**SUBMISSION 05/09/2024**

**MODIFICATION-3: SSI-9687 - SNOWY 2.0 - MARICA ADIT & TBM-4**

**Snowy Monaro Community Advocates**
**Peter Anderson – Convenor**
**P.O. Box 913, COOMA NSW 2630**
**E: peter@rockcity.com.au**
**M: 0412-696699**

**We OBJECT to the Modification Application in its current form for the following reasons (pg.'s 1-33 including two attachments):**

## 1. INTRODUCTION:

The site of Snowy 2.0 and the proposed MOD-3 are in the highly sensitive and protected Kosciusko National Park, an asset of the people of NSW. This proposed MOD-3 introduces additional major works not envisaged, considered, 'approved', nor conditioned via any existing Approval.

These additional MOD-3 major works include:

Additional Clearing of KNP of habitat
- Road access to the 'adit' entry.
- Area in and around the 'adit' entry

Tunnel Waste Management
- 605,100 cubic meters (one NRL football field 80m high)

Misc Increased activity
- 14 Segment trucks movements per day
- 123 additional workers plus additional 42 truck drivers
- Truck drivers
- 36 Truck movements Marica to Rock Forest
- 204 Truck movements NOA Marica to Tantangara
- Accommodation in surrounding towns (av round travel distance 100km)

N.B. The MOD-3 Report states it has approval to temporarily store tunnel waste at Marica and the suggests approval to permanently leave tunnel waste around the 'shaft collar'.

**We request Planning provides the 'approval' to store 605,100 cubic meters of tunnel waste, and the EIS for the disturbance of the many hectares of undisturbed KNP and the required traffic management studies and public safety plans for 204 truck movements from Marica to Tantangara return.**

Any assessment of the SSI is to include the social impacts. Snowy Hydro conducted a community/public Snowy 2.0 survey months ago. Snowy Hydro is aware of the negative results this survey has produced; it would appear Snowy Hydro does not intend to release the results of this survey until after the MOD-3 is approved.

**We request the results of this survey are made publicly available and MOD-3 re-exhibited so the actual economic and social impacts, as experienced locally may be considered.**

MOD-3 involves significant works which may not meet the definition of 'modification'.

*5.25(1): **modification***
*Modification of an approval means changing the terms of the approval, including revoking or varying a condition of the approval or imposing an additional condition on the approval.*

**We request Planning considers if it may be more appropriate for Snowy Hydro to withdraw the 'modification application' and re-apply as a separate but linked 'approval'. And, Planning compiles the SEAR's, and the proponent undertakes the required EIS assessment.**

## 2. NON-COMPLYING EXHIBITION - Notification and Exhibition:

i) Exhibition period:
Planning: *"all SSI applications are exhibited to the public for at least 28 days."*
The Snowy Hydro, Planning and other government departments have been discussing the requirements to obtain 'approval' for MOD-3 since early this year.

Planning has not provided any reason that necessitates reducing their required 28-day notification period to only 14 days.

ii) Exhibition Documents Publicly Available
***5.28** (1) The following documents under this Division* (includes modifications) *in relation to State significant infrastructure are to be made publicly available by the Planning Secretary in accordance with the regulations—*
*(a) applications to carry out State significant infrastructure,*
*(b) environmental assessment requirements for State significant infrastructure,*
*(c) environmental impact statements*

The "applications" are required by the Regulations to be in the prescribed form (see attached 'application' (ANNEXURE 1)). Planning has not made the MOD-3 'application', and the 'environment assessment requirements' available. As required at 5.28 of the EP&AA. On request Planning has refused do so. This may be fatal to a complying exhibition.

The 'Application' (in the prescribed form) attached, was recently provided along with all other 'applications. Planning heavily redacted these 'applications' at the request of Snowy Hydro. These are publicly available documents (5.28(1)(a) &(b)), Snowy Hydro has no jurisdiction or authority to overrule NSW Law which provisions these 'applications' be publicly available (without redaction).

The 'Application' requires the proponent to declare the value of the capital works for which approval is sort. The Australian public has become highly critical of this project due to a lack of transparency, particularly regarding cost which appears to have no ceiling.

**We request the MOD-3 'application' and the 'environmental assessment requirements' be made publicly available and MOD-3 re-exhibited.**

iii) How exhibited documents are to be provided:

Planning has chosen its 'Planning Portal' to provide public access to the documents to be exhibited. Many members of the public have complained they are unable to view the documents. Using various computers and multiple search engines including Safari, Firefox and Google Chrome we, and others were unable to access the documents on exhibition.

Failure to provide the public a user-friendly access to the exhibited documents would appear fatal to a complying exhibition process.

Consequently any approval from this flawed process may be overturned on judicial appear.

**We request Planning fixes their exhibition platform portal to make it readily accessible to the public and re-notifies and re-exhibits MOD-3**

## 3. WATER TABLE IMPACTS:

i) Significant Water Table Impacts:

The MOD-3 Report indicates further and significant impacts to the water table. However, consequences and environmental impacts have not been assessed. We remind Planning and the proponent they are working in the highly sensitive and protected environment of KNP.

**We request Planning prepares a SEAR's and the proponent undertakes a full EIS to consider all environmental impacts including those resulting from impacts to the water table.**

**ii) The Main Works EIS (Critically Endangered Stocky Galaxias fish):**

The Main Works EIS (Part 2 - pg.19) identifies significant impacts to baseflows in two of the 4 streams the 'headrace tunnel' will tunnel under:

| Water Body | Impact |
|---|---|
| Nungar Creek | - **Not assessment provided** |
| Gooandra Creek | - baseflow is conservatively predicted to decline by **28.8%** |
| Tantangara Creek | - **No assessment provided** |
| Eucumbene River | - Baseflow is conservatively predicted to decline by **12.5%** |

The Main Works EIS also identifies the location of Stocky Galaxias fish in the Tantangara Creek and minimises impacts from the introduction of the predator 'climbing galaxias." Snowy 2.0 will introduce a variety of pest fish and pathogens to the pristine waters of Tantangara from Talbingo located 1km in elevation below., during the operation of Snowy 2.0.

At the time this EIS was undertaken Tantangara Creek was the only known ecological natural habitat of the critically endangered Stocky Galaxias fish. This fish is listed as 'critically endangered 'on both the NSW and National registers.

**We request Planning:**

**i) Directs Snowy Hydro to make available, or completes, the EIS for stream flow impacts to Nungar Creek and Tantangara Creek with specific consideration to any impacts to the eco system of Tantangara Creek where the Stocky Galaxias reside.**

**ii) Ensure Snowy Hydro refers any Stocky Galaxias impacts to the appropriate authority for consideration under the NSW Biodiversity Conservation Act, Fisheries Management Act, Biosecurity Act and Protection of the Environment Operations Act. And, the Federal Environment Protection and Biodiversity Conservation Act where such impacts result from Mod-3 and or any continuation of the headrace tunnel by TBM-4.**

**NOTE: while at the time of the original 2020 Approval Stocky Galaxias were conveniently not listed Federally as 'critically endangered, this occurred in 2021. Consequently any impacts by TBM-4 and or MOD-3 are post this declaration date and will need to be considered as part of MOD-3 Application.**

## 4. FALSE OR MISLEADING APPLICATION (MOD-3)

i) <u>The Distance MOD-3/TBM-4 will tunnel:</u>

The MOD-3 Report: *"Following completion and commissioning of the additional adit, the HRT will be excavated from CH17+049 to CH15+400 (including 815 m through the LPFZ). Excavation* ***<u>may</u>*** *<u>then continue</u>".*

Snowy Hydro have publicly stated their disappointment and frustrations with the tunnelling progress of 'Florence' commenced at Tantangara. Florence has averaged approximately 1m per day over the past 18 months since its launch. Snowy Hydro's other TBM's have averaged 7m per day in completing their tasks.

Assuming Florence encounters no further issues causing delay, and averages the 7m per day achieved from the other two machines Snowy Hydro cannot meet its announced Snowy 2.0 operational date of 2027 nor its 2028 handover date. Snowy Hydro is on public record as introducing a fourth TBM (MOD-3) so they can tunnel from both directions to catch up on delays and deliver the headrace tunnel as quickly as possible.

However, even with two machines, TBM 4 (MOD-3) and Florence, both tunnelling at 7m per day, and assuming no further delays, Snowy Hydro cannot not meet these deadlines. This will be further exacerbated as the MOD-3 Report advises TBM-4 is not anticipated to commence operations until the end of 2025.

The public has <u>not</u> lost sight of the fact that the Snowy 2.0 project was announced in 2017 by an Australian Prime Minister, Malcolm Turnbull, as a 'nation building project that would be completed in 2 years for a budget of $2B. It would appear now this announcement was knowingly false or misleading and the Australian public have been drip fed the truth ever since via massive time and cost blow outs.

**MOD-3 is false or misleading where it suggests TBM-4 is not intended to continue its journey to Tantangara. Consequently, all environmental impacts of MOD-3 have not been considered in the documents on exhibition.**

ii) <u>The Geotechnical Baseline Issues</u>

The attached Snowy Hydro Geotechnical Baseline Report for Snowy 2.0 is dated May 2021 (ANNEXURE 2). Snowy Hydro has been aware since at least 2021 of 10 geological faults, of varying consequence, that will be encountered during the Headrace tunnelling.

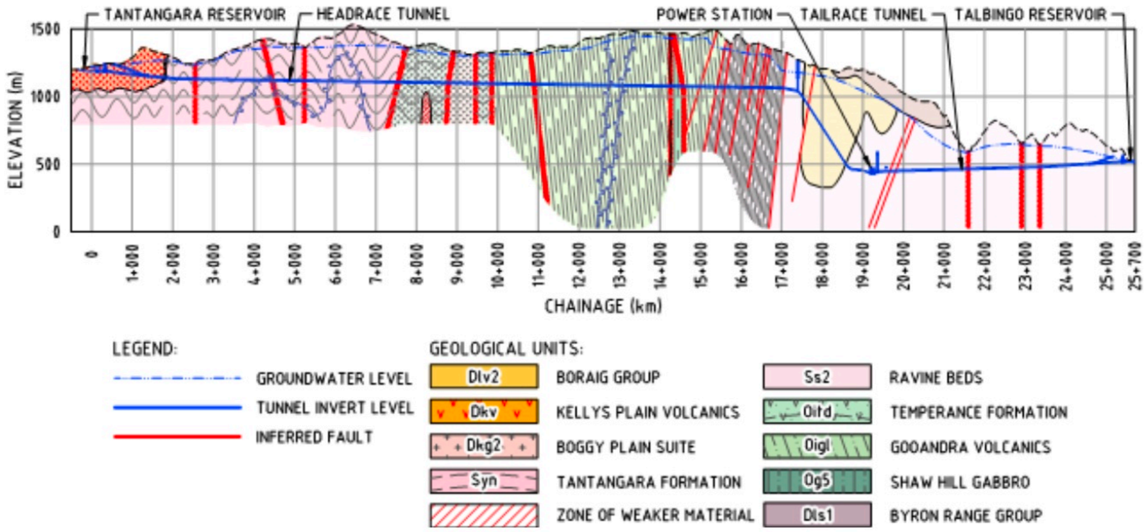
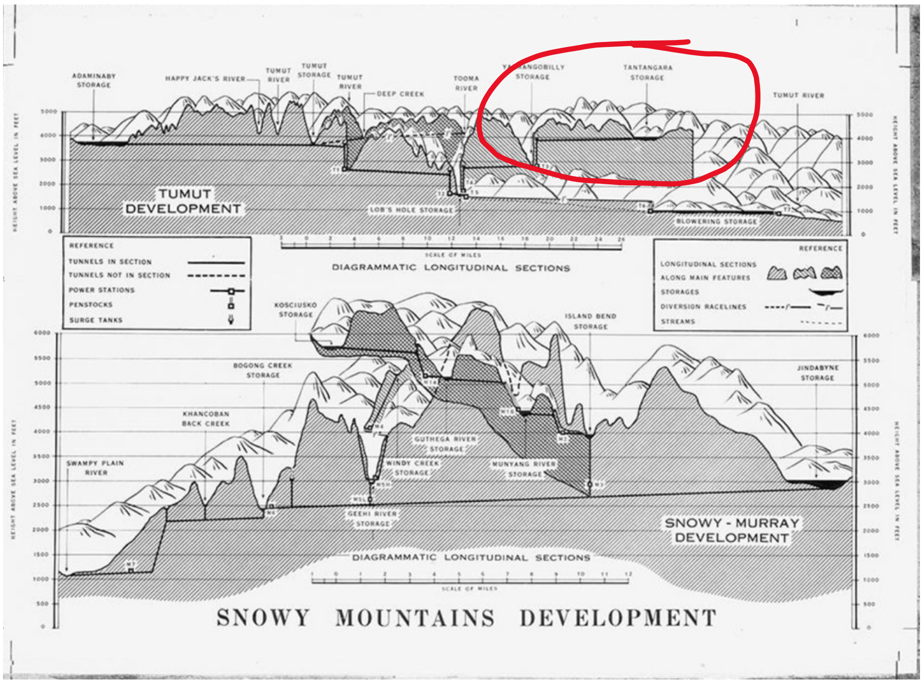



**FIG 4** – Snowy 2.0 geotechnical longitudinal section.

One would expect Snowy Hydro have known since at least the 1950's when the proposed tunnel connection from Tantangara to Talbingo (Snowy 2.0) was abandoned for this very reason of the difficult geotechnical baseline issues..

1950's Cross Section Showing the Headrace Tunnel (abandoned)




**The MOD-3 Report is false or misleading where it indicates the project was not aware of the extent of geotechnical baseline issues prior to 2023.**

**We request MOD-3 is amended to reflect TBM-4's continuation to Tantangara and re-exhibited. The amendment should account for the significant:**

**i) Increase operational time at Marica, and,**
**ii) Additional tunnel waste extracted through Marica, and,**
**iii) All social, economic and environmental impacts. and,**
**iv) Full EIS**

## 5. SLURRY MODE

Previous Approval calls for naturally occurring asbestos (NOA) to be tunnelled with the TBM in 'slurry mode' to produce a dust free wet slurry. This is to minimize exposure of workers to the inhalation of life-threatening asbestos dust.

The MOD-3 Report provides inadequate information to assess and provide a submission.

**We request MOD-3 is amended to include these details and to address the management of this risk to workers, the environment and the public including when continuing to Tantangara. And re-exhibited.**

## 6. BIODIVERSITY OFFSET

<u>Biodiversity Offset:</u>
The public assume the offset paid where habitat and species are destroyed and damaged, is to reestablish these environments elsewhere in KNP.

**MOD-3 should be amended to consider any Biodiversity Obligations, and re-exhibited. The public should be advised the existing Biodiversity Offset (approx. $100M) has been paid to the NSW National Parks and Wildlife Services to allocated <u>as they see fit</u>. There is no obligation NPWS to account for these funds or to use the funds to re-create destroyed fora, fauna and habitat within KNP. NPWS are spending these funds on roads, tracks and infrastructure, and not necessarily withing KNP. The public has a right to be made aware of this.**

## 7. KNP – AN ASSET OF THE PEOPLE OF NSW

KNP is an asset of the people on NSW. Planning is a Government Department which can only act in the interests of the people of NSW. Snowy 2.0 claims a significant benefit to all Australians via the 'grid'. However, only the people of NSW are giving up their asset to make way for Snowy 2.0. An asset diminished by the destruction of a highly protected and fragile KNP.

**Please advise**

- **Why was the proponent not required to pay a commercial rate to leave its rubbish in KNP (disposal of tunnel waste)?**
- **Why the people of NSW were not paid a commercial rate for areas of the park permanently destroyed to make way for Snowy 2.0.**
- **Are the people of NSW obtaining a preferential energy tariff offset?**

## 8. PLANNING – STATE SIGNIFICANT INFRASTRUCTURE:

https://www.planning.nsw.gov.au/assess-and-regulate/development-assessment/planning-approval-pathways/state-significant-infrastructure#:~:text=Critical%20SSI%20applications%20all%20go%20to%20the%20minister%20for%20a%20decision.&text=All%20SSI%20applications%20are%20exhibited,for%20at%20least%2028%20days.

# ANNEXURE 1: APPLICATION FOR SSI MODIFICATION



## State Significant Infrastructure Application

### Introduction & Notes

This form should be used to lodge an application for State significant infrastructure in accordance with Part 5.1 of the *Environmental Planning & Assessment Act 1979*.

State significant infrastructure (SSI) is identified in Schedule 3 & 4 of *State Environmental Planning Policy (State and Regional Development) 2011* (SRD SEPP).

**If your proposal does not meet the criteria in the SRD SEPP, and has not been called in by the Minister, it is not SSI and you should not lodge an application for SSI.**

You must submit a supporting document with this application. The supporting document should include the following information:

1. Site details: Provide high-quality aerial photographs, maps or figures that clearly depict the following:
    - the local and regional context of the proposal,
    - surrounding development and any potentially affected properties,
    - the location of key infrastructure and environmental features
2. Development description: Provide a clear and concise summary of the proposal that describes the types of activities that will be undertaken during each stage of the development.
3. Permissibility and Strategic Planning: Identify the strategic planning documents, environmental planning instruments and key development standards applying to the proposal, including any development standards not being met.
4. Preliminary environmental impact assessment: Identify and prioritise the expected environmental impacts (positive and negative) associated with the proposal, based on a preliminary risk assessment. Briefly outline any strategies to address the impacts identified.
5. Justification: Explain why the site was chosen for the proposal and briefly discuss the alternatives considered. Outline the strategic context for the proposal, including the benefits to the region and/or State.
6. Consultation: Outline any consultation (with the community, local councils, other Government agencies) already undertaken and proposed to be carried out for the proposal.
7. Capital investment value: Provide an accurate estimate of the cost of carrying out the proposal. If your proposal is identified as State significant by a capital investment value threshold in Schedule 3 & 4 of the SRD SEPP, a quantity surveyor's report confirming the capital investment value of the development is required. The supporting document can be attached to the application in Step 6 of this form.

**Your application will not be accepted if you fail to submit all relevant information.**

If your application is not accepted, you will be advised within 14 days of lodgement. If your application is accepted, you will receive Secretaryâ€™s Environmental Assessment Requirements (SEARs), unless otherwise agreed with the Secretary. Once you have lodged your application, you will be sent an email acknowledging your application and providing a reference number to use when discussing the application with the Department. The Department may request additional information from you at any time and may also amend the SEARs at any time.

Australian phone numbers and addresses are required when completing this form.

Persons lodging applications are required to declare reportable political donations (including donations of $1,000 or more) made in the previous two years. For more details, go to www.planning.nsw.gov.au/Assess-and-Regulate/Development-Assessment/Systems/Donations-and-Gift-Disclosure. You can attach a Political Donations Disclosure Statement to the application in Step 7 of this form.

## Applicant Details

| | |
|---|---|
| Title: | |
| Firstname: | 3(a)(b) |
| Surname: | 3(a)(b) |
| Day Phone: | 3(a)(b) |
| Fax: | |
| Mobile: | |
| Email: | 3(a)(b) |
| Company: | Snowy Hydro Limited |
| ABN: | 17090574431 |
| Physical Address: | Monaro Highway Cooma, NSW 2630 |
| Postal Address: | Monaro Highway Cooma, NSW 2630 |

## Site details

| | |
|---|---|
| Site Title: | Exploratory Works |
| Site Location: | Kosciusko National Park Cooma, 2630 |
| Site Government Area: | Snowy Monaro, Snowy Valleys |
| Lot/DP: | |

## Project Details

### Staged Infrastructure:

You can apply for approval for only part of your proposal now, and for the remaining part(s) at a later stage.

Are you applying for approval in stages?

- No
- Yes

### State & Regional Development SEPP: Schedule 3 - State Significant Infrastructure

- Clause 1: General Public Authority Activities
- Clause 2: Port Facilities and Wharf or Boating Facilities
- Clause 3: Rail Infrastructure

- Clause 4: Water Storage or Water treatment Facilities
- Clause 5: Pipelines
- Clause 6: Submarine Telecommunication Cables

### State & Regional Development SEPP: Schedule 4

- State Significant Infrastructure: - specified development a specified land

## Online information provided by the applicant

| | |
|---|---|
| Title: | Exploratory Works: Snowy 2.0 |
| Applying for development consent in stages: | no |
| State Significance: | State Significant Infrastructure: - specified development a specified land |
| Clause/Description of why: | Snowy 2.0 is declared CSSI under Clause 9 Schedule 5 of State Environmental Planning Policy (State and Regional Development) 2011. |
| Description: | Snowy Hydro Limited proposes to develop Snowy 2.0, a large scale pumped hydroâ€electric storage and generation project. It would link the existing Tantangara and Talbingo reservoirs within the Snowy Scheme through underground tunnels and a hydroâ€electric power station. Exploratory Works includes the construction of an exploratory tunnel and portal, establishment of a construction compound and supporting infrastructure, excavated rock stockpile and the construction and upgrade of new and existing access infrastructure. The primary purpose of the Exploratory Works is to gain a greater understanding of the underground conditions at the proposed location of the power station cavern. |
| Capital Investment Value: | 4(b)(d) |
| Construction "jobs": | 100 |
| Operational "jobs": | |
| Landowner's Consent Provided? | |

### Approvals

Would the development otherwise, but for section 89J of the EP&A Act, require any of the following (select all that apply)?

- the concurrence under Part 3 of the <em>Coastal Protection Act 1979</em> of the Minister administering that Part of that Act
- a permit under section 201, 205 or 219 of the <em>Fisheries Management Act 1994</em>
- an approval under Part 4, or an excavation permit under section 139, of the <em>Heritage Act 1977</em>
- an Aboriginal heritage impact permit under section 90 of the <em>National Parks and Wildlife Act 1974</em>
- an authorisation referred to in section 12 of the <em>Native Vegetation Act 2003</em> (or under any Act repealed by that Act) to clear native vegetation or State protected land
- a bush fire safety authority under section 100B of the <em>Rural Fires Act 1997</em>

- a water use approval under section 89, a water management work approval under section 90 or an activity approval under section 91 of the <em>Water Management Act 2000</em>

Do you require any of the following approvals in order to carry out the development (select all that apply)?

- an aquaculture permit under section 144 of the <em>Fisheries Management Act 1994</em>
- an approval under section 15 of the <em>Mine Subsidence Compensation Act 1961</em>
- a mining lease under the <em>Mining Act 1992</em>
- a petroleum production lease under the <em>Petroleum (Onshore) Act 1991</em>
- an environment protection licence under Chapter 3 of the <em>Protection of the Environment Operations Act 1997</em> (for any of the purposes referred to in section 43 of that Act)
- a consent under section 138 of the <em>Roads Act 1993</em>
- a licence under the <em>Pipelines Act 1967</em>
- an aquifer interference approval under section 91 of the <em>Water Management Act 2000</em>

### Online information provided by the applicant

- an aquaculture permit under section 144 of the <em>Fisheries Management Act 1994</em>
- an environment protection licence under Chapter 3 of the <em>Protection of the Environment Operations Act 1997</em> (for any of the purposes referred to in section 43 of that Act)
- a consent under section 138 of the <em>Roads Act 1993</em>
- a licence under the <em>Pipelines Act 1967</em>
- a permit under section 201, 205 or 219 of the <em>Fisheries Management Act 1994</em>
- an approval under Part 4, or an excavation permit under section 139, of the <em>Heritage Act 1977</em>
- an Aboriginal heritage impact permit under section 90 of the <em>National Parks and Wildlife Act 1974</em>

## Consultation and concurrence

Would the infrastructure, but for Section 115ZF(1) of the EP&A Act have required a concurrence under Section 112C of the Act, including a concurrence under the Threatened Species Conservation Act 1995?

### Online information provided by the applicant

- no

## Supporting Documents

You must submit a supporting document with this request. The supporting document should include the following information:

1. Site details: Provide high-quality aerial photographs, maps or figures that clearly depict the following:
    - the local and regional context of the proposal,
    - surrounding development and any potentially affected properties,
    - the location of key infrastructure and environmental features
2. Development description: Provide a clear and concise summary of the proposal that describes the types of activities that will be undertaken during each stage of the development.
3. Permissibility and Strategic Planning: Identify the strategic planning documents, environmental planning instruments and key development standards applying to the Infrastructure, including any development standards not being met
4. Preliminary environmental assessment: Identify and prioritise the expected environmental impacts (positive and negative) associated with the Infrastructure, based on a preliminary risk assessment. Briefly outline any strategies to address the impacts identified.

5. Justification: Explain why the site was chosen for the proposal and briefly discuss the alternatives considered. Outline the strategic context for the proposal, including the benefits it would bring to the wider region and/or State.
6. Consultation: Outline any consultation (with the community, local councils, other Government agencies) already undertaken and proposed to be carried out for the proposal
7. Capital investment value: Provide an accurate estimate of the cost of carrying out the proposal. If your proposal is identified as State significant development by a capital investment value threshold in Schedule 3 of SRD SEPP, a quantity surveyorâ€™s report confirming the capital investment value of the development is required.
8. Landowner's consent or notification (if required): Provide the landowner's consent or notification if required.
   **Note: Clause 193 of the *Environmental Planning and Assessment Regulation 2000* lists the types of applications for which landowners consent is not required.**
9. **Since no Lot/DP details were entered at step 3, a map must be uploaded. This application will not be accepted unless at least one of these conditions is met**

### Submitted files:

- J17188_PEA_Exploratory_Works_FINAL.pdf

## Political Donation

Persons lodging applications are required to declare reportable political donations (including donations of $1,000 or more) made in the previous two years. For more details, go to www.planning.nsw.gov.au/Assess-and-Regulate/Development-Assessment/Systems/Donations-and-Gift-Disclosure.

Do you need to make a political donations disclosure statement?

### Online information provided by the applicant

- No

## Prior discussion with Department

| | |
|---|---|
| Has the project been the subject of prior discussion with the Department? | yes |
| Name of person spoken to at the department: | David Kitto and Mike Young |

## Submitter details

| | |
|---|---|
| Name: | 3(a)(b) |
| Capacity: | 3(a)(b) |
| Submitted: | 2018-03-15 17:57:1521097078 |

# ANNEXURE 1: 2021 SNOWY 2.0 GEOTECHNICAL BASELINE REPORT



Development of the Geotechnical Baseline Report for the Snowy 2.0 pumped storage project



Alexandre R.A. Gomes
SMEC (member of the Surbana Jurong Group)



Francisco Cortes
CIMIC Group Limited



Ben Chapman
SMEC Australia Pty. Ltd.



**Development of the Geotechnical Baseline Report for the Snowy 2.0 pumped storage project**

*A R A Gomes1, B Chapman2, N Chapman3 and F Cortes4*

1. Chief Technical Principal – Tunnels, SMEC, North Sydney NSW 2060. Email: alexandre.gomes@smec.com
2. Tunnel Engineer, Snowy Hydro, Cooma NSW 2630. Email: ben.chapman@snowyhydro.com.au
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4. Formerly Technical Principal – Tunnels, SMEC, North Sydney NSW 2060. Email: facortesf@gmail.com

**ABSTRACT**

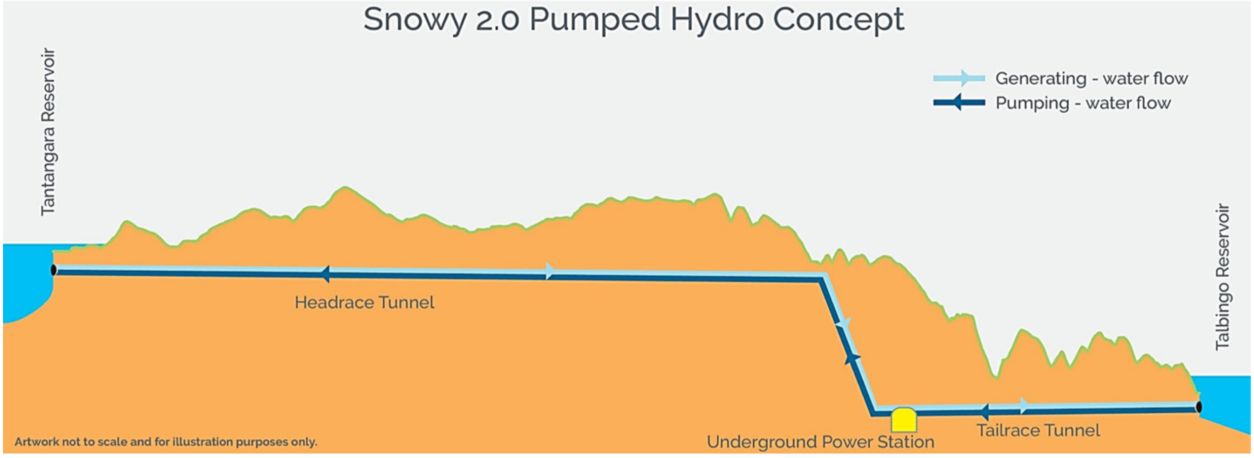
The Snowy 2.0 pumped storage project is a major expansion of the existing Snowy Mountains Hydro- electric Scheme which will almost double the existing scheme's capacity, adding 2000 MW of energy generation and large-scale energy storage of 350 000 MW hours. The project combines a high head differential, long and deep waterway tunnels and reversible pump-turbines housed within a deep underground power station. The project site is situated within a complex alpine geological and hydrogeological setting which presents significant geotechnical uncertainties for subsurface construction, making it difficult to accurately predict construction time and costs in anticipation of construction. To address these conditions, the contract for the construction of the project's underground works incorporates a Geotechnical Baseline Report (GBR) to set out geotechnical risk- allocation mechanisms, with an aim for fair and balanced allocation of geotechnical risks between the Employer and the Contractor. This paper presents key concepts applied in the development of the risk-sharing mechanisms and GBR for Snowy 2.0.

**INTRODUCTION**

The Snowy 2.0 pumped storage project is a major expansion of the existing Snowy Mountains Hydro- electric Scheme, operated by Snowy Hydro Limited. Snowy 2.0 will provide an additional half of the existing scheme's capacity, adding 2000 MW of energy generation and large-scale energy storage of 350 000 MW hours. At full capacity, Snowy 2.0 could operate for almost seven days without recharge pumping. Snowy 2.0 is vital to Australia's economy and energy transmission, by providing massive storage and generation needed to balance the growth of wind and solar power and the retirement of Australia's aging thermal power stations. Snowy 2.0 will underpin the stability of Australia's energy system as it moves into a low-emissions future.

Snowy 2.0 combines a high head differential (approximately 700 m), long and deep waterway tunnels and six 340 MW reversible pump-turbines. It will link two existing reservoirs, Tantangara (elevation 1231 m) and Talbingo (elevation 546 m), through 27 km of waterway tunnels and an underground power station. The project also includes 1.3 km of shafts and 10.4 km of access tunnels (Figure 1).

**FIG 1** – Snowy 2.0 pumped storage project concept.




The construction of the extensive underground works for Snowy 2.0 will be carried out within complex subsurface conditions, entailing significant geotechnical uncertainties and risks. This required specific and commensurate contractual treatment which lead to the inclusion of a Geotechnical Baseline Report (GBR) in the contract for the design and construction of the project's underground works, with the aim to allocate geotechnical risks in a fair and balanced way between the Employer and the Contractor. The GBR sets out the sub-surface physical conditions anticipated by the Parties, in the context of the contractually agreed construction methods, allowing for the contractual allocation of foreseeable ground related risks arising from physical conditions to be defined.
This paper presents key concepts applied in the development of the risk-sharing mechanisms and GBR for Snowy 2.0.

**Project background**
Australia's energy market is changing. Its fleet of coal-fired power stations are aging and beginning to retire progressively, while renewable sources including wind and solar are increasing significantly in market supply. To capitalise on the low cost and zero-emission advantages of renewable energy, significant energy storage is required. This is where Snowy 2.0 comes to the fore.

The Snowy scheme can already store huge amounts of energy, and while this is sufficient for Australia's national energy market (NEM) as it operates now, it is not enough in a lower emissions economy, powered by wind and solar generation with supply patterns that are difficult to predict and do not always coincide with the energy demands of households and businesses. The huge storage capacity of Snowy 2.0's reservoirs will help ensure the stability and reliability of the NEM, even during prolonged weather events, such as wind or solar 'droughts'.

The original Snowy scheme was constructed between 1949 and 1974 and is the largest hydro- electric scheme in Australia, with a total generating capacity of 4100 MW. It currently has nine power stations (including two underground stations), one pumping station, one pump storage facility, 16 reservoirs and 135 km of interconnected tunnels. The existing scheme is operated and maintained by Snowy Hydro, the Employer for Snowy 2.0.
Augmentation of the Snowy scheme to include pumped storage developments was first considered in 1966, with subsequent studies undertaken until the 1990s. One of the schemes proposed was used as the basis for commissioning the preparation of a feasibility study in 2017, which resulted in the feasibility level design of Snowy 2.0, undertaken by SMEC and Snowy Hydro.

The project was further developed into a reference design which provided a basis for contractors to tender, cost and program baselines to be developed for the contract and for enabling Snowy Hydro to arrive at a final investment decision.
The tender process concluded in April 2019 with the award of the main contract to deliver Snowy 2.0 to the Future Generation Joint Venture, comprising Salini-Impregilo, Clough and Lane.

**Project details**

***General arrangement***
The Snowy 2.0 site is located within the northern part of the Snowy Mountains region of New South Wales, Australia. The eastern part of the alignment is located on an elevated plateau, while the western part lies below a well-defined escarpment, with deeply incised valleys forming what is commonly known as the Ravine area. This area is drained by tributaries of the Tumut River and Talbingo Reservoir. The area has a high relief of 500 m to 600 m, with slopes commonly steeper than 30 degrees. Figure 2 shows the Snowy 2.0 horizontal alignment and project area plan.
The scheme consists of intake structures located in each reservoir, connected by the power waterway. A single headrace tunnel of 9.9 m internal diameter, approximately 17 km long, trends due west from the upper intake structure at Tantangara reservoir across the Kiandra plateau to the headrace surge tank located at the escarpment. The surge tank is approximately 250 m high and has an internal diameter of 25 m.

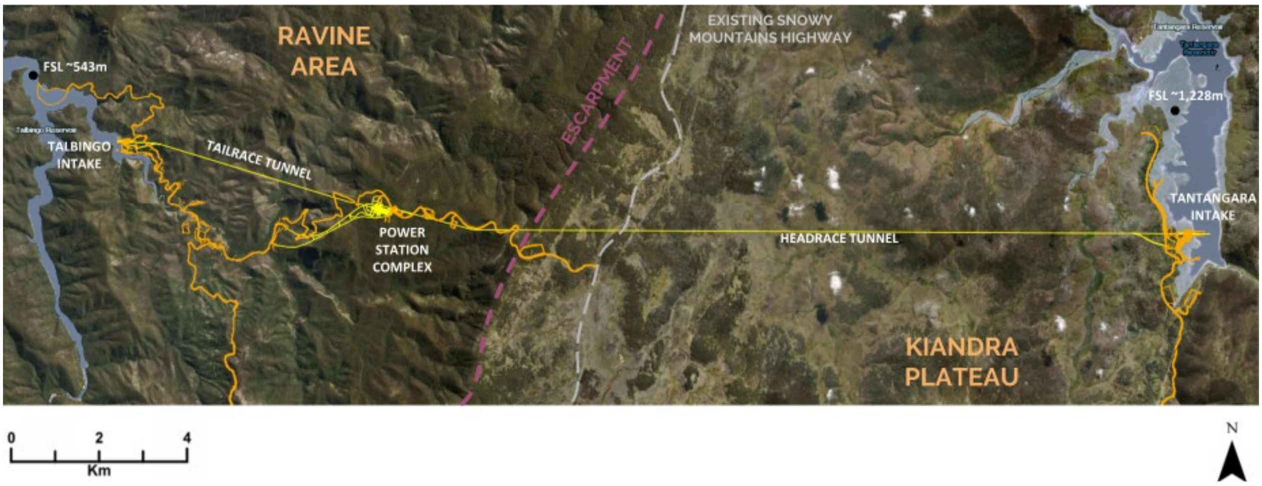


**FIG 2** – Snowy 2.0 alignment and project area plan.

Downstream of the surge tank, the headrace tunnel feeds a single 1.6 km long pressure shaft, inclined at 25 degrees from the horizontal. A manifold at the base of the pressure shaft divides into six penstock tunnels, each feeding a single unit in the machine hall of the power station.
The draft tube tunnels on the downstream side of the machine hall combine into three collector tunnels which meet at the bottom of the tailrace surge tank, which is close to 200 m high. The waterway continues as a single 9.9 m diameter tailrace tunnel for approximately 6 km to the lower intake structure at the Talbingo reservoir.
In total, there is approximately 27 km of combined waterway tunnels and 1.3 km of shafts. The maximum depth of overburden reaches 400 m in the headrace tunnel and 750 m in the power station and tailrace tunnel.
Supporting the scheme is a combined length of 10.4 km of access tunnels and construction adits. The primary access tunnels into the power station are the main access tunnel (MAT)

and the emergency egress, cable and ventilation tunnel (ECVT), both of which are approximately 2.5 km long.

***Alignment***

The horizontal alignment is governed by the intake locations and the headrace surge location. The intakes have been located at the edge of the reservoir to minimise waterway length. The headrace surge tank has been located to contain transient surges predominantly below ground level, which avoids the requirement for surface structures within the Kosciuszko National Park. Several alternative horizontal alignments were considered during early stages of the project. However, the initial alignment documented in previous studies was found to be close to the optimum shortest waterway length. The Talbingo Intake was shifted upstream within the reservoir once bathymetry confirmed adequate submergence could be achieved, which reduced the tailrace tunnel length by nearly 800 m.

The vertical alignment is governed by the intake elevations and headrace surge location. The power station, headrace and tailrace tunnel vertical alignments have been set to meet hydraulic requirements of the system and comply with submergence requirements. Consideration has also been given to the confinement and leakage of the waterway and limiting the extent of steel lining.

One of the main options adopted from the feasibility study was the shift of the power station complex downstream whilst maintaining the headrace surge tank location. The power station complex is on the construction critical path given the lengthy activities of cavern excavation, structural erection, mechanical and electrical installation and commissioning. Shifting the power station complex downstream presented the opportunity to shorten the access tunnels and therefore gain early access to the power station complex, leading to a direct program reduction. As the headrace surge tank location is essentially fixed due to topography, the extent to which the power station can shift downstream is constrained by hydraulics and machine operational requirements.

***Power station complex***

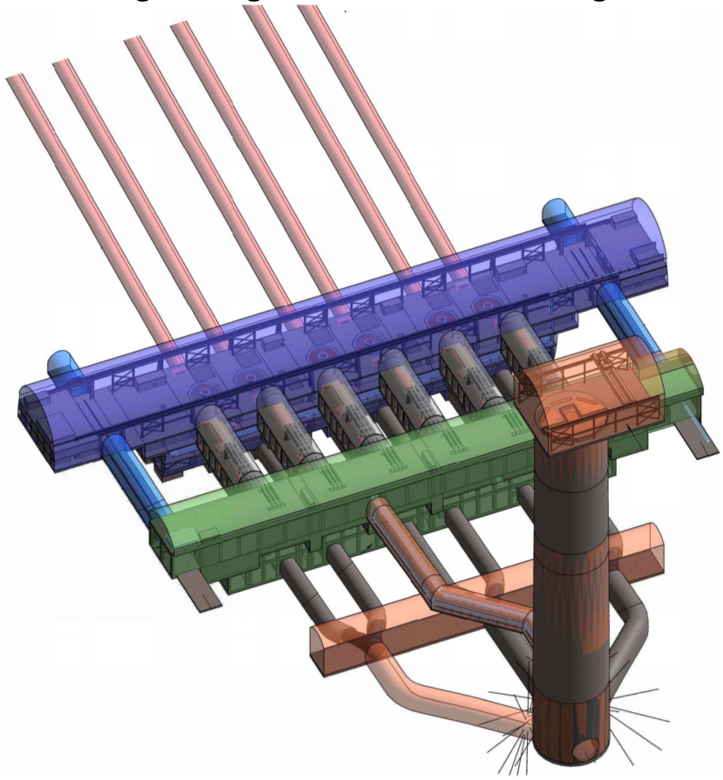
The main components of the underground power station complex are the machine hall, transformer hall and tailrace surge tank. These components are connected via the waterway tunnels, shafts and access tunnels. The complex is located approximately 750 m below ground.

The power station complex is the main permanent working area for the scheme and therefore has many specific operation and maintenance requirements which are well established with Snowy Hydro being operators of the existing scheme. The machine hall will be 30 m wide, 55 m tall and 238 m long. It will house the six pump-turbines, motor-generators, main inlet valves and auxiliary balance of plant.

The transformer hall will be 21 m wide, 28 m tall, 204 m long and be located downstream of the machine hall. It will house the six three-phase main transformers, draft tube valves and cooling water equipment. The machine hall and transformer hall will be connected by two main access tunnels and six Isolated Phase Busbar (IPB) galleries which will house the electrical equipment required between the motor-generators and the main transformers. The layout of the power station cavern complex is shown in Figure 3.

**FIG 3** – Snowy 2.0 power station complex (source: FGJV). ***Geological, geotechnical and hydrogeological conditions***

The project site is located within the Kosciuszko National Park, where only limited information about the geological and hydrogeological conditions was available at the time of the project's inception. While the site is near to the existing Snowy Mountains Scheme, the relevant geological formations have not been majorly intersected by any existing tunnels. Comprehensive geotechnical investigations which had commenced during the early stages of the project allowed a better understanding of the ground conditions and associated geotechnical hazards. To date, site investigations have included some 30 km of borehole drilling, with 15 boreholes deeper than 750 m. Site investigations have also included geophysics (electrical resistivity, seismic refraction, seismic reflection), an exhaustive set of laboratory tests, *in situ* testing (stress and strength/stiffness) and groundwater testing and monitoring, among more. Additional investigations are currently ongoing.



***Geological setting***

Regionally, the project site is situated within the south-eastern portion of the Lachlan Orogen (fold belt) of New South Wales, a geological province of old volcanic belts, sedimentary basins and intrusive rocks that have been affected by several episodes of orogenesis and metamorphism.

At a local scale, the alignment passes through several geological formations of highly variable nature, comprising a wide range of rock types and geological structures. In total, more than 28 different lithologies haven been encountered along the waterway alignment. The majority of rock units span from the Ordovician to Devonian, except for isolated occurrences of Tertiary basalt.

The presence of Naturally Occuring Asbestos (NOA) has been detected within the Gooandra Volcanics formation, which is intersected by the headrace tunnel.
A geotechnical longitudinal section for the power waterway alignment is shown in Figure 4.

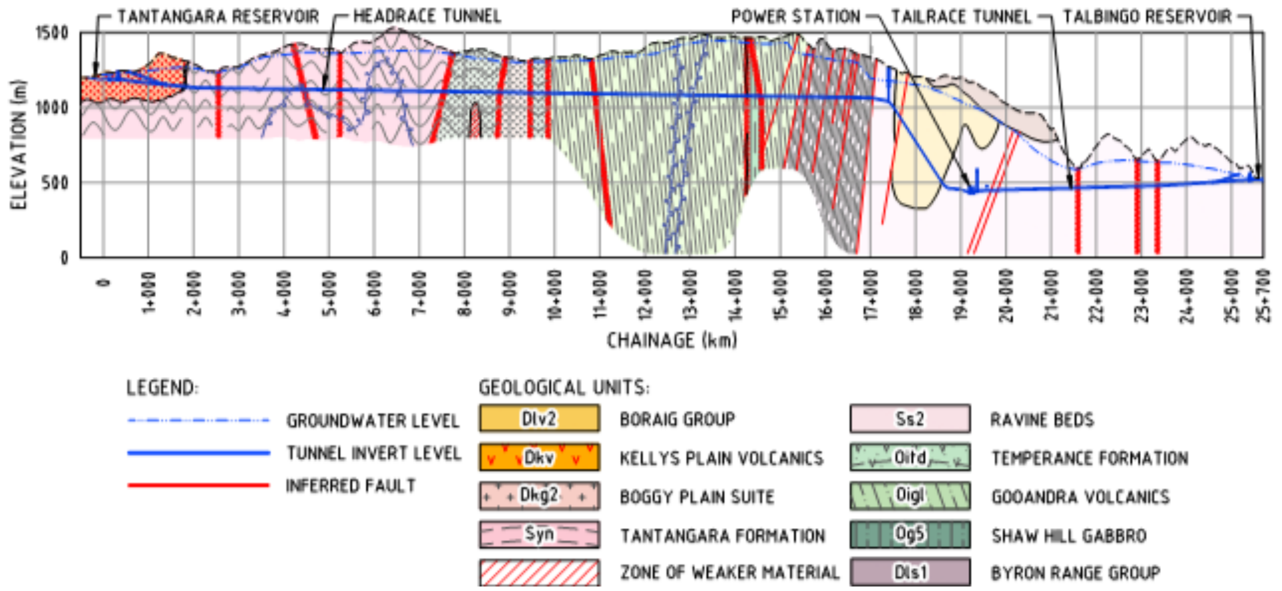



**FIG 4** – Snowy 2.0 geotechnical longitudinal section.

The project area crosses two major structural zones, including the Tumut Block and the Tantangara Block. The two blocks are bounded by the Long Plain Fault, a major tectonic suture separating the Silurian sedimentary rocks in the west from the Ordovician volcanics in the east. The Tumut Block is anticipated to comprise an open folded syncline in which Devonian sediments and volcanics rest unconformably on Silurian sediments. The Tantangara Block is anticipated to be intercepted by numerous faults, though few have been observed at the surface. Folding is well developed throughout the majority of the project area. The project alignment runs perpendicular to the regional structural trends and geological contacts.

Of the geological features identified, the Long Plain Fault is of most engineering significance. The fault can be traced for a distance of more than 200 km and is estimated to comprise an affected zone which may be over 2 km wide at the intersection with the alignment. This zone is likely to comprise several individual faults ranging from minor shears to major fractured and brecciated zones of tens of metres thickness.

The fault zone is thought to be associated with a reverse thrust and possible strike-slip mechanism, generally dipping eastwards at angles of between 45 and 60 degrees. The general trend is north to north-east, therefore intersecting the project alignment near perpendicularly. There is poor exposure at the surface, but the western limit of the fault zone is interpreted to be near the main escarpment. The majority of the fault zone is therefore expected to intersect the headrace tunnel, with some associated affected ground expected at the location of the headrace surge shaft and upper portions of the inclined pressure shaft, located immediately to the west.

### *Hydrogeological setting*

Based on the current information, there appear to be two major groundwater systems along the alignment separated by the Long Plain Fault. Groundwater on the plateau, east of the fault appears to have a typically high recharge and a relatively shallow flow system, while locations to the west have a lower potential recharge and a deeper flow system.
The entire alignment is expected to be contained within fractured rock aquifers which range from unconfined to confined at depth and are often influenced by steeply dipping structural

controls, which are regionally common. Within the Gooandra Volcanics and Long Plan Fault zone, an interconnected system is indicated down to headrace tunnel level. A vertical hydraulic gradient has been detected within the Ravine Beds West unit, indicating less vertical connectivity in the area of the power station complex and high-pressure tunnels. Separate upper and lower aquifers may exist in this area due to the overlying Boraig Group unit.

Groundwater discharge zones are inferred at four locations along the alignment featuring major creeks and the two reservoirs. Groundwater recharge zones are inferred at three elevated hills. Notably, the location of the Long Plain Fault corresponds with a recharge zone and appears to be a significant hydrogeological feature which is likely influencing groundwater movement.

Hydrogeological investigations and modelling indicate that potential tunnel inflow rates could typically reach between 2 and 5 L/sec/km, with short-term inflows likely to be five to ten times higher. The majority of inflows are expected to occur due to a limited number of discrete structures. There are likely to be several areas of interconnectivity between the surface and tunnel alignments which may cause high inflows during tunnelling.

***Geotechnical conditions***

The complex and highly variable alpine geological and hydrogeological setting presents many geotechnical challenges for the design and construction of the underground works. Tunnelling conditions are anticipated to experience a wide range of ground behaviours, comprising both structurally controlled and stress-controlled mechanisms, ranging from brittle spalling to deep- reaching shear failure of weaker rock masses under high-stress conditions. In addition, excavations will frequently face mixed ground conditions, involving regularly transitioning through different lithologies, faults and weak zones. Based on the understanding of the hydrogeological setting, high groundwater inflow may impact on construction and ground stability if no pre-grouting treatment is carried out in advance of critical areas.

***Construction methodology***

Future Generation will use three single shield TBMs (two open mode, one dual mode) for the construction of the headrace and tailrace tunnels, main access tunnel, ECVT tunnel and the inclined pressure shaft. The TBMs will each have a nominal excavation diameter of approximately 11 m. The dual mode machine has been selected to manage the occurrence of NOA in the headrace tunnel.

The TBM tunnels will be lined with concrete segments produced at a local precast factory located in Polo Flat, Cooma. A steel lining will be installed in limited locations where leakage or confinement issues are identified.

The remainder of the underground works, including the remaining access tunnels, adits, shafts and power station complex will be constructed with drill and blast methods, given the size, length or shape of the structures.

## PROCUREMENT STRATEGY

### General

Early during the project development, Snowy Hydro considered various delivery methods, finally deciding to adopt a modified EPC/Turnkey contract for both the civil and mechanical and electrical works. In the case of the underground works, Snowy Hydro recognised that the inherent uncertainties associated with the project's complex subsurface conditions required specific and commensurate contractual treatment. For this reason, for the construction of the underground works, geotechnical risk-sharing mechanisms based on the use of a GBR were built into the contractual framework to allow for a balanced allocation of geotechnical risks between the Employer and the Contractor.

The use of GBRs for risk allocation has become a widely accepted practice in the tunnelling industry, having first evolved in the USA in the mid-1990s to mid-2000s. The basic premises of a contractual geotechnical baseline setting out the anticipated subsurface conditions for the underground works have been outlined in the guidelines prepared by the Underground Technology Research Council (UTRC/ASCE, 1997, 2007).

For Snowy 2.0, an innovative 'balanced' GBR was implemented, including not only physical and behavioural baselines, as suggested in the UTRC/ASCE Guidelines (1997, 2007), but also a baseline of items of work ('rate elements'), which will be the de-facto baseline used for remeasurement and adjustment of construction cost and time. In this GBR modality, the time for project completion can be extended if the conditions are more onerous than described in the GBR, while also reduced if ground conditions are better.

Besides the UTRC/ASCE Guidelines (1997, 2007), the approach considered for the development of Snowy 2.0's GBR drew on the recommendations of the International Tunnelling and Underground Space Association (ITA-AITES, 2011). Particular reference was made to the principles promoted by the FIDIC Emerald Book Conditions of Contract for Underground Works (2018), which was jointly developed by FIDIC and ITA-AITES and was still under preparation at the time of the GBR definition, but has a general philosophy which was already publicly known. According to these principles, geotechnical risks should be allocated to the party best prepared to manage them. In the case of underground works, this translates into the Employer bearing risks related to the subsurface conditions, and the Contractor bearing risks associated with production rates and performance under the agreed baselined conditions.

Snowy Hydro and developed a strategy to fast-track the delivery process by considering an Early Contractor Consultation (ECC) phase. The procurement process commenced in 2017 with ECC phase in parallel with the development of the reference design, providing involved contractors with early and advanced information on the project and associated challenges. Two bidders were finally shortlisted to go into the final bidding preparation stage and submit their respective proposals. The tender process concluded in April 2019 with the award of the main contract to deliver the Snowy 2.0 to Future Generation Joint Venture.

**Contractual risk allocation framework**

Whilst the GBR is the key document defining the contractual baselines and associated risk allocation mechanisms, it is part of a comprehensive contractual framework, which includes among others, the following related documents:

- Geotechnical Data Report: factual information and data, included as part of the contract.
- Tender Design Drawings: construction solutions developed for the agreed baselines.
- Employer's Technical Requirements: minimum technical requirements to be fulfilled by the successful tenderer.
- Risk Register and Risk Management Plan: following the IMIA International Insurers Group/ITA- AITES (2012) Code of Practice for Risk Management of Tunnel Work.

- Schedule of Rates and Prices and Commercial Clauses: schedules including rates and prices for the items of work and commercial regulations for the compensation mechanisms, including a clause for unforeseeable conditions, denominated in the contract as Extraordinary Geological Occurrences (EGOs).

  The risk share concept includes the remeasurement of items of work if the actual geological conditions vary from the assumptions made in the GBR, with adjustments both in time and cost as stipulated in the contract. For some ancillary structures, such as construction tunnels, lump sum (fixed amount) works have also been considered. Specific types of risks identified in the Risk Register have also been allocated to the parties as agreed and stipulated in the risk matrix included as part of the GBR.

  Additionally, to achieve speedy resolution and avoid arbitration, clear mechanisms of compensation for construction and dispute resolution have been established, including the incorporation of a clause for unforeseen conditions and a Dispute Avoidance and Adjudication Board (DAAB).

**Staged GBR Development**

A three-step GBR approach was adopted for Snowy 2.0 (Figure 5), as suggested by the ASCE Guidelines (UTRC/ASCE, 2007). Snowy Hydro prepared an initial GBR (called GBR-A, for Tender), which was reviewed and amended by Tenderers and submitted as the GBR-B version (for Bid) as part of their respective proposals. Following the final Employer's revision, the definitive contractual document (called GBR-C, for the Contract) was agreed between Snowy Hydro and the awarded tenderer during the contract negotiation stage. Table 1 describes some key deliverables associated with the GBR development at each stage of the project.


**FIG 5** – Snowy 2.0 staged GBR development.

**TABLE 1**
Staged GBR preparation.

| Project Stage | Key deliverables/activities |
|---|---|
| Employer's tender documents | • GBR-A: This corresponds to the GBR submitted by the Employer to Tenderers to be used as the basis for the tender, corresponding to the Employer's best understanding of the geological conditions likely to be encountered during construction. While it setup a conceptual framework for the development of the GBR-B, Tenderers were given the freedom to propose alternative solutions for the design and construction of the scheme to avoid restricting innovation and optimisation. |

| | |
|---|---|
| | • Associated Schedule of Baselines/Completion Schedule.<br>• Supporting Reference Design including feasible design solution, Employer's Technical Requirements and Particular Conditions. |
| Proposals by tenderers | • GBR-B: includes the review, complements and adjustments made by the Tenderer in the GBR-A, resulting from the proposed design and construction methodology. The preparation of the GBR-B also considered the factual information provided at tender and during the tender period.<br>• Set of returnable documents, including tender design based on the GBR-B baselines, schedule of rates and prices, completion schedule based on the baseline schedule. |
| Contract negotiation and award | • GBR-C: corresponds to the final step in the GBR development process, being the version mutually agreed between the Employer and the awarded Tenderer to represent the geological and hydrogeological conditions which can be anticipated to be encountered during construction at the time of tender, subject to the limitations and exclusions set out in the GBR schedules. |
| Detail design and construction stage | • Development of detail design in compliance with the GBR framework.<br>• Remeasurement and adjustment of construction cost and time based on the conditions specified in the GBR-C. |

**GBR FRAMEWORK**

**General**

The GBR is a contractual document, which once set out, is independent of any factual or interpreted data. However, since the GBR should ideally represent the parties best understanding of the anticipated subsurface conditions at the time of tender, results and findings of geotechnical investigations, interpretation and engineering studies are required to guide the preparation of the corresponding baselines and definition of reasonable compensation mechanisms, which relates anticipated conditions with the associated construction effort for the estimation of cost and time.

For Snowy 2.0, the developed GBR structure consists of hierarchical layers of baselines which are derived from and tacitly reflects the typical steps considered as part of the studies carried out as part of the underground works' geotechnical engineering design.
These steps comprise the following:

- the characterisation of the physical subsurface conditions
- the assessment of ground behaviours
- the design of sets of construction solutions and auxiliary measures required to deal with the anticipated subsurface conditions.

Table 2 presents a description of the baselines considered in Snowy 2.0's GBR.

**TABLE 2**
GBR baselines considered for the geotechnical risk allocation.

**GBR baselines**

1. Geotechnical Physical Baseline

2. Geotechnical Behavioural Baseline
3. Baseline of Tunnelling Classes (Systematic Conditions)
4. Baseline of Non- systematic Conditions/Geohazards

**Description (*)**
Geotechnical Physical Baseline
Baseline of Ground Types (GTs), groundwater and *in situ* stress conditions, natural and made geohazards and constraints.
Geotechnical Behavioural Baseline
Baseline of Ground Behaviours (GBs), which take into account the specific construction considered methodology.
Baseline of Tunnelling Classes (Systematic Conditions)
Baseline of typical project-specific Tunnelling Classes (TCs) that represent the level of effort associated with excavating and supporting the ground, so that appropriate cost and time (production rates) values can be assigned and used as a basis for compensation and re-measurements during construction.
Baseline of Non- systematic Conditions/Geohazards
Baseline of construction measures and activities (NCs) required to deal with non-systematic conditions/geohazards, or other hindrances not covered by the TCs. This included care of water, abrasivity, accepted geological overbreak (AGO), naturally occurring asbestos (NOA) and drilling and grouting requirements.

(*) See also the following sections for further explanation of baselines.
The generic GBR's risk allocation structure is illustrated in Figure 6.

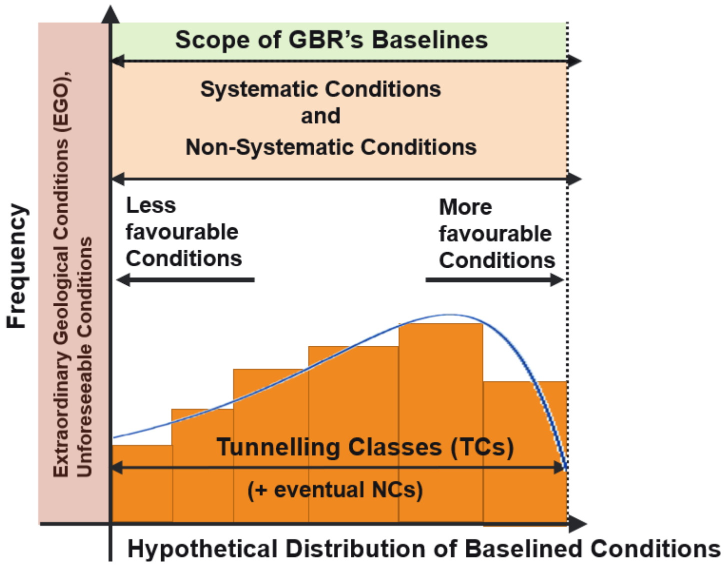



**FIG 6** – Illustration of the GBR's risk-allocation structure.

The hierarchical relationship between the GBR elements is defined by the Ground Classification System (GCS), which stipulates how the items of work are assigned to anticipated subsurface conditions when they are encountered during construction.

**Baseline of physical conditions**
The baseline of subsurface physical conditions of Snowy 2.0 was characterised in terms of Ground Types (GT), which correspond to relevant ground volumes at the scale of the underground works with similar (homogeneous) geotechnical properties and characteristics

that are relevant for design and construction. The baselined parameters were determined in terms of representative ranges and/or statistical distributions for each specific GT.

In general, GTs were mainly related to specific geological formations, however, in some cases, GTs include lithologies that belong to different geological formations. GTs generally included more than one lithology, as many formations are composed of multiple lithologies at relatively close spacings. A total of 20 different GTs have been developed, discriminating geological formations, ranges of GSI value, intact rock properties (Unconfined Compressive Strength, UCS, rock moduli values Ei, abrasivity values CAI), ground overburden/depth of excavation (degree of weathering and fracturing). Rock mass parameters can be derived from GTs based on agreed methodologies.

Other key aspects addressed in the baseline of physical conditions were the following:

- The magnitude and orientation of *in situ* ground stresses.
- Groundwater conditions, including estimated inflows.
- Other ground related hazards, termed Geohazards (Non-systematic conditions, NCs).

A comprehensive set of geohazards identified for the project site have been included in the GBR risk matrix for allocation between the Employer and Contractor. Among others, these risks included the following: high groundwater inflows, hot ground or water, highly deformable ground, rock burst, karst, natural-occurring asbestos (NOA), heterogeneous ground, igneous intrusions, mixed face conditions, rock high silica content, alkali-silica reaction, swelling/slaking ground, rock burst, unstable ground, aggressive water, karst, seismicity, gas, TBM jamming and low confinement conditions.

**Baseline of behavioural conditions**

The baseline of behavioural conditions defines the expected ground response to proposed construction means and methods upon the anticipated physical baselines. The baseline must be developed for each particular structure and relevant section under its specific boundary condition.

The baseline of behavioural conditions was classified in terms of Ground Behaviour types (GBs), which correspond to general categories describing similar ground behaviours concerning failure modes and displacement characteristics, following the philosophy proposed by the Austrian Geomechanical Society Design Guideline (2011). The way the ground responds to construction is a three-dimensional and time-related problem, which can occur in combinations of dominant and secondary failure mechanisms and also be subdivided in various degrees of magnitude.

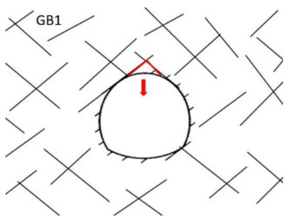
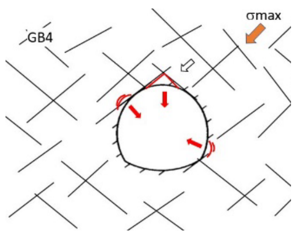
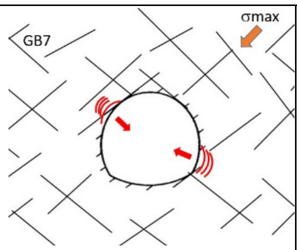
GBs were assessed and described with consideration of all relevant influencing factors, including but not limited to prevailing ground types (GTs), *in situ* stress conditions, shape, size and orientation of the excavation, construction methodology, location with respect to surface or existing infrastructure, groundwater, seepage and hydraulic head and time-associated mechanisms, among other project-specific boundary conditions. These mechanisms often occur concurrently in various levels of intensity and predominance and detailed assessments and characterisation are required for each project-specific conditions and work section.

The purposes of GBs are:

• To provide a catalogue of typical key controlling ground failure mechanisms triggered by the changes in stress and confinement conditions caused by the excavation and by any other relevant influencing factors, such as groundwater and chemical processes.
• To provide a classification that can guide the selection of suitable excavation and support strategies based on the key controlling failure mechanisms.

Tables 3, 4 and 5 provide a summary of typology of GBs.

**TABLE 3**
Ground Behaviour types (GBs) associated with massive to blocky/very blocky rock mass with favourable joint or block wall conditions/interlocked structure.

| **Ground behaviour type** | **Failure mechanisms and inferred stress conditions (based on a 100 m2 tunnel excavation cross-section)** | **Specified criteria** |
|---|---|---|
| | Massive to blocky/very blocky rock mass with favourable joint or block wall conditions/interlocked structure. Referential GSI(≈ RMR89)≥ 60 ±5 | |
| <br>**GB1 – Stable ground** | • Local discontinuity-controlled rock blocks/wedge falls.<br>• No rock overstress and negligible displacements.<br>• Water inflow has little or no influence on rock mass behaviour, except in case of localised discontinuities susceptible to water (eg clayey material). | • σmax/UCS |
| <br>**GB4 – Shallow Brittle Failure** | • Failure mainly controlled by intact rock with shallow and minor spalling and ruptures in areas of low confinement around the excavation; no to minor overbreak.<br>• Displacements usually associated with local volume increase of the rock mass due to buckling of bedded rocks and/or rock mass bulking.<br>• There is no indication that sudden and violent brittle failure with rock block ejections will occur during construction. | • Referential GSI/RMR89<br>• σmax/UCS<br>• UCS/T (susceptibility to brittle failure) |
| <br>**GB7 – Brittle Failure** | • High rock mass overstress. Moderate overbreak.<br>• Failure mainly controlled by intact rock with relevant slabbing, buckling of bedded rock.<br>• There is no indication that sudden and violent brittle failure with rock | • Referential GSI/RMR89<br>• σmax/UCS<br>• UCS/T (susceptibility to brittle failure) |

| | | |
|---|---|---|
| | block ejections will occur during construction. | |

**TABLE 4**

Ground Behaviour types (GBs) associated with Blocky to disintegrated rock mass. Fair to very poor discontinuities conditions with clay infillings.
Ground Type Description: blocky to disintegrated rock mass. Fair to very poor discontinuities conditions with clay infillings. Referential 40 ±5 ≤ GSI (≈RMR89) ≤ 60 ±5

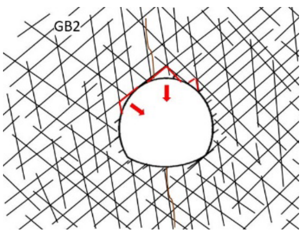
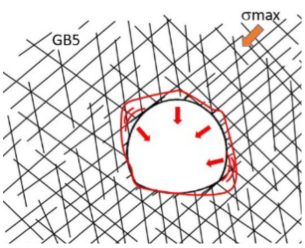
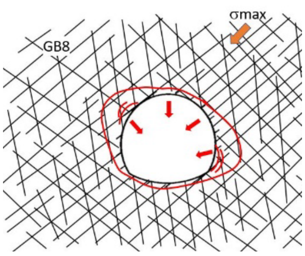
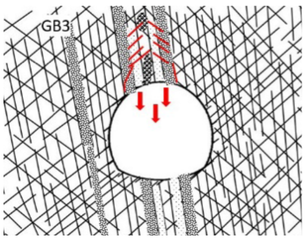
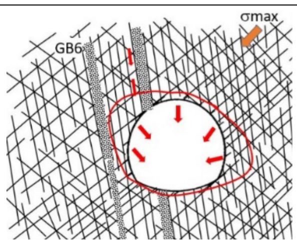
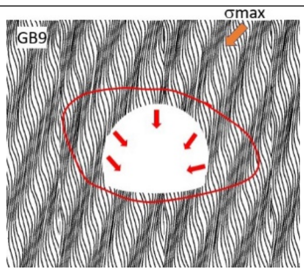
| **Ground behaviour type** | **Failure mechanisms and inferred stress conditions (based on a 100 m2 tunnel excavation cross-section)** | **Specified criteria** |
|---|---|---|
| | Massive to blocky/very blocky rock mass with favourable joint or block wall conditions/interlocked structure. Referential GSI(≈ RMR89)≥ 60 ±5 | |
|   **GB2 – Discontinuity controlled** | • Discontinuity controlled rock block/wedge falls.<br>• No rock overstress and negligible excavation/support displacements.<br>• Groundwater may affect ground behaviour if discontinuities (infillings) are susceptible to water (eg clayey material).<br>• Shotcrete and bolts for support of blocks/wedges. | • Referential RMR89 thresholds<br>• σmax/UCS<br>• σcm/σmax<br>• UCS/T (susceptibility to shear/brittle failure) |
|   **GB5 – Shallow Hybrid Failure** | • Shallow-seated shear failure of the rock mass and buckling of bedded rock and less probably in combination with tensile failures (minor spalling and ruptures) depending on the GSI and the ratio UCS/T.<br>• Displacements may be associated with local volume increase of the rock mass due to buckling of bedded rocks and/or rock mass bulking. | • σmax/UCS<br>• σcm/σmax<br>• UCS/T (susceptibility to shear/brittle failure)<br>• tunnel strain (ε) |
|   **GB8 – Hybrid Failure** | • Shallow to deep-seated shear failure of the rock mass and buckling of bedded rock and less probable in combination with tensile failures (minor spalling and ruptures) depending on the GSI and ratio UCS/T (see notes).<br>• Displacements may be associated with local volume increase of the rock mass due to buckling of bedded rocks and/or rock mass bulking. | • σmax/UCS<br>• σcm/σmax<br>• UCS/T (susceptibility to shear/brittle failure)<br>• tunnel strain (ε) |

**TABLE 5**

Ground Behaviour Types (GBs) associated with very blocky to disintegrated rock mass.

| **Ground behaviour type** | **Failure mechanisms and inferred stress conditions (based on a 100 m2 tunnel excavation cross-section)** | **Specified criteria** |
|---|---|---|
| | Ground Type Description: very blocky to disintegrated rock mass. Referential 20 <= GSI (≈RMR89) <= 40 ±5 | |
| <br>**GB3 – Ravelling, Chimney** | • Low rock stress and confinement and/or zones with very poor rock mass interlocking leading to local ground loosening up to voluminous overbreak, with ravelling ground and risk of progressive crown failure (ie chimney failure).<br>• This ground behaviour can occur localised in the cross-section or consist of short longitudinal sections confined between good quality rock volumes, where the onset of a stress concentration effect in the surrounding walls (silo effect) and the prevailing occurrence of 'caving' instabilities are likely. | • Referential RMR89 thresholds<br>• σcm/σmax |
| <br>**GB6 – Shear Failure** | • High rock mass overstress.<br>• Development of deformations due to shear failure of the rock mass. Overstress causing yielding and large displacements.<br>• Potential shearing sliding and failure along principal schistosity, generosity and joint planes. | • σmax/UCS<br>• σcm/σmax<br>• tunnel strain (ε) |
| <br>**GB9 – Deep Shear Failure** | • Development of deep-seated shear failure with yielding and large deformations of the rock mass (pressure exerting).<br>• High rock and rock mass overstress.<br>• Potential shearing sliding and failure along principal schistosity, generosity and joint planes. | • σmax/UCS<br>• σcm/σmax<br>• tunnel strain (ε) |
| | • | |

Legend: GSI...Geological Strength Index (Marinos and Hoek, 2000). UCS/T...ratio between the uniaxial compressive strength and tensile strength (Diederichs, 2003). σmax/UCS...ratio (damage index, Di) between the maximum tangential stress on the opening contour and the uniaxial compressive strength of the intact rock. σcm/σmax...ratio (competency index, IC) between the unconfined compressive strength or the rock mass (based on the GSI System) and the maximum tangential stress around the excavation. Strain ε(%) ...ratio between the tunnel wall displacement and the tunnel radius. Strain, competency index, damage index refers to an estimated intrinsic condition.

## Baseline of tunnelling classes (TCs)

***General***

One of the key features considered in Snowy 2.0's GBR was the introduction of Tunnelling Classes (TCs), which serve as a baseline of systematic excavation, support and lining works, which are used with the purpose of remeasurement during construction based on the actual encountered conditions.

While consideration of unit rates for each individual material and element of work is a common practice in European projects, in the case of Snowy 2.0, TCs were organised in the form of 'sets of construction measures' with ascending/descending levels of effort in terms of cost and time. The measures include all activities or items of work upon which the Contractor committed costs, production rates and durations as set out in the schedule of rates and prices.

Each TC is designed to deal with specific ranges of baseline conditions, including the provision of measures to maintain impacts on adjacent facilities and the environment (eg groundwater table) to acceptable levels and the verification of compliance with the project's long-term structural and serviceability requirements.

These classes were defined for each singular type of work section and construction methodology, taking into account the aspects that affect the cost and time of underground construction, as described in Table 6.

**TABLE 6**

Aspects affecting the determination of construction cost and time for the design of Tunnelling Classes in the case of D&B and TBM.

| Item | D&B | TBM |
|---|---|---|
| Excavation works | Round lengths and heading method (ie full-face or partial drifts) | Stroke length, cutterhead penetration rates, tool wear and maintenance requirements, type of machine (eg face pressure requirement, gripper/single/double shield) etc |
| Support works | Support type, quality, amount and location of installation (working or rear zone) | For shield TBM: types of segmental lining and associated reinforcement |
| Lining works | Inner lining type, grouting, waterproofing | Inner lining types and reinforcement details (eg inner *in situ* concrete lining, steel lining |

The categories of TCs, defined for Snowy 2.0, are listed in Table 7.

**TABLE 7**
Tunnelling Classes (TCs).

| **Tunnelling Class (TC)** | **Description** |
|---|---|
| Excavation and Support Classes (ESCs) | These classes apply for Conventional D&B with ESCs catering for the combination of excavation sequence and support for each underground work. |
| Boreability Classes (BCs)<br>Support Classes (SCs)/(BCSCs) | For Shield TBM excavation, Boreability Classes (BCs) were defined to cater for the excavation effort, based on pre-defined ranges of Net Penetration Rates (measured in mm/rev), as obtained from TBM Field Penetration Tests (Dragg Tests) carried out during excavation.<br>Support Classes (SCs) corresponds to the different types of precast concrete in terms of details, materials and structural capacity, which are installed inside the shield skin of the Shield TBM. These support classes are defined with basis on the estimated GBs, as explained earlier. |
| Lining Classes (LCs) | These classes apply for D&B *in situ* inner concrete lining, including waterproofing, contact grouting, and other ancillary works, as well as for Shield TBM segmental lining in case a secondary lining is required to cater for structural and functional requirements during the project life. |

**Other compensation mechanisms – non-systematic conditions (NCs)**
Other types of compensation mechanisms were established to cater for the occurrence of sporadic and localised Geohazards and hindrances, being denominated Non-systematic conditions (NCs). These events may have a significant impact on the required construction effort and therefore required specific positions in the Schedule of Baselines for compensation purposes. Non-systematic conditions considered in the GBR with the purposes of compensation are summarised in Table 8.

**TABLE 8**
Non-Systematic Conditions (NCs) – eg compensation items.

| | |
|---|---|
| Care of water | Specific for heading zones and rear zones and compensated for an excess of *n* L/s (for selected inflow ranges). |
| Abrasivity | Use of Cerchar Abrasivity Index (CAI), with compensation for values above certain pre-defined ranges of abrasivity not covered by the Boreability Classes. |
| Accepted Geological Overbreak (AGO) | Acc. to Swiss standard SIA 198. |
| Naturally Occurring Asbestos (NOA) | Provision for dealing with highly asbestiform mineral fibres. |
| Drilling and Grouting | Acc. to the Employer’s requirements and established trigger levels. |

**Ground classification system**

The Ground Classification System sets out the hierarchical correlations between the physical/ behavioural baselines and the corresponding attributable TCs and NCs, being therefore a central component of the GBR.

Figure 7 shows the general criteria applied for the correlation between ground behaviours (GBs), TBM field testing and identification of specific geohazards and applicable construction measures (e.g Tunnelling Classes/Systemaican or complementary/Non-systematic construction measures).

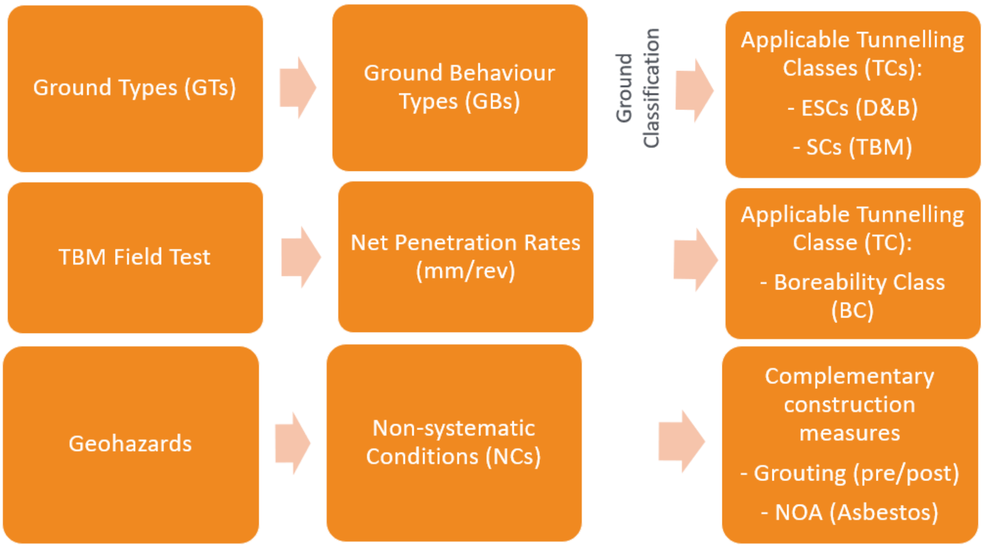



**FIG 7** – Mechanisms applied to define applicable TCs and other complementary construction measures.

**Summary of risk-sharing mechanisms**

In summary, the following risk-sharing mechanisms were included in the GBR:

- Baseline of systematic conditions – Tunnelling Classes (TCs) for structures with longitudinal development, such as tunnels and shafts.
- Lump Sum for the excavation of the power station complex and galleries, ventilation shaft and intakes.
- Adjustment Sum for the excavation supports of power station complex and galleries, which means they are subject to readjustment of cost and time as variance to GBR geologic and geotechnical baseline conditions.
- Compensation mechanisms for Non-systematic Conditions, associated with identified Geohazards, including care of water, abrasivity, accepted geological overbreak, naturally occurring asbestos (NOA) and drilling and grouting.
- Extraordinary Geological Conditions (EGO).

**GBR IMPLEMENTATION AND REMEASUREMENT OF WORKS**

The agreed baselines and the estimated percentages of occurrence of the various types of physical, behavioural and construction solutions (designed to deal with systematic and non-systematic conditions) are the basis for the determination of the construction baseline schedule. This corresponds to the initial baseline construction program derived from the GBR baseline with associated costs as committed by the Contractor in the schedule of rates and prices.

Following the balanced GBR principle, applicable items of work (TCs, NCs and others) are implemented during construction on the basis of the actual encountered ground conditions. Any deviations in the baselined schedule triggers remeasurement with corresponding contractual adjustment of cost and time, as described in the GBR and supporting documents.

The implementation of the GBR on-site during construction involves a multistep cyclic process which is repeated at every construction cycle. The process can generally be grouped into the following main activities:

- collection of site data
- ground classification
- execution of the works
- remeasurement of the works.

The generic steps of the GBR implementation process are also illustrated in Figure 8.


**FIG 8** – Generic steps of the GBR implementation process.

Relevant geotechnical parameters and properties must be collected, recorded, and evaluated on- site at each excavation cycle, excavation round or construction stage, as required for ground classification purposes, verification of design assumptions and safety reserves. Typical geotechnical information collected during construction generally include but is not to be limited to:

- visual characterisation of the ground (face mapping)
- results of probe drilling/coring/sample testing
- geophysical measurements
- groundwater measurements
- monitoring of stress, strain and displacements
- TBM operational data, such as face pressure, thrust and penetration rates (field-test, if applicable)
- verification of design assumptions regarding *in situ* and deviatoric stress conditions (theoretical basis) etc.

The collected and interpreted geotechnical data form the basis for the implementation of the Ground Classification System and the definition of the actions to be taken for the tunnelling work ahead, including attribution of suitable TCs, NCs and any required additional construction measures. Conditions at the rear zones of excavated sections and at adjacent infrastructure must also be continuously assessed and observed to identify any abnormal behaviour, presence of geohazards (eg water inflow) and define the opportunity for the installation of the final/inner lining.

As part of the risk management plan, all relevant geohazards must be included in the risk register and treated in the geotechnical risk management plans prepared as part of the overall construction risk management plan. The GBR must be integrated with the Construction, quality and safety management plans.

Due to the significance of the GBR implementation, a robust technical and commercial management is required from both parties during construction to agree on the encountered conditions, solve potential divergences and enact a proactive and cooperative attitude towards sensibly dealing with technical challenges encountered during construction.

**CONCLUSIONS**

The GBR is a multistage, multistep process which commences in the early project stages, extending through to the reference design, the tender and construction stages, being only concluded once the contract is finished. This involves not only the preparation of comprehensive contractual documents but also proper management and implementation on-site during construction. Whilst the design shall ensure that risks have been properly identified and that a feasible construction solution has been developed to cover the full spectra of expected physical conditions, the actual management and implementation of the GBR on-site, during the construction, is also crucial for the success of the procurement model and for the overall project outcome.

The preparation of the GBR requires an integrated effort across several technical disciplines, including the contractual, commercial and legal areas. It is noticeable that the process of preparing the GBR is often beneficial for the project, as it generates a platform for interdisciplinary team collaboration both within and across the Parties, enabling discussions and a deeper understanding of the project’s technical challenges and risks ahead of the bid and the construction phase.

The Snowy 2.0 pumped storage project is an excellent example of how a project with large complexity could be taken from the feasibility stage into the contract award in a period of about two years. It was achieved through the implementation of a successful procurement strategy including an early contractor engagement (ECC) stage and the development of a GBR as the key document for the project de-risking, management and allocation of identified geotechnical risks.

In the context of the Australian tunnelling industry, where the contracts underpinning many multibillion-dollar projects shifts all financial risk associated with delays or cost overruns on the contracting and engineering companies, the inclusion of risk allocation mechanisms in the Snowy 2.0 contract and adoption of the best international contractual practices for underground works can be seen as a major positive development.
The consideration of fair and balanced risk allocation practices is well-known for contributing to significantly lower project costs, allow for easier project implementation and improve the overall sustainability of the industry. A successful implementation of this procurement modality could help setting a new paradigm, providing renewed incentives for other Employers and Authorities to follow similar approaches. This would certainly generate many benefits to all stakeholders, including taxpayers, contractors and employers, and the society as a whole.

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