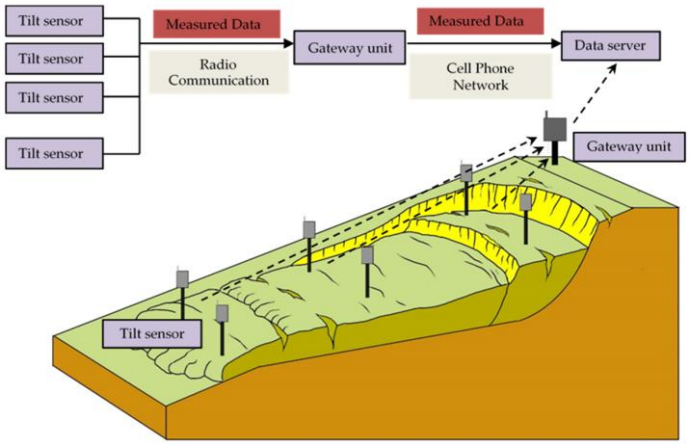


**Figure 2. Example tilt sensor array**

The installed tilt sensors will provide early indications of ground movement and will be compared with regular 1D levelling surveys along the tunnel axis to verify the results once per week.

If movement is detected by the tilt sensors outside of baseline readings and reported in the daily Geotechnical Monitoring meeting, a 1D levelling survey will occur weekly for all the installed points, daily along the tunnel axis and continue until the tilt sensors return to baseline. When this method is unsuitable, prisms will be installed and readings taken with an Automated Total Station (theodolite). Both techniques can achieve measurement accuracies of +/- 1mm.

For both the tilt sensors and 1D levelling, survey marks similar to the below example will be installed. These marks are removable and are minimally invasive to the natural surface whilst still providing a reliable measuring point. Marks will be installed in arrays perpendicular to the alignment at 10 m intervals parallel to the alignment. Four tilt sensors will be installed in each array with two sensors on each side of the alignment center line, at both 10 m and 20 m offset to the center line. Seven 1D leveling marks will be installed in each

array starting from the alignment center line at 10m intervals. Where possible the same marks will be used for both 1D leveling and tilt sensors. Details of the survey plan are provided in attachment 4 .

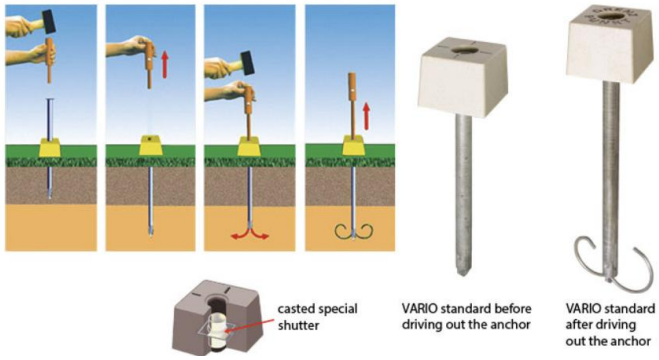


**Figure 3. Proposed Survey Mark Tilt Sensor Mark**

The initial survey will form the baseline for subsequent measurements to overlay, and thus determine any variations. This comparison work will be demonstrated and reported daily.

Regarding the execution of leveling surveys, while the ideal methodology involves linear traverses, site-specific constraints imposed by terrain topography and vegetation necessitate the establishment of a non-linear survey path to circumvent physical obstructions and arboreal features. This carefully planned traverse will minimize environmental impact and ensure the integrity of the leveling measurements. All survey methodology is to conform with the Surveying and Spatial Information Regulation 2017 by the NSW government.

Settlement frequency monitoring will be undertaken at least once a day during excavation. Monitoring of the mark array will start 30m ahead of the TBM mining face beneath as the drive progresses.

### 4.3.3. Surface Subsidence Monitoring Outside EIS Boundary

Depending on the monitoring results found in the first 200m of the drive along the alignment, the following monitoring program is available to continue assurance of ground stability along the TBM alignment.

This approach will require notification and approval from NPWS. Items 1 to 3 outline this approval process:

- SHL to notify NPWS in writing (email acceptable) prior to 200m the need to install equipment outside the EIS boundary
- SHL applies to NPWS for a one-off authorisation to access outside the EIS boundary including the submission of a Conservation Risk Assessment (CRA) to NPWS.
- NPWS to assess the CRA and provide approval advice within 10 business days of receipt.

Pending NPWS approval, the area outside the EIS boundary will be monitored using tilt sensors for approximately three months, that will be installed on spikes that can be removed at the completion of the subsidence monitoring program.

These tilt sensors are highly sensitive, linked over radio, and have long battery life. This will allow the alignment to be monitored remotely, in real time, with minimal impact to the surface. Refer example, Figure 2 above.

The extent of the area to be observed will be a minimum of 400m from the Marica Adit Portal to a width of at least 60m (30m either side of the TBM alignment).

Marks similar to the above example will be installed in the same array as detailed in section 4.3.2

The initial survey will form the baseline for subsequent measurements to overlay, and thus determine any variations. This comparison work will be demonstrated and reported daily.

Where alarm levels are triggered, consultation with DPHI, DCCEEW and NPWS will be required. As required, a physical survey can be conducted as these spikes can also be used to take advantage of 1D levelling survey techniques. When this method is unsuitable, prisms will be installed and readings taken with an Automated Total Station. Both techniques can achieve accuracies of +/- 1mm.

Where Action or Alarm level is reached from the 'in tunnel' TARP criteria, DPHI and NPWS will be notified.

Monitoring will be undertaken daily during TBM excavation until the excavation face reaches 50m past the monitoring area and 3 consecutive readings indicate movements have stabilised. Depending on monitoring results, the monitoring area will be either up to CH0+200m or CH0+400m. This 100m depth of cover will be reached at Ch. 0+400, and from that point CH0+400m forward the tunnel cover does not reduce to less than 100m again.

# 5. Ground Subsidence Review

## 5.1. Trigger Action Response Plan

Survey data will be used as part of a Trigger, Action and Response Plan (TARP), designed to manage and control the risk of impacts on the ground surface and surrounds.

The TARP will operate within the framework of the existing Daily Geotechnical Monitoring and Permit to Tunnel meetings, during which data will be reviewed by the project team within 24 hours of collection. Data review will involve the following:

- Confirmation of baseline readings
- Comparison of actual results to predicted results and trigger levels
- Assessment of current monitoring frequencies and need for change based on results
- Relationship to construction process
- Review of action plans
- Completion of monitoring.

The following three (3) trigger levels shall apply during tunneling:

- Trigger / Alert Level - Set to the anticipated design case
- Action Level - Set to approximately 75% of acceptance criteria
- Response / Alarm Level - Set to nominally 100% of acceptance criteria

Acceptance criteria limits have been selected based on similar criteria applied on recent tunnelling projects in NSW.

In the event that monitoring results equal or exceed trigger levels, an Excavation Performance Review (EPR) meeting will be convened with persons listed in Section 6.1 of this Plan, to review the situation and define the requirements for revised support arrangements that will prevent ongoing deformation.

Where necessary, contingency measures will be implemented as defined within the Design and Construction Method Statements, in relation to:

- Additional instrumentation and monitoring
- Additional structural ground support measures, and
- Changes to the excavation methodology.
- Revised trigger levels, if required

A full list of relevant contingency measures for consideration are provided in the TARP for the respective trigger levels. Please refer to Attachment 2 for the Trigger Action Response Plan (TARP) that will be implemented during the tunnelling re-commencement works. If during the first 200m of TBM excavation the Action Trigger Level is reached, the surface monitoring array will be extended up to CH0+400m.

## 5.2. Trigger Levels

Based on the current geotechnical assessments the excavation is expected to be in weak rock material as assessed in case B. However a credible lower bound design case has been undertaken, considering a granular and non cohesive material, which the settlement triggers have been based on. The full list of trigger levels are provided in Attachment 2. Key trigger levels are summarised as follows:

**Surface Settlement**

| Measured Parameter | Alert Level | Action Level | Alarm Level |
|---|---|---|---|
| Settlement at Surface | 20 mm | 30 mm | 40 mm |
| Angular Distortion at Surface | 1 in 833 | 1 in 500 | 1 in 250 |

**In-tunnel Convergence and Stress**

| Measured Parameter | Alert Level | Action Level | Alarm Level |
|---|---|---|---|
| Tunnel Convergence | 5 mm | 10 mm | 20 mm |
| Segmental Lining Strain Gauges Stresses | 320 Mpa | 400 Mpa | 500 Mpa |

**Excavated Volume**

Guidance sheet showing the muck tonnage required for the given length of the mining. Any breach in the muck tonnage by +10% at every 600mm will activate the given TARP.

# 6. Compliance Management

## 6.1. Roles and Responsibilities

Key project personnel are outlined in Table 6.1. These key personnel are primarily responsible for the following:

- Overall coordination of site operation procedures for TBM 4;
- Recording and verification of all monitoring instrument readings;
- Collection, management and reporting of the monitoring results;
- Review and action as necessary, contingency plans and recommendations.

Area construction teams, survey team and the geotechnical team are responsible for the installation of the monitoring instruments.

**Table 6.1 Roles and responsibilities for the operation of TBM 4**

| Role | Responsibility |
|---|---|

| | | |
|---|---|---|
| **FGJV Construction Team** | **Project Director** | • Manage the delivery of the Snowy 2.0 Project including overseeing Instrumentation and Monitoring (I&M) planning and management.<br>• Immediately notify SHL of the enactment of the Emergency Response Plan.<br>• Formal communication with external authorities, where necessary.<br>• Direct communication from the media to SHL except where FGJV has an obligation to meet legal requirements. |
| | **TBM Construction Manager** | Ensure that the design aspects of the I&M system are being correctly interpreted and implemented on site through the following;<br>• Provide review and input into the design for the I&M Plan<br>• Provide review and input into Construction Method Statements<br>• Allocate resources and personnel suitably qualified & experienced in underground construction, namely the Project Manager, Engineers and Supervision.<br>• Conduct regular reviews of the instrumentation and monitoring data together with the TBM Senior Project Engineer and Project Manager.<br>• Attend Excavation Performance Review (EPR) meetings<br>• Monitor the implementation of the Emergency Response Plan and provide high level decisions and instruction regarding the implementation of this Plan. |
| | **TBM Senior Project Engineer & TBM Engineer** | • On the ground implementation of this Plan as directed by the roles listed above<br>• Review and interpret I&M data<br>• Chair Permit to Tunnel (PTT) Meetings<br>• Chair Excavation Performance Review (EPR) meetings<br>• Confirm I&M complies with the design drawings, or in cases of departure from the design, that technical validation has been achieved and documented. |
| | **TBM General Superintendent** | • Ensure TBM operation in accordance with all design and construction documentation, including this Plan.<br>• Immediately notify the roles above where trigger values are approached or exceeded. |
| | **TBM Superintendent** | • Ensure TBM operation in accordance with all design and construction documentation, including this Plan.<br>• Immediately notify the roles above where trigger values are approached or exceeded. |
| | **TBM Pilot** | • Ensure TBM operation in accordance with all design and construction documentation, including this Plan.<br>• Immediately notify the roles above where trigger values are approached or exceeded. |
| | **Geotechnical Engineer and Geologist** | • Undertake geological inspections and/or mapping of the excavation face or spoil material and produce associated records<br>• Review and interpret I&M data<br>• Advise the convening of the Excavation Performance Review meeting, where necessary<br>• Chair the Geotechnical Monitoring Meetings (GMM)<br>• Advise the Permit to Tunnel (PTT) meetings |

| | | |
|---|---|---|
| | | • Attend Excavation Performance Review (EPR) meetings |
| | **Survey Manager** | • Manage all survey resourcing and data collection for I&M activities.<br>• Oversee implementation of this plan and the I&M process with regard to manual instrument installation.<br>• Ensure consistent application of I&M across all areas of responsibility.<br>• Review and interpret I&M data.<br>• Provide survey data for Geotechnical Monitoring and Permit to Tunnel meetings. |
| **Design Team** | **Design Site Representative** | • Review and interpret I&M data<br>• Review any trigger-level breaches and provide design input for any required remediation.<br>• Design validation (confirming the works and geology are performed in accordance with the design intent and limits).<br>• Attend Geotechnical Monitoring, Permit to Tunnel and Excavation Performance Review (EPR) meetings<br>• Attend geological inspections and/or mapping of the excavation face or spoil material |
| **SHL Assurance Team** | **Project Manager** | • Oversight of the implementation of the I&M planning and management (including required reporting). |
| | **Site Tunnel Engineer** | • Oversight that all controls are in place and all relevant documentation and checklists are completed prior to the commencement of excavation works.<br>• Oversight of compliance with Construction Method Statements, Inspection and Test Plans, IFC Design Drawings, I&M Plan and other relevant documentation<br>• Undertake geological inspections and review of excavation face mapping and associated records, as necessary to satisfy the Owner's assurance and oversight responsibilities |
| | **Underground Surveillance Officer** | • Oversight of TBM operation and monitoring activities in accordance with the I&M Plan and other design and construction documentation, including this Plan. |
| | **Environmental Assurance Officer** | • Liaison with NPWS including ensuring assurance oversight with approvals and incident reporting. |

## 6.2. Training and Awareness

All persons including but limited to engineers, surveyors, supervisors and management personnel involved in the subsidence monitoring and management will undergo a specific activity induction which will include the TARP, compliance approval reporting and notifications.

Similarly, all Project personnel are required to undergo the Future Generation site induction training prior to commencing works onsite. The Project induction covers key environmental protection risks and their management.

## 6.3. Audits

Internal audits will be undertaken to assess the effectiveness of the management measures and compliance with this Subsidence Management Plan, the Infrastructure Approval and other approvals and licences listed in Section 2 of this Plan.

An independent audit will be undertaken as described in Modification 3 and in accordance with Schedule 3, Condition 66 of the Project Approval. The audit will be conducted by a suitably qualified, experienced and independent team of experts, including a lead auditor whose appointment has been endorsed by the Planning Secretary and meet the requirements listed in Condition 66 (refer to Table 2.1).

The independent audit will be based on a compliance audit of the Subsidence Management Plan with consideration to the monitoring reports and documents generated as listed by the Subsidence Management Plan. It is noted that the audit will occur following tunnelling for the section of Marica west adit with less than 100 m overburden.

Following the commissioning of the independent audit (within 12 weeks), SHL will submit the following to DPHI via the Major Projects Portal:

- a copy of the audit report
- response to the recommendations in the audit report
- a copy of the proposed audit action plan to address the recommendations
- Following which, SHL including FGJV where applicable, will be required to implement the audit action plan.

## 6.4. Reporting and Incidents

### 6.4.1. Ground Subsidence Reporting

SHL will report on the following monitoring aspects related to the Headrace Tunnel operations within the scope of this Subsidence Management Plan described in Section 1.4:

1. During construction, groundwater monitoring data will be collected, tabulated and assessed against thresholds. Reporting will occur in accordance with the GMP
2. A Subsidence Monitoring Progress Report will be submitted to the NSW Department of Planning, Housing, and Infrastructure on a fortnightly basis, and
3. Notification will be provided to the NSW Department of Planning, Housing, and Infrastructure in the event that any Action (yellow) or Alarm (red) trigger levels are reached, along with a description of the actions being undertaken in response. Refer to Attachment 3 for an example notification form.

### 6.4.2. Incident Reporting

SHL, in collaboration with its Contractor for these works (Future Generation Joint Venture) through the Project's Incident Reporting Procedure will report any environmental incidents in accordance with the requirements outlined in the Project's Environment Protection Licence, EPBC Referral and Conditions of Approval as outlined in Sections 2.1 to 2.4 of this Plan.

DPIE, NPWS and NSW EPA will be notified in the event of an actual or potential incident that may cause or threaten to cause material harm on the National Park Estate, including but not limited to water, biodiversity or heritage values, or may cause a non-compliance with the Project Approvals or this Plan.

# References

R.J. Mair, R.N. Taylor, A. Bracegirdle, (1993) Subsurface settlement profiles above tunnels in clays, Géotechnique, 43 (2), pp. 315-320

# Attachment 1 Assessment Examples

Case A – Material To Be Excavated Supposed Granular And Non-Cohesive:

VL= 0.50%

K= 0.3

Tunnel diameter D = 11.07m

Tunnel depth Z0 = Varies

| Smax (mm) | VL (%) | D (m) | K | Z0 (0) |
|---|---|---|---|---|
| 21.2 | 0.50% | 11.98 | 0.3 | 35 |
| 18.5 | 0.50% | 11.98 | 0.3 | 40 |
| 16.5 | 0.50% | 11.98 | 0.3 | 45 |
| 14.8 | 0.50% | 11.98 | 0.3 | 50 |
| 13.5 | 0.50% | 11.98 | 0.3 | 55 |
| 12.4 | 0.50% | 11.98 | 0.3 | 60 |
| 11.4 | 0.50% | 11.98 | 0.3 | 65 |
| 9.9 | 0.50% | 11.98 | 0.3 | 75 |
| 8.7 | 0.50% | 11.98 | 0.3 | 85 |
| 8.2 | 0.50% | 11.98 | 0.3 | 90 |
| 7.4 | 0.50% | 11.98 | 0.3 | 100 |
| 6.7 | 0.50% | 11.98 | 0.3 | 110 |
| 5.9 | 0.50% | 11.98 | 0.3 | 125 |

Case B – Material To Be Excavated Supposedly Weak Rock.

VL=0.10%

K=0.5

Tunnel diameter D = 11.07m

Tunnel depth Z0 = Varies

| Smax (mm) | VL (%) | D (m) | K | Z0 (0) |
|---|---|---|---|---|
| 2.5 | 0.10% | 11.98 | 0.5 | 35 |
| 2.2 | 0.10% | 11.98 | 0.5 | 40 |
| 2.0 | 0.10% | 11.98 | 0.5 | 45 |
| 1.8 | 0.10% | 11.98 | 0.5 | 50 |
| 1.6 | 0.10% | 11.98 | 0.5 | 55 |
| 1.5 | 0.10% | 11.98 | 0.5 | 60 |
| 1.4 | 0.10% | 11.98 | 0.5 | 65 |
| 1.2 | 0.10% | 11.98 | 0.5 | 75 |
| 1.0 | 0.10% | 11.98 | 0.5 | 85 |
| 1.0 | 0.10% | 11.98 | 0.5 | 90 |
| 0.9 | 0.10% | 11.98 | 0.5 | 100 |
| 0.8 | 0.10% | 11.98 | 0.5 | 110 |
| 0.7 | 0.10% | 11.98 | 0.5 | 125 |

# Attachment 2 - TARP Monitoring triggers for TBM Excavation

| Trigger Level | Condition | Action Plan |
|---|---|---|
| **Alert Level** | Movement is occurring, but system behaviour still within the range of target behaviour according to specifications of the design | • Performance of the ground support system to be more closely assessed<br>• Team undertaking monitoring, such as Survey Manager, or Geotechnical Engineer to immediately review the readings/assessments to ascertain the readings are reliable and not related to errors or other anomalies<br>• If the event is not caused by erroneous readings, the TBM Senior Project Engineer to be notified and is required to convene the Excavation Performance Review (EPR) meeting within 48 hours. Construction Team and Design Team to be notified by TBM Senior Project Engineer on becoming aware of the measurements<br>• Review the event and determine the cause and potential effects of the deformation<br>• Continue work as per normal operation |
| **Action Level** | System deviated from expected behaviour, and movement exceeding design value | • Cease mining/excavation<br>• Monitoring team to immediately review the readings to ascertain the readings are reliable and not related to errors or other anomalies<br>• Team undertaking monitoring, such as Survey Manager, or Geotechnical Engineer to immediately review the readings/assessments to ascertain the readings are reliable and not related to errors or other anomalies<br>• If the event is not caused by erroneous readings, the TBM Senior Project Engineer to be notified and is required to convene the Excavation Performance Review (EPR) meeting within 24 hours. Construction Team and Design Team to be notified by TBM Senior Project Engineer on becoming aware of the measurements.<br>• Monitoring frequency will be increased<br>• The deformation will be reviewed by the designer to confirm that the tunnel is performing as anticipated<br>• Carry out structural survey for the tunnel to confirm structural stability<br>• Review available data and construction/excavation methodology, including;<br>  ○ Geotechnical, instrumentation and monitoring data<br>  ○ TBM operating parameters<br>  ○ Backfill (annulus) grout volume, injection pressure and gelling time targets<br>  ○ EPB face pressure<br>  ○ Excavation rate<br>  ○ Ground conditioning process<br>**Additional Contingency Measures:**<br>• Review ground support performance and install additional support or undertake additional measures where necessary, such as;<br>  ○ Installation of Support Class SC2.<br>  ○ Additional proof drilling and secondary backfill (annulus) grouting<br>  ○ Installation of additional drainage holes |

| | | |
|---|---|---|
| | | ○ Installation of additional monitoring instrumentation<br>○ Post excavation grouting<br>○ Installation of steel ribs within installed segment lining<br>● Request NPWS for access outside of EIS boundary to extend surface monitoring array up to CH0+400<br>● Determine necessary actions to be investigated, such as confirming necessary equipment and ground support elements are available for immediate installation if necessary and if surface monitoring is required.<br>● Notification to relevant stakeholders of the potential requirement to revise trigger levels. |
| **Alarm Level** | Movement reaches acceptable tolerance level for the ground surface | ● Immediately cease all construction work. No further excavation shall be allowed until deformation is controlled<br>● The TBM Senior Project Engineer to be notified and is required to convene the Excavation Performance Review (EPR) meeting as soon as reasonably practicable, but within 24 hours. Construction Team and Design Team to be notified by TBM Senior Project Engineer immediately on becoming aware of the measurements.<br>● Consider the enactment of the Emergency Response Plan<br>● Review available data and construction/excavation methodology, including;<br>○ Geotechnical, instrumentation and monitoring data<br>○ TBM operating parameters<br>○ Backfill (annulus) grout volume, injection pressure and gelling time targets<br>○ EPB face pressure<br>○ Excavation rate<br>○ Ground conditioning process<br>**Additional Contingency Measures:**<br>● Review ground support performance and install additional support or undertake additional measures where necessary, such as;<br>○ Installation of Support Class SC2.<br>○ Additional proof drilling and secondary backfill (annulus) grouting<br>○ Installation of additional drainage holes<br>○ Installation of additional monitoring instrumentation<br>○ Post excavation grouting<br>○ Installation of steel ribs within installed segment lining<br>● Carry out structural survey for the tunnel to confirm structural stability<br>● Carry out remedial works where necessary<br>○ Implementation of Exclusion Zones<br>○ Installation of steel rib support within installed segmental lining<br>○ Backfilling of any voids or over excavations<br>○ Implement a recovery path, where TBM has deviated from the design alignment<br>● Monitoring frequency, extent of monitoring, Trigger Levels and if surface monitoring is required to be reviewed by the design and construction teams.<br>● Agree any revised trigger levels with relevant stakeholders<br>● Work may only proceed if remedial measures and any other required actions are implemented |

Table 02

| **Surface Monitoring During Excavation** | **Alert Level** | **Action Level** | **Alarm Level** |
|---|---|---|---|
| Settlement at surface, measured by survey of targets | 20mm | 30mm | 40mm |
| Angular Distortion at Surface | 1 in 833 | 1 in 500 | 1 in 250 |
| Settlement at surface, visual observation from drone | - | - | Any visual settlement |
| **Geotechnical Monitoring of the Excavated Tunnel and Segmental Lining** | **Alert Level** | **Action Level** | **Alarm Level** |
| Tunnel Convergence measurements taken from Displacement Monitoring Points | 5mm | 10mm | 20mm |
| Segmental Lining Strain Gauge Stresses | 320 Mpa | 400 Mpa | 500 Mpa |
| **TBM Navigation** | **Alert Level** | **Action Level** | **Alarm Level** |
| TBM Vertical Deviation | - | 25mm | 50mm |
| TBM Horizontal Deviation | - | 25mm | 50mm |
| TBM Pitch | -10% | -13.5% | -15% |
| **TBM Operating Parameters (Continuously adjusted to suit the conditions through Job Order)** | | **Maximum Allowable Limit** | |
| **Thrust Force** | | As per job order | |
| **Contact Force** (Should there be a significant drop in contact force, excavation to be stopped immediately) | | As per job order | |
| **Maximum Torque** | | As per job order | |
| **Cutterhead rpm** | | As per job order | |
| **Maximum Advance Speed** | | As per job order | |
| **Cutterhead maintained against the excavated face** | | At all times | |
| **Backfill Grout Volume** (Backfill Grout Pressure to be up to 2bar. If the amount of the grout exceeds 25% of the required volume during the advance, Inform TBM Supervisor and Engineer. Further assessment must be conducted) | | As per job order | |
| **Ground Water Ingress** | | **Trigger Value Action** | |
| **Probe Hole Triggers and Groundwater Inflow Performance Criteria** (Marica Adit Tunnel is considered under Inflow Performance Class 1) | | **Class 1:** Inflow > 2.0 l/s from Probe Holes | |
| **Excavated Volume (based on TBM belt scale measurements when excavated in Open Mode)** | | | |

During excavation, TBM operators will be provided with the guidance sheet showing the muck tonnage required for the given length of the mining. Any breach in the muck tonnage by + 10% at every 600mm will activate the given TARP.

**Below flow Chart is to be Followed if Excavation Tonnage Breaches the Parameters**

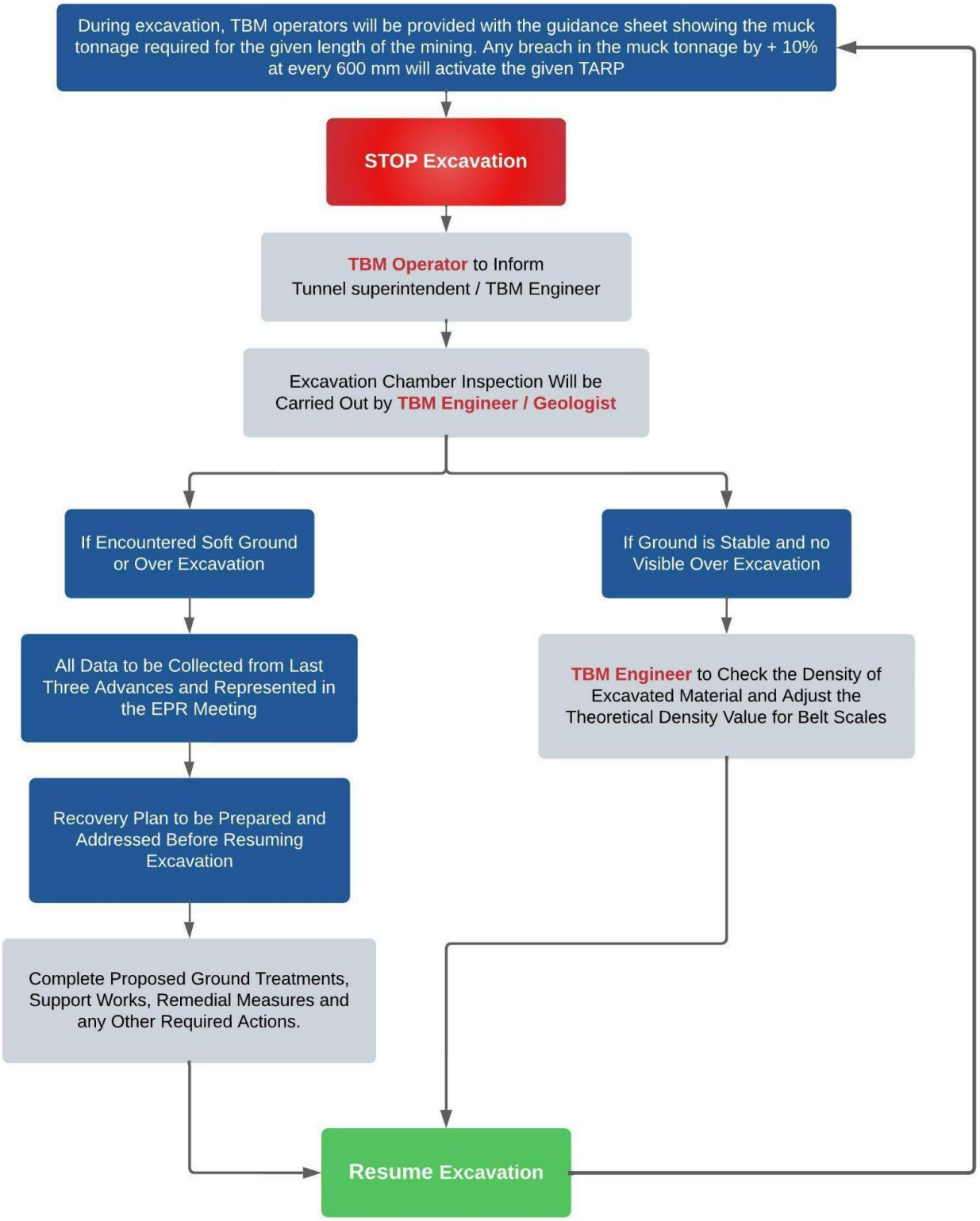


**Figure 01**

**Below Flow Chart is to be Followed if Settlement Alert (or greater) Triggered or Any Visual Observation of Ground Movement**

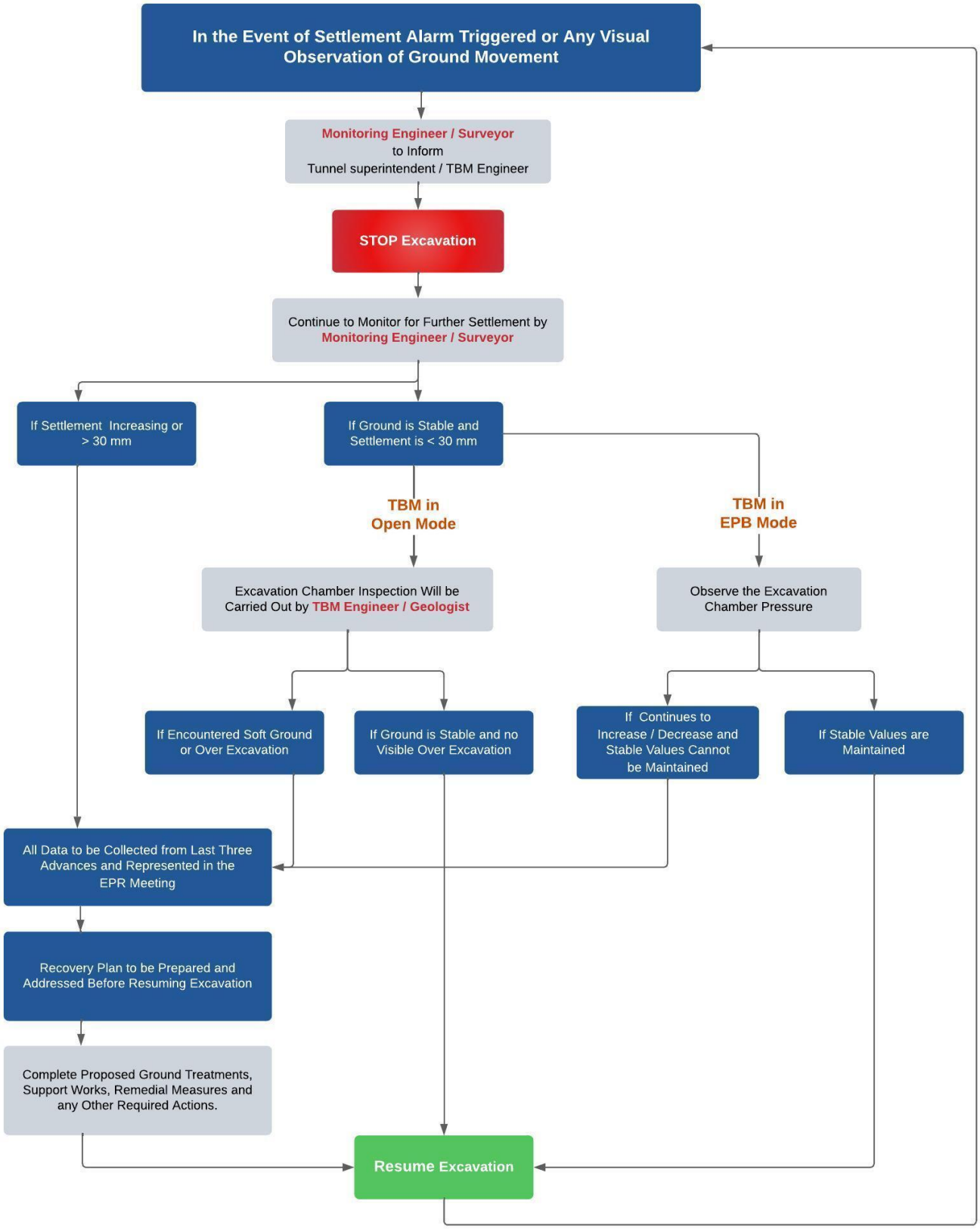
In the Event of Settlement Alarm Triggered or Any Visual Observation of Ground Movement
Monitoring Engineer / Surveyor to Inform Tunnel superintendent / TBM Engineer
STOP Excavation
Continue to Monitor for Further Settlement by Monitoring Engineer / Surveyor
If Settlement Increasing or > 30 mm
If Ground is Stable and Settlement is < 30 mm
TBM in Open Mode
TBM in EPB Mode
Excavation Chamber Inspection Will be Carried Out by TBM Engineer / Geologist
Observe the Excavation Chamber Pressure
If Encountered Soft Ground or Over Excavation
If Ground is Stable and no Visible Over Excavation
If Continues to Increase / Decrease and Stable Values Cannot be Maintained
If Stable Values are Maintained
All Data to be Collected from Last Three Advances and Represented in the EPR Meeting
Recovery Plan to be Prepared and Addressed Before Resuming Excavation
Complete Proposed Ground Treatments, Support Works, Remedial Measures and any Other Required Actions.
Resume Excavation

**Figure 02**

## Attachment 3 - Instrumentation & Monitoring Notification of Alert Form

| | | |
|---|---|---|
| Document No: | Snowy 2.0<br>Instrumentation and<br>Monitoring Notification of Alert |  |
| Issue: 01 | | |
| Date & Time: | | |

Trigger Level Exceedance - Action and Alarm

| The purpose of this form is to provide notification of trigger | |
|---|---|
| Drive: | Headrace Adit / Headrace Tunnel |
| Instrumentation Type: | |
| Instrument ID: | |
| Chainage: | |
| Current Value: | Trigger Value: |

Details of alert:

| |
|---|
| Area of Work Affected: |
| Monitoring Details: |
| General Information: |

| |
|---|
| Proposed Action: |

| | |
|---|---|
| Prepared: FGJV TBM Construction Manager | Reviewed: SHL Senior Project Manager |

| | |
|---|---|
| **Signature:** | **Signature:** |
| **Name:** | **Name:** |

## Attachment 4 - Survey Monitoring Plan