APPENDIX C

PROJECT DEVELOPMENT, OPTIONS AND ALTERNATIVES

Snowy 2.0 Main Works

Project development, options and alternatives

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Contents

Tables

Figures

1 Introduction

1.1 The project

Snowy Hydro Limited (Snowy Hydro) proposes to develop Snowy 2.0, a large-scale pumped hydro-electric storage and generation project which would increase hydro-electric capacity within the existing Snowy Mountains Hydro-electric Scheme (Snowy Scheme). Snowy 2.0 is the largest committed renewable energy project in Australia and is critical to underpinning system security and reliability as Australia transitions to a decarbonised economy. Snowy 2.0 will link the existing Tantangara and Talbingo reservoirs within the Snowy Scheme through a series of underground tunnels and a new hydro-electric power station will be built underground.

Snowy 2.0 has been declared to be State significant infrastructure (SSI) and critical State significant infrastructure (CSSI) by the former NSW Minister for Planning under Part 5 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) and is defined as CSSI in clause 9 of Schedule 5 of the *State Environmental Planning Policy (State and Regional Development) 2011* (SRD SEPP). CSSI is infrastructure that is deemed by the NSW Minister to be essential for the State for economic, environmental or social reasons. An application for CSSI must be accompanied by an environmental impact statement (EIS).

Separate applications are being submitted by Snowy Hydro for different stages of Snowy 2.0 under Part 5, Division 5.2 of the EP&A Act. This includes the preceding first stage of Snowy 2.0, Exploratory Works for Snowy 2.0 (the Exploratory Works) and the stage subject of this current application, Snowy 2.0 Main Works (the Main Works). In addition, an application under Part 5, Division 5.2 of the EP&A Act is also being submitted by Snowy Hydro for a segment factory that will make tunnel segments for both the Exploratory Works and Main Works stages of Snowy 2.0.

The first stage of Snowy 2.0, the Exploratory Works, includes an exploratory tunnel and portal and other exploratory and construction activities primarily in the Lobs Hole area of the Kosciuszko National Park (KNP). The Exploratory Works were approved by the former NSW Minister for Planning on 7 February 2019 as a separate project application to DPIE (SSI 9208).

This project development, options and alternatives report has been prepared to accompany an application and supporting EIS for the **Snowy 2.0 Main Works**. As the title suggests, this stage of the project covers the major construction elements of Snowy 2.0, including permanent infrastructure (such as the underground power station, power waterways, access tunnels, chambers and shafts), temporary construction infrastructure (such as construction adits, construction compounds and accommodation), management and storage of excavated rock material and establishing supporting infrastructure (such as road upgrades and extensions, water and sewage treatment infrastructure, and the provision of construction power). Snowy 2.0 Main Works also includes the operation of Snowy 2.0.

The Snowy 2.0 Main Works do not include the transmission works proposed by TransGrid (TransGrid 2018) that provide connection between the cableyard and the NEM. These transmission works will provide the ability for Snowy 2.0 (and other generators) to efficiently and reliably transmit additional renewable energy to major load centres during periods of peak demand, as well as enable a supply of renewable energy to pump water from Talbingo Reservoir to Tantangara Reservoir during periods of low demand. While the upgrade works to the wider transmission network and connection between the cableyard and the network form part of the CSSI declaration for Snowy 2.0 and Transmission Project, they do not form part of this application and will be subject to separate application and approval processes, managed by TransGrid. This project is known as the HumeLink and is part of AEMO's Integrated System Plan.

With respect to the provisions of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), on 30 October 2018 Snowy Hydro referred the Snowy 2.0 Main Works to the Commonwealth Department of the Environment and Energy (DoEE) and, on a precautionary basis, nominated that Snowy 2.0 Main Works has potential to have a significant impact on MNES and the environment generally.

On 5 December 2018, Snowy 2.0 Main Works were deemed a controlled action by the Assistant Secretary of the DoEE. It was also determined that potential impacts of the project will be assessed by accredited assessment under Part 5, Division 5.2 of the EP&A Act. This accredited process will enable the NSW Department of Planning, Industry and Environment (DPIE) to manage the assessment of Snowy 2.0 Main Works, including the issuing of the assessment requirements for the EIS. Once the assessment has been completed, the Commonwealth Minister for the Environment will make a determination under the EPBC Act.

1.2 Purpose of this report

Since the project was announced in March 2017, a huge amount of work has gone into development and planning for Snowy 2.0. The project has considered numerous options, scenarios and alternatives and has been continuously refined and improved on all fronts. The proposed development presented in the Snowy 2.0 Main Works EIS is the result of this extensive process.

This report provides a summary and details of project development, options and alternatives considered in the design and assessment of Snowy 2.0. It has been prepared to support the Main Works EIS and brings together information from various reports and documents to provide an outline of the project development process to date and the main design options and alternatives considered throughout that process.

The project development has involved wide ranging consideration of technical, social and environmental, economic and commercial aspects of the project. The purpose of the report is to provide information relevant to the EIS and its consideration of how the project has avoided and minimised environmental impacts through project optimisation and design refinement.

2 Developing Snowy 2.0

2.1 Snowy 2.0 inception

In March 2017 Snowy Hydro announced a plan to conduct a Feasibility Study into Snowy 2.0 for a possible pumped hydro-electric expansion of the existing Snowy Mountains Hydro-electric Scheme (Snowy Scheme). The concept for a connection between Tantangara and Talbingo reservoirs has been considered since the original Snowy Scheme and this study recognised its potential for creating a significant pumped hydro-electric storage facility.

Snowy Hydro's guiding principles for the design and the Employer's Requirements for the Project evolved from the objective of meeting the needs of the National Electricity Market (NEM) as variable intermittent generation is added and will become a significant source of the energy supplied to the NEM.

To meet this goal, the Snowy 2.0 project must:

- Provide a safe and robust facility designed in accordance with national and international standards;
- Comply with the requirements of Australian legislation and regulatory bodies; and
- Possess high operational reliability and flexibility.

The process that Snowy Hydro undertook to develop Snowy 2.0 is extensive. Initially at a macro level, options to Snowy 2.0 were investigated. This focused on determining what the most feasible pumped hydro storage scheme was for Snowy Hydro. Once the concept for a connection between Tantangara and Talbingo reservoirs was determined to be the most feasible for Snowy 2.0, the process to determine the options within Snowy 2.0 was undertaken in order to determine the final engineering outcome that has been described within this EIS.

2.2 Key design phases

The development of Snowy 2.0 has progressed in phases both before and following the project's public announcement in 2017. The main phases of project development for Snowy 2.0 are:

1. Historical investigations;
2. Feasibility Study;
3. Reference Design; and
4. Competitive tender design and post-tender optimisation.

In regards to these project development phases, the Historical Investigations and early stages of the Feasibility Study focused primarily on determining the options for Snowy 2.0 that Snowy Hydro would consider. The later stage of the Feasibility Study, as well as the Reference Design and competitive tender design and post-tender optimisation dealt with the options and alternatives within Snowy 2.0. The following section is broken out to reflect this development of the Project.

2.3.1 Historical investigations

Proposals for the development of hydro-electric facilities in the area around Lobs Hole and the Yarrangobilly River have existed since before the formation of the Snowy Mountains Hydro-Electric Authority in 1948. These early proposals, along with several others across the Snowy Mountains region, were eventually abandoned during the course of the Snowy Mountains Scheme on the basis of economic (whole of Scheme) budget considerations which forced the development of only the most financially attractive sites. The subsequent investigations for a development in the Lobs Hole/Yarrangobilly River area is recognition that this area constitutes one of the most attractive, and currently un-utilised, sites that has the potential to take advantage of original engineering foresight.

A pumped hydro-electric storage connection between Tantangara and Talbingo reservoirs had been considered since the original Snowy Scheme development. The Snowy Mountains Hydro Electric Authority (original name for Snowy Hydro) carried out various geological surveys and studies between 1963 and 1991 with specific studies of Tantangara and Talbingo Reservoirs. A map showing a concept for a hydro-electric connection between Tantangara and Talbingo reservoirs during the original Snowy Scheme development is provided in Figure 1.

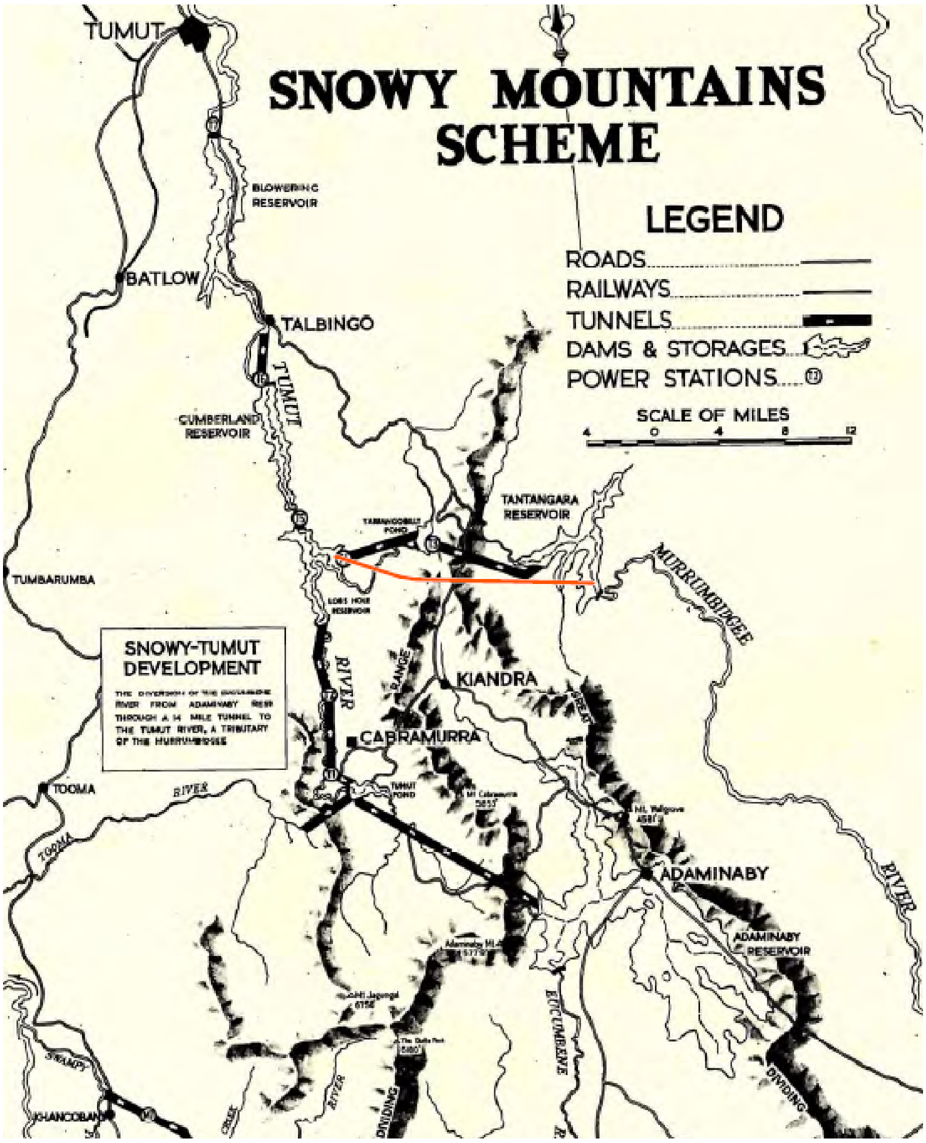


Figure 1: Historic Snowy Scheme map

Snowy Mountains Scheme Augmentation Ranking Study

Prior to the Snowy 2.0 Feasibility Study, several studies were undertaken to investigate augmentation of pumped hydro-electric capacity in the Snowy Scheme. The most comprehensive historical study preceding the Feasibility Study was the Snowy Mountains Scheme Augmentation Ranking Study (SMA 1991). The Ranking Study investigated new water management infrastructure between existing reservoirs in the Snowy Scheme including three tunnel alignment options for linking Tantangara and Talbingo Reservoirs and design for a 1,000 MW pumped hydro-electric power station. The Ranking Study also provides a summary of studies undertaken prior to 1991.

> Augmentation studies of pumped storage schemes were first considered in 1966 during the design and construction phase of the Snowy Mountains Hydroelectric Scheme. Further studies concerned with energy reserve capability and mostly of pumped storage schemes were undertaken from 1980-1986. The most recent study prior to 1991 was of a mini-hydro development at Khancoban Dam in 1990.

These historical studies provided forward planning for an option to augment pumped hydro-electric storage within the Snowy Scheme and informed the scope and design of Snowy 2.0.

The comprehensive assessment of options for the augmentation of the Snowy Scheme prepared for the Snowy Mountains Scheme Augmentation Ranking Study (SMA 1991) involved consideration of 10 conventional hydro power alternatives and four pumped storage alternatives. The options considered are provided in Figure 2.

The Ranking Study included consideration of a pumped hydro connection between Talbingo and Tantangara reservoirs similar to the Snowy 2.0 alignment, called the Yarrangobilly Pumped Storage Scheme. This option was found to be the lowest cost alternative for large scale pumped hydro energy storage of 18 GWh for 10 day capability. This option was not considered economic at the time largely due to the comparative cost of gas turbines. The Yarrangobilly Pumped Storage Scheme was investigated further in 2017 in the Snowy 2.0 Feasibility Study as it was identified that the economic viability of large scale pumped hydro energy storage had improved. It is this scheme which has been developed into Snowy 2.0.

When compared to the other four pumped hydro alternatives in the Ranking Study, the Yarrangobilly Pumped Storage Scheme was clearly superior to the others because:

- The proposed Wandilla and Jagumba Pumped Hydro Schemes would require the construction of new storages; and
- None of the other three options provide the same high head potential linked to the high storage capacity of Snowy 2.0. A detailed comparison of the four schemes is set out in Table 1 below.

Table 1: Ranking Study (SMA 1991) options

Scheme option	New storages required	Potential storage	Potential head	Tunnelling required
Yarrangobilly	No	238 GL	680 m	~27 km
Wandilla	Yes	6.3 GL	270 m	~1.5 km pressure pipeline
Jagumba	Yes	25.5 GL	680 m	~10 km
Upper Tumut	No	52 GL	610 m	~24 km

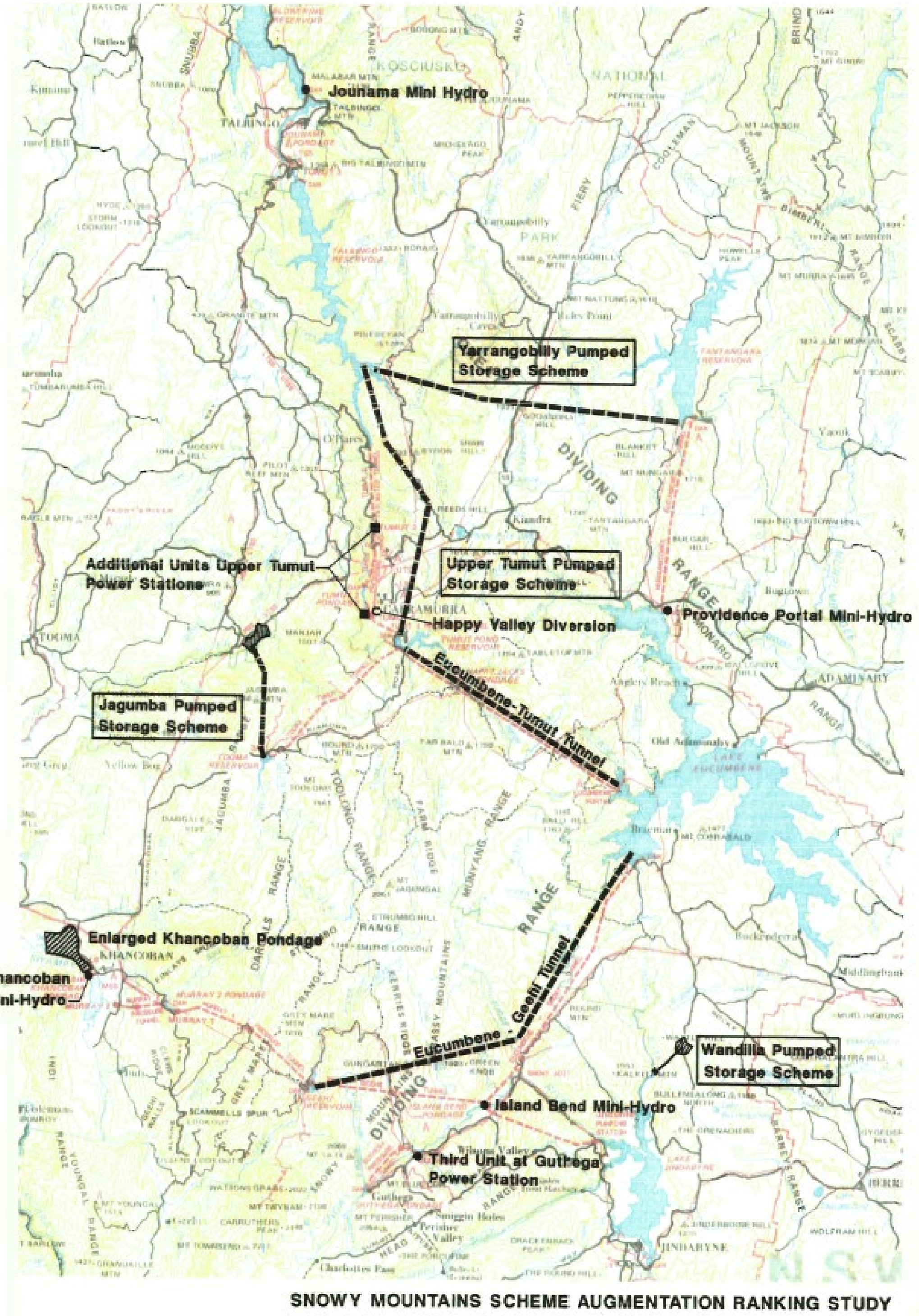


Figure 2: Ranking Study (SMA 1991) map of options

In light of the unique nature of the opportunity offered by the Snowy 2.0 Main Works, Snowy Hydro embarked on a Feasibility Study of the development in March 2017. The progress of that Feasibility Study, and the options within the Snowy 2.0 development are described more fully in Section 3.

2.3.2 Feasibility design

In March 2017, Snowy Hydro announced the Feasibility Study for Snowy 2.0. The decision to pursue a Feasibility Study for a pumped hydro-electric storage connection between Tantangara and Talbingo was driven by market changes in the Australian National Electricity Market (NEM) with a large supply-side shift away from baseload (coal) generation and towards intermittent renewable generation. These market changes and existing knowledge of the potential for augmenting pumped hydro storage in the Snowy Scheme provided a unique opportunity to increase much needed energy storage and security in eastern Australia.

The Feasibility Study commenced in April 2017 and was completed with the delivery of the Feasibility Study Report in December 2017. During the Feasibility Study detailed analysis was undertaken for the following key areas of design:

- geological, geotechnical and hydrogeological conditions;
- intake structures;
- power waterway;
- power station complex;
- access options for tunnels and roads;
- excavated material management; and
- turbine, hydromechanical equipment and balance of plant.

2.3.3 Reference design

Following approval by Snowy Hydro, the feasibility design was progressed to the Reference Design which formed the basis for the tender documents for issue to prospective contractors wishing to tender for the construction of the civil works and procurement of the electrical and mechanical plant required for the operation of the pumped storage hydropower project. The key objectives of the Reference Design were to develop a design that:

1. Enhances the operational safety and reliability of Snowy Hydro’s power generation system;
2. Optimises hydraulic performance and efficiency of the power waterway and plant;
3. Minimises construction costs;
4. Minimises construction time; and
5. Minimises operation and maintenance cost incurred during the life of the Project.

The Reference Design is a base design from which tenderers, both Civil and electrical and mechanical (E&M) were able to develop their own design for the Project based on their preferred construction method and construction experience.

The Reference Design illustrates Snowy Hydro’s design intent with regards to the standard of quality, functionality and performance expected to be provided in the tender submissions and is further conditioned in the Employer’s Requirements. The Employer’s Requirements are a series of contractual documents that were developed throughout the process that specify all of Snowy Hydro’s requirements for what is to be designed and constructed, in order to meet the purpose of Snowy 2.0. The Contractors were not required to adopt the Reference Design in its entirety but were encouraged to propose optimised designs provided that their designs met the Employer’s Requirements.

The general approach adopted for the design of Snowy 2.0 was to develop a design which is robust to ensure safe and reliable performance of the civil, electrical and mechanical works under all operating conditions for the expected life of the Project, whilst minimising the impact on the surrounding environment.

2.3.4 Contractor design and post-tender optimisation

The Project has been running a collaborative process, or Early Contractor Consultation (ECC) process with both the Civil and E&M contractors since mid-2017, and commenced the formal competitive tender process in mid-2018.

The purpose of this process was to undertake optimisation of the Reference Design and finalisation of the Employer's Requirements by having contractors challenging them from a design and construction point of view. This was an important element of the process as it allowed Snowy Hydro to understand where the Employer's Requirements were positioned within the market and how constructable and realistic the requirements were. The output of the process also left scope for the contractors to still input innovation and further optimisation into their final tender designs.

The key activities undertaken in this process were:

1. Review of the Reference Design and optimisation by the contractors;
2. Review of the Employer's Requirements by the contractors;
3. Issuing of clarifications of the Employer's Requirements to Snowy Hydro through a Request for Information (RFI) process;
4. Development of pump-turbine models by the E&Ms and completing of associated witness tests;
5. Face-to-face collaborative workshops between Snowy Hydro and the contractors to enhance understanding of all aspects of the Project, eg: Employer's Requirements, approvals, safety expectations, environmental requirements and development of the Contractor's design;
6. Updating of Employer's Requirements where required to reflect optimised contractor's design;
7. Optimisation between the Civil and E&M contractors in consultation with Snowy Hydro.

One of the main reasons for these key activities was to achieve a best-for-project outcome by creating an engaged relationship between the Employer, Snowy Hydro, and the contractors. This meant that whenever issues presented themselves, they could be quickly and openly discussed and resolved. By investing significant time in this tender development phase, a significant amount of risk has been removed and managed from the final tender submissions.

Under an Engineer, Procure and Construct (EPC) contract delivery model, the contractor is responsible for the design of Facilities. Through the contracting instrument, Snowy Hydro will establish appropriate review and sign-off points to ensure that key operational aspects of the design are consistent with the Employer's Requirements.

Since submitting the tender design, the selected Contractor has proposed several key optimisations. These optimisations were analysed from the following perspectives;

1. Technical feasibility - review of the proposal by Snowy Hydro and their consultants
2. Constructability - optimising to ensure the most safe and efficient construction methodology is adopted;
3. Environmental analysis - undertaking where required a review of environmental factors to ensure any impacts are assessed and mitigated where possible;
4. Commercial viability - ensuring the solution is analysed from a cost perspective and that it is within the bounds of the Project; and
5. Stakeholder engagement - review by key Stakeholders both internally and externally to ensure any impacts are assessed and addressed.

3 Alternatives within Snowy 2.0

Alternatives to Snowy 2.0 have been addressed previously within the Exploratory Works EIS (EMM 2018) and the Strategic context and need for Snowy 2.0 (report) appended to the Snowy 2.0 Main Works EIS (EMM 2019). This chapter describes the options and alternatives within Snowy 2.0 that ultimately led to the selection of the preferred design for which approval is sought (ie Snowy 2.0 Main Works). Each element discussed further in this chapter is listed in Table 2 for reference.

Table 2: List of elements subject to optioneering

Element	Description	Section
Power waterway horizontal alignment	Alternative horizontal alignments for linking of reservoirs	3.1
Location of power station	Alternative locations along the alignment	3.2
Design of power station	Alternative underground designs	3.3
Hydraulic layout	Design options for hydraulic tunnels and shafts	3.4
Water intakes	Alternative locations and intake design	3.5
Tunnel construction methodology	Alternative tunnelling methods	3.6
Pressure shafts and inclined pressure shaft	Design options for pressure shafts	3.7
Construction sites and adits	Other sites or additional locations considered	3.8
Power, communications and utilities	Requirements and alignments considered	3.9
Transmission network connection	Alternative connection options to the NEM	3.10
Construction delivery	Alternative construction delivery including transport of materials, segment production, construction site locations, etc	3.11
Excavated rock management	Alternative rock placement methods and locations	3.14 and Annexure A

3.1 Power waterway horizontal alignment

Several power waterway alignments were investigated during the Feasibility Study. The alignment options considered in the Feasibility Study used the previous Ranking Study (SMA 1991) to provide a high-level design on which to build upon. Additional alignment options beyond those considered in the Ranking Study were also developed for assessment and consideration. The following alignment options were assessed and are shown in Figure 3:

- Base case alignment;
- Northern alignment;
- Mt Byron alignment;
- O'Hares Hill Option 1 alignment; and
- O'Hares Hill Option 2 alignment.

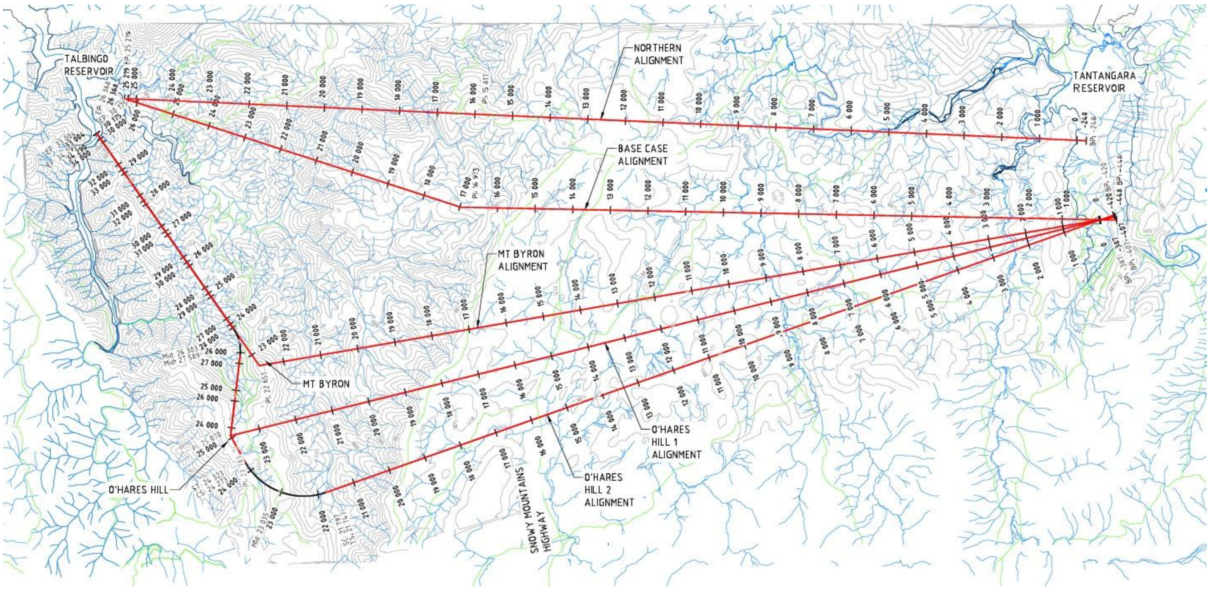


Figure 3: Feasibility Study power waterway alignment options

A desktop study was undertaken to develop these potential alternatives with the key criteria for assessing the options being:

1. Functional performance (hydraulic layout and efficiency etc.);
2. Geological risk (fault zones, weaker material, limestone);
3. Total length of tunnels (headrace, tailrace and access tunnels);
4. Access road construction (length and ease of access);
5. A preliminary construction cost estimate;
6. A preliminary construction schedule; and
7. Ancillary factors (surge tank design, sufficient cover for tunnels, spoil disposal, transmission).

The base case alignment was determined to provide the best alignment option and was carried forward as the preferred option. The Mt Byron, O'Hares Hill Option 1 and O'Hares Hill Option 2 alignments were considered less favourable due to longer total tunnel routes, limited surge tank options due to lower topography and poorer geology in the tailrace section compared to the base case. The Northern alignment provided reduced tunnel lengths but was considered unfavourable due to the risk of intersecting limestone and poor location for the main access tunnel. The base case alignment was considered preferable as it provided improved surge tank options, reduced geological risk, had the second shortest total tunnel length and notably, allowed easier access to the power station complex offering substantial construction program benefits.

3.2 Location of power station

The selection of the optimum location for the power station is based on several factors including; hydraulics, geology, geography, accessibility, safety, environmental impacts, construction schedule and cost. During the feasibility study, reference design and tender design, the location of the power station was constantly challenged and developed with four locations along the chosen 'base case alignment' assessed in detail to determine the optimum location, considering all key aspects.

It is common for the construction of the access tunnels and power station (main machine hall) to be on the critical path on any underground hydropower scheme and Snowy 2.0 is no different. Major programme benefits were identified in reducing the length of the access tunnels to the power station complex. Moving the power station west along the chosen alignment achieved a reduction in the length of the access tunnel and a reduced construction programme. This has been a main driver in the development of the power station location because a shorter construction brings both cost reductions, helping ensure the project feasibility, and also reduces the duration of all environmental impacts of the construction activities. The geological condition, however, have largely governed how far west the power station could move.

The location of the power station was assessed progressively following the selection of the preferred power waterway alignment. The options considered for the power station location are listed below:

- Ravine cavern – which was the location identified in the existing Ranking Study;
- Plateau cavern – located just east of the Snowy Mountains Highway in the plateau area;
- Ravine West cavern 1– located 1.5 km west of the Ranking Study location towards Talbingo Reservoir; and
- Ravine West cavern 2 – located 2 km west of the Ranking Study location towards Talbingo Reservoir.

To select a preferred power station location, engineering design was developed to a level necessary to determine technical feasibility and assess the expected cost and schedule of the option.

During feasibility two initial locations were developed in detail along the base case alignment, the Ravine location was taken as the base case for design and costing and the Plateau option was assessed in parallel as an alternate. The Ravine option was the preferred option however the geological conditions were still relatively unknown during feasibility and the Plateau location, being in a different geological unit, was developed as an alternate location incase the geological conditions at ravine proved unfeasible.

Ravine West cavern 1 location was also identified as an attractive location during feasibility but had high risks associated with geological conditions that prevented it's adoption as a base case until conditions could be investigated.

Following the feasibility stage and the commencement of the geotechnical investigation confidence in the Ravine location grew and the alternate Plateau option was no longer required. The Ravine location was then developed further for the reference design. The Ravine West cavern 1 location was still being considered throughout reference design as geotechnical investigations progressed.

During the tender process the Ravine West cavern 1 location was adopted by the tender designers as the prefered location and developed further as their proposed tender design. Following award of the contract the power station has continued to be optimised as more geotechnical information continues to feed the design. The contractors design team proposed Ravine West West Cavern 2 location as part of the design optioneering development. Geotechnical investigations have targeted this new West West location and the initial results are good.

The optimised Ravine West cavern 2 location has been carried forward as the preferred solution for Snowy 2.0 Main Works and provides great engineering, cost, schedule and environmental benefits.

The Feasibility Study power station options are shown in Figure 4.

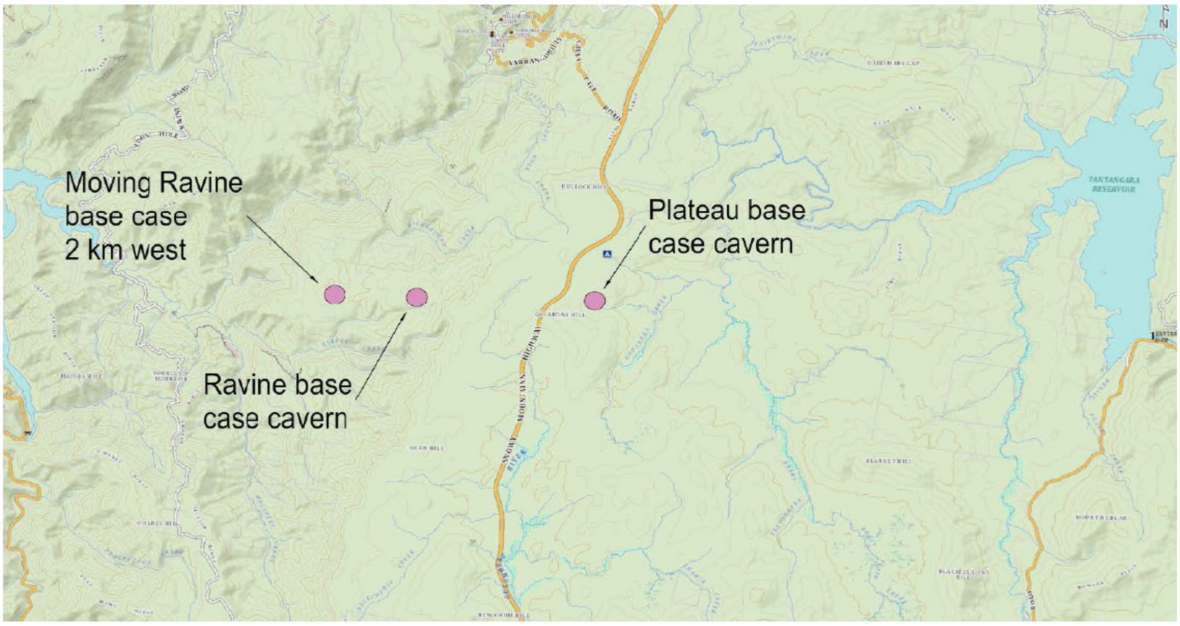


Figure 4: Feasibility Study power station location options

3.3 Design within the power station complex

Snowy Hydro has extensive experience with operating and maintaining power stations, experience which has been developed over the last 70 years since the beginning of the scheme. As such, the on-going development and optimisation of the power station complex was of key importance to Snowy Hydro throughout the multiple stages of the Project. Importantly however, changes that occur solely underground have limited to no impact on the surface.

A number of elements that have since changed throughout the design optimisation process to ultimately lead to this configuration are based on the following:

- During the early stages of the Feasibility Study design, the draft tube valves were originally in a separate cavern. To accommodate this, an access tunnel was required along with a crane system to allow maintenance to be undertaken. In the design development however, these draft tube valves were relocated to below the Transformer Hall, therefore removing the need for an additional cavern structure and all the associated operational access requirements. The need for the additional cavern was therefore removed, reducing excavation and spoil disposal volumes.
- Cooling water tunnel removed from design and services that used this tunnel now embedded (drainage & dewatering pipework and cooling water pipework);

- Cavern for draft tube tunnel to collector tunnel bifurcations removed and bifurcations moved into niche directly downstream of draft tube valves resulting in reduced excavation and spoil disposal volumes; and
- With the change from three vertical pressure shafts to one single inclined pressure tunnel during the competitive tender process, it removed the need for the penstock guard valves near the upstream surge tank and the associated access tunnel. This resulted in a reduction to excavation and spoil disposal volumes.

3.4 Hydraulic layout

The hydraulic layout of the proposed facilities was subject to an iterative design process throughout all design phases of the Project. The hydraulic layout includes the diameters and number of the hydraulic tunnels and shafts, and defines the capability of the station to hydraulically convey the volume of water required to produce the power desired within the time frames required for the design life specified. The design parameters that were used to optimise the hydraulic layout through the Feasibility Study are listed below:

- 2,000 MW power station output;
- Round-trip efficiency (RTE) target;
- start time of 90 seconds;
- number of pressure shafts;
- high-pressure tunnels and collector tunnels; and
- surge tank layout optimisation.

The key impact of changes to the hydraulic layout of the facilities is that it has a direct impact on the final constructed facilities. For example, any reduction in tunnel diameter has a direct reduction in the amount of excavated material generated from the Project, improving the environmental outcomes. Table 3 summarises the key changes that have occurred for the hydraulic layout, with the final competitive tender process changes outlining the design that has been carried forward.

Table 3: Development of hydraulic layout

Design phase	Summary of design
Feasibility study	• Headrace tunnel and tailrace tunnel internal diameter initially at 10.8m and then reduced down to 9m following a detailed analysis into the relationship between excavated diameter and capital cost changes against the change to round trip efficiency of the system during operations; • Intake structure approach velocities of 1m/s were increased to 2m/s to allow for an optimised size of the intake structure and associated reduced excavation and spoil disposal volumes; • Single 20m diameter headrace surge tank that is confined to below ground surface; and • Three vertical pressure shafts.
Reference design	• Headrace tunnel and tailrace tunnel internal diameter increased to 10m; • Headrace tunnel surge tank altered to 3 x 12m diameter surge tanks due to poor geological conditions and concerns around the constructability of the structures.

Design phase	Summary of design
Competitive tender process	• Headrace tunnel and tailrace tunnel diameter increased to 10.5m to provide for secondary internal lining in areas of por geological conditions. With additional geotechnical information available, the diameter of the tunnels was reduced to 9.8m. • Change from in-situ concrete lined headrace tunnel and tailrace tunnel to segmentally lined tunnels using TBMs as discussed in section 3.6; • Movement of power station further west as discussed in section 3.2; • Single 25m diameter headrace tunnel surge tank returned, and moved west to facilitate movement of the power station complex further west. This results in the surge tank now extending above the ground surface, up to a maximum of 15m; • Adoption of a single inclined pressure tunnel instead of three vertical pressure tunnels.

3.5 Water intakes

The following section outlines the design and engineering optimisation that has been undertaken throughout the project to ensure the best solution is adopted. Each of the areas: intake location, access, the structure and flow velocities all outline the preferred solution that has been carried forward.

3.5.1 Intake locations

The intake locations selected for the Feasibility Study were based on the base case power waterway horizontal alignment. An alternate horizontal alignment was also identified through the feasibility study with alternate intake locations. This involved relocating the Tantangara intake connection to the Murrumbidgee River. This proposed alternate options for intakes and power waterway alignment was referred to as the Northern Tantangara alignment and was previously considered in a 1949 report (Ivanac and Glover 1949) during the early stages of the Scheme development. The Northern Tantangara alignment and intake locations is shown in Figure 5.

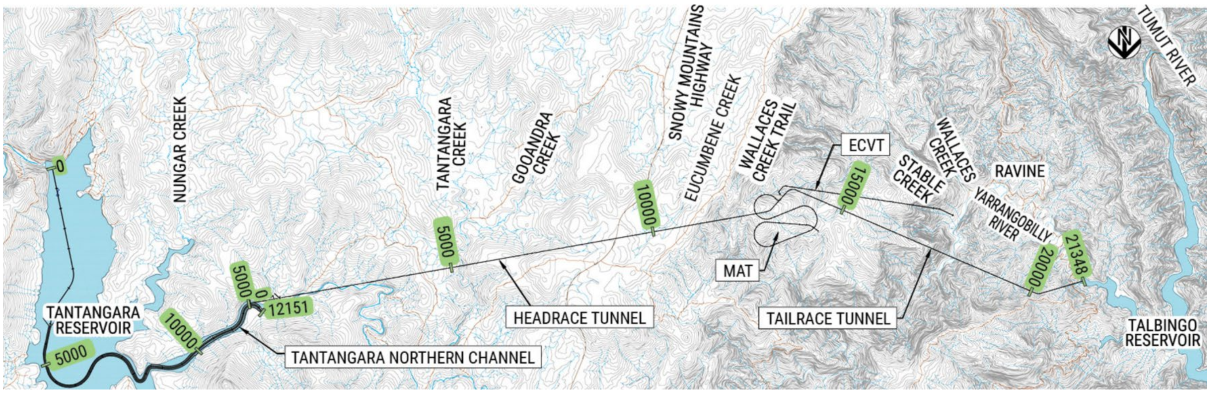


Figure 5: Northern Tantangara alignment

The purpose of this option was to reduce the distance of the power waterway between the intake structures. The Feasibility Study estimated that the Northern Tantangara alignment would reduce the length of the headrace tunnel by 4.5 km and the tailrace tunnel by 2 km but that there would be additional challenges in requiring greater surface excavations by dredging for establishing an adequate headrace channel and a greater potential for sediment mobilisation. A closer investigation of the feasibility of the Northern Tantangara alignment concluded that this option was not commercially attractive, nor appealing environmentally due to the remoteness of its location.

For the final tender design, the location of the water intake structure on Tantangara reservoir was a location near Tantangara Dam and for Talbingo reservoir at a point where the Yarrangobilly river enters Talbingo reservoir.

The design of the intake structures aimed at minimising the visual impact on the Park by locating the civil works either underground or permanently submerged below MOL. This resulted in the hydromechanical plant such as stoplogs and control gates which are required for flow control to be accessible from the ground surface via intake gate shafts instead of a tower and bridge arrangement jutting out into the reservoir. The top of the intake gate shaft and access into a gate maintenance chamber would be above maximum flood level. The intake structures itself would be permanently submerged leaving only the excavation cuts of the intake approach channels exposed above reservoir level and reducing the visible evidence of the presence of the intake structure.

3.5.2 Access bridge to intakes

Based on Snowy Hydro's experience, very little debris accumulates at the trashracks of the intakes of its existing hydropower operations. It was therefore decided that no access bridge should be provided at the intakes of the Snowy 2.0 Project for the servicing of the trashracks. Any maintenance on the permanently submerged trashracks would be carried out by divers detaching the fixings holding the trashrack panels in place and removing the trashrack panels from the intake orifice for inspection, an activity which may be required every 20 years of operational service.

3.5.3 Combined intake/intake gate structure

Given the steepness of the terrain at the Talbingo intake site, the Contractor proposed the construction of a free-standing intake gate tower and combining the intake gate tower with the submerged intake in a single structure rather than providing a separate underground gate shaft and intake structure, as was envisaged by Snowy Hydro's Reference Design. The visual impact of the intake tower, extending about 20 m above FSL, would be mitigated by backfilling around the tower with rockfill, leaving only the tower's wall facing the reservoir exposed to view over the full width of the intake tower and a height of about 5 m. Acceptance of the Contractor's proposal allowed the height of the intake gate structure to be reduced which offers improved safety for maintenance personnel accessing the gate maintenance chamber and a reduction in the excavation volume and height.

3.5.4 Flow velocities at intakes

It is general design practice to limit flow velocities through the trashracks at the intakes to about 1 m/s to limit the formation of vortices and surface waves. However, in order to meet this design criteria for the large design flow involved in the operation of the Snowy 2.0 Project, a very long transition section would be required for the reduction of the 400 m^2 orifice at the exit of the intake structure to the tunnel section of about 80 m^2. It was therefore concluded that a relaxation of the minimum flow velocity requirement to 2 m/s would be acceptable provided that the Contractor carries out hydraulic model studies which prove compliance with the maximum average flow requirement of 2.0 m/s and that velocities would not exceed 2.5 m/s at any point through the trashracks. Further protective measures may include the provision of an exclusion zone around the intake structure to keep members of the public at a safe distance from the submerged intakes.

3.6 Tunnel construction methodology

The following section outlines the development of the tunnel construction methodology throughout the Project and establishes the reasons for the preferred solution that has been adopted.

The Reference Design (Figure 6) was initially developed based on assumed tunnel construction methodologies which comprised a combination of drill and blast and mechanised excavation by tunnel boring machine (TBM). These methods were selected based on assessments of the functional scheme requirements (e.g. excavation shape and hydraulic efficiency), structural support requirements (temporary support and final lining types), geotechnical and project risks, safety implications, potential environmental impacts and impacts on construction costs and program.

As an outcome of the assessments, the eastern half of the headrace tunnel was assumed to be constructed by TBM, driving in a westerly direction from Tantangara Intake. The western half of the headrace tunnel was assumed to be constructed by drill and blast, in both an easterly direction from a construction adit near the Surge Shaft off Marica Trail and a westerly direction from an intermediate adit located within the Gooandra Plain. The drill and blast methodology was selected to manage potential geotechnical risks associated with the Long Plain Fault.

The access tunnels including the MAT and ECVT were assumed to be constructed by drill and blast methods as it was thought that TBM procurement lead times may cause construction program delays. The tailrace tunnel was assumed to be constructed by TBM comprising a precast concrete segmental lining.

During the tender process, the Contractors revisited the construction method assessment and in the process challenged some of Snowy Hydro's functional project requirements. This resulted in changes to the scheme arrangement and the adoption of alternative tunnel construction methodologies.

In the Contractor's tender design, the MAT and ECVT construction methodologies were changed from drill and blast to TBM. This offers quality benefits given the lining can be precast in controlled conditions and safety benefits given the size of tunnelling crew can be reduced and segmental lining will be installed immediately behind the excavation face. The Contractor was able to overcome TBM procurement lead time issues, offering a comparable overall construction program.

In addition to the above, the Contractor also revised the construction strategy for the headrace tunnel by replacing almost all drill and blast portions with a TBM drives. The revised approach involved constructing the majority of the headrace tunnel by a single TBM drive in a westerly direction from Tantangara Intake. The proposed changes offer construction program benefits, minimise the number of tunnelling operations and the overall construction footprint. Significantly, the intermediate headrace construction adit within the Gooandra Plain was omitted, avoiding environmental disturbance within a sensitive area of Kosciuszko National Park. The geotechnical risks identified during the Reference Design can be mitigated by adaptations to the TBM design.

The headrace tunnel TBM is proposed to be a shielded type, which allows the installation of a precast concrete segmental lining as the excavation progresses. The TBM will be capable of operating in both open face and slurry mode where necessary. This allows the management of health and safety risks associated with the potential presence of naturally occurring asbestos (NOA), while also additional control of high groundwater inflows during construction.

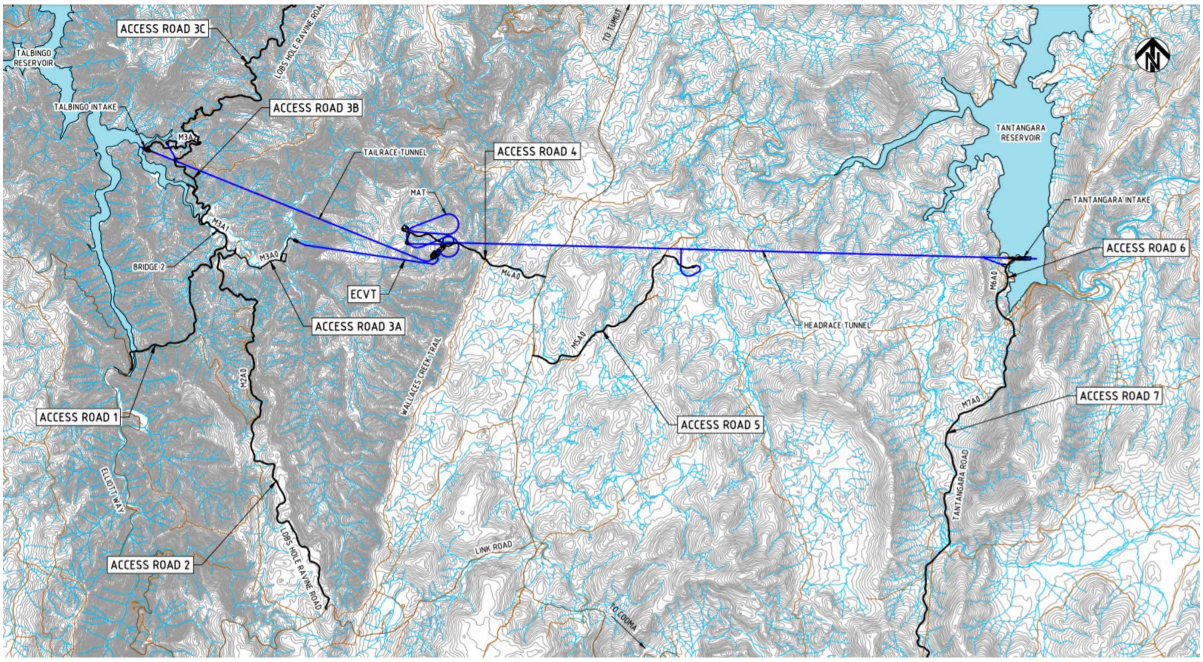


Figure 6: Reference design

3.7 Pressure shafts and inclined pressure shaft

In both the Reference Design and original Tender Design, the headrace tunnel trifurcated into three vertical pressure shafts on the downstream side of the upstream surge shaft. These three pressure shafts connected with three deep pressure tunnels which subsequently transitioned into the Machine Hall.

The vertical shafts were each proposed to be excavated separately from an underground chamber near the Upstream Surge Shaft, with access to be provided from an adit constructed from Marica Trail. The deep pressure tunnels were proposed to be constructed by drill and blast methods, with access to be provided from the MAT or ECVT.

During post tender design optimisations, the Contractor proposed to replace the three vertical shafts and deep pressure tunnels with a single inclined pressure shaft connecting the Upstream Surge Shaft with the Machine Hall. The change was made possible by agreement with Snowy Hydro to omit the upstream guard valves from the project requirements.

In the revised arrangement, the Contractor proposes to construct the inclined pressure shaft using a single TBM drive which will form an extension of either the MAT or ECVT. The change will reduce the number of tunnelling operations and construction footprint and reduce the construction personnel requirements. Quality and safety benefits of using a TBM will also apply as discussed previously. This design has therefore been adopted as the preferred solution.

In addition, the underground chamber for the pressure shaft construction and the associated access adit from Marica Trail can be omitted, reducing spoil volumes and the construction footprint.

3.8 Relocation of the Main Access Tunnel

For the Ravine base case power station location, two options for the location of the Main Access Tunnel (MAT) portal were identified. The first option involved locating both the MAT and Emergency, Cable and Ventilation Tunnel (ECVT) portals in Lobs Hole, with access to be via Lobs Hole Ravine Road. The alternative option involved locating the MAT portal on top of the escarpment off the Snowy Mountains Highway near the surge shaft, with the ECVT portal to be located in Lobs Hole as per the first option. As seen in Figure 7 the MAT had a length of 6.5km with a typical gradient of 12%.

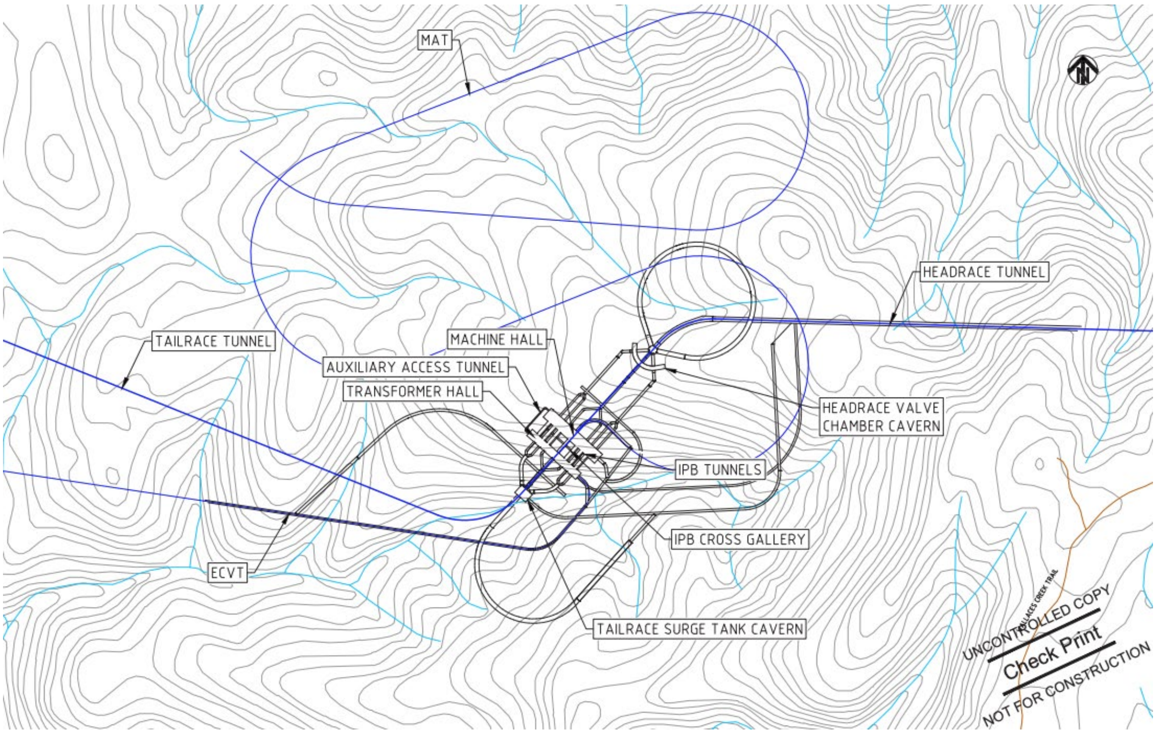


Figure 7: Original MAT from near the current Marica area

The MAT will be the main operational access to the Power Station. The first option was initially selected as the base case arrangement due to it having the shortest travel time from Cabramurra (the closest existing Snowy Hydro regional production office) to the MAT, as well as two alternative directions of egress from the power station in the case of an emergency (e.g. bushfire). However, following a review of the available options it was decided to adopt the alternative MAT option instead as the preferred solution for the project.

Whilst the alternative arrangement is less favourable for operational access due to the long drive required into Lobs Hole, it has a significantly reduced length of MAT, reducing tunnel spoil quantities and allowing earlier construction access to the Power Station Complex which improves the overall project construction program. Importantly, by not selecting the MAT from the top of Marica area, there is less impact environmentally as this area is more sensitive ecologically than Lobs Hole.

3.9 Power, communications and utilities

3.9.1 Construction power

Multiple options were developed during the Feasibility Study for electric power supplies during construction. These included non-network (e.g. diesel) and network (grid connection) solutions. Sole use of diesel power stations for construction were deemed cost prohibitive, environmentally deleterious and considerably increased truck movements through the National Park during the height of construction. The Feasibility Study found that an upgrade of the Providence Portal to Tantangara 11 kV line was necessary for power supplies on the Tantangara side. Likewise, in Lobs Hole, power would be reticulated from Upper Tumut Switching Station at 33 kV using a new power line following the 330 kV transmission line easement as far as practicable. Any surplus power was to be supplied from localised, small diesel generators.

Changes in the construction methodology for the facility and an increase in power requirements resulted in a shift to having a substation built in Lobs Hole. This substation would connect to an existing transmission line and be an installation that provides permanent power to the facility post construction. Development in construction methodology included excavation by TBM in the Plateau/Marica area at the western end of the headrace. The solution for the power supply was to build another substation on the Plateau that connects to another transmission line in this area. This Plateau substation was to be a temporary installation as there are no large permanent power requirements in that area. This Plateau substation would also allow some redundancy with the Lobs Hole substation i.e. transformers and other equipment could be used as spares across both installations. However, the final construction methodology changed to launch the TBM at Tantangara and the requirement for the substation disappeared.

The construction power requirements at Tantangara increased considerably as a result of the final execution methodology. This pushed the upgrades on the Providence Portal to Tantangara power lines out of commercial feasibility. The solution for this was to investigate whether power could be reticulated from the Lobs Hole substation to Tantangara via the Plateau using underground power cables. This feasibility was verified for both the construction and permanent loads and upgrade works to the Providence Portal Tantangara power lines ceased development. The option exists, once the facility is complete, to relinquish and remove the Providence Portal to Tantangara line, returning the easement to National Parks. However, it is not part of this Approval.

The substation in Lobs Hole will be kept to a minimum size through the use of gas insulated switchgear (GIS). An option would have been for an air-insulated substation to keep capital costs lower. The footprint for this substation would be much larger and visually far less acceptable.

In summary, the construction power methodology has been selected on only one source location, removing the requirement for multiple substation sites across the project alignment. The power supply cable will be in the same alignment as the communications cable which is a permanent requirement for the project, therefore not requiring any additional disturbance areas. This has been adopted for the Project.

3.9.2 Communications cable

The requirement for communications is dual, redundant paths between the power station, headrace surge tank, Tantangara intake gate structure and Talbingo intake gate structure. This communications infrastructure is required for personnel and plant protection, data acquisition and control, corporate networking at all sites and general radio/mobile/telephone communications. Multiple options were investigated during the Feasibility Study including:

- Microwave radio solutions from Tantangara intake structure to the power station;
- Underwater fibre-optic cabling in Talbingo reservoir to communicate from Talbingo intake structure to existing infrastructure at Tumut 3 Power Station; and
- Fibre-optic cabling installed the hydraulic tunnels from the power station to Tantangara.

Use of microwave radio solutions was largely eliminated due to the reliability of the systems during weather events and general technology limitations. As a result, dual, redundant fibre-optic communications systems between all sites is required. However, fibre-optic cabling in hydraulic tunnels was eliminated as the risk of cable issues warranting a tunnel dewater was too great. The construction methodology of the hydraulic tunnel (which was still in development) would also impact the cable installation feasibility. Ideally, solutions where fibre-optic cabling is buried were the most advantageous as it is the best way of ensuring cable security.

For the Talbingo intake structure, dual, redundant fibre-optic systems will be achieved via the cable in Talbingo reservoir and some terrestrial fibre-optic cabling to the MAT portal. The loop would be completed via overhead optical ground wire (OPGW) from the facility to Tumut 3 Power Station via new and existing transmission lines.

For Tantangara intake structure and the headrace surge tank in the Plateau/Marica area, one path of fibre-optic cabling would be buried along the same route as the permanent electrical power cabling. This route will join Tantangara to the MAT portal via Gooandra Trail, the Snowy Mountains Highway, Marica Trail and Marica Trail West. Sections on this route not on existing access tracks would be horizontally under-bored to reduce environmental disturbance.

The other path from Tantangara to complete the loop was originally selected as follows:

- Power line easements from Tantangara to Providence Portal;
- Power line easements and access tracks from Providence Portal to Kiandra; and
- Kiandra to Cabramurra via Link Road and Kings Cross Road

Some problems with this route were identified; the sections in the power line easements had some challenging terrain constraints, and required discussions/negotiations with the third-party easement holder. An option was developed that effectively ‘bridged’ Kiandra to Tantangara via existing access tracks and Tantangara Road. This completely removed the in-easement solutions. The new route from Kiandra to Tantangara via Alpine Creek Fire Trail, Nungar Creek Fire Trail and Tantangara Road reduced the total route by about 5 kilometres. In areas where no access track existed, sections would be horizontally under-bored to reduce environmental disturbance. The link from Tantangara to Kiandra would continue to Cabramurra via Link Road and Kings Cross Road to connect into existing Snowy Hydro communication networks in Upper Tumut.

3.10 Transmission network connection

The Feasibility Study analysed different configurations and line route options for connection of the motor-generators into the National Electricity Market (NEM). One design criteria was minimisation of lines in the National Park to reduce environmental footprint whilst maintaining electrical redundancy in case of failure or maintenance (i.e. ability to still generate/pump when one or more lines are out of service). The Feasibility Study found that six lines, strung on three towers, was the optimal configuration with one motor-generator arranged on each line. This considerably reduced the size of the cable yard (where the underground power cables from the motor-generators terminate at the surface in the Ravine and transition to overhead conductors). The line route selected is one of the shortest routes out of the National Park. These lines connect into the shared transmission network at a location approximately 9 kilometres west of Lobs Hole.

Further iterations of design reduced the number of lines for connection into the shared transmission network. This reduced the environmental footprint without forsaking electrical redundancy for the facility. However, this required connecting the six motor-generators into a switching station that reduced the number of outgoing lines to four or three. To optimise the environmental footprint in the cable yard, this switching station was originally specified as an underground gas-insulated switchgear (GIS) substation, abutted against the transformer hall. During tender, concerns were raised about maintenance challenges with the switchgear underground. Complexities in addressing the SF6 gas in the underground ventilation system and the additional spoil from the cavern added further detriment to this solution. To this end, the GIS substation was moved to the surface in the original location of the cable yard. The footprint comparison of the original cable yard, where six cable systems transitioned to six overhead lines, is of similar disturbance to the GIS substation.

3.11 Construction delivery

As the Project progressed through the various phases, from Feasibility Study to the competitive tender process, the construction delivery methodology of the Project has also progressed. The key items discussed are:

- On-water transport and delivery to site;
- Segment factory location;
- Changes to construction sites and adits;
- Reduction in roads needed for construction; and
- Accommodation changes for personnel.

3.11.1 On-water transport

During the development of the Exploratory Works EIS and the ecological assessments undertaken, certain mitigations were investigated to minimise vehicle movements along Lobs Hole Ravine Road. One mitigation option considered was utilising Talbingo Reservoir for the delivery of large equipment and machinery in order to reduce the design standard of the access road required for the accommodation of the largest design vehicle accessing the site by road.

During the competitive tender process, one of the tenderers proposed to take this concept further, and deliver all personnel, equipment and plant via Talbingo Reservoir. This would allow for access directly into Lobs Hole via water therefore reducing significantly the quantity of both, light and heavy vehicles, that utilise Snowy Mountains Hwy, Link Rd and Lobs Hole Ravine Rd during the construction phase of the Project.

In both cases, and particularly for the latter, the option increased construction risks through the higher chance of poor weather restricting the use of water-based transport for materials and supplies to site, therefore increasing the storage area required within Lobs Hole to ensure sufficient contingency for uninterrupted supply. When these options were priced by the tenderers during the competitive tender process, they were found to not be economically feasible due to the large capital and mobilisation cost of all the on-water equipment required for transport.

A key benefit of not continuing with this option was that it reduced the restrictions on recreational users on Talbingo Reservoir by removing the majority of the water transport movements. The use of Miles Franklin Drive through Talbingo township was also concurrently significantly reduced.

3.11.2 Segment factory

As discussed previously, during the competitive tender process, the main construction methodology for the headrace and tailrace tunnels was changed from drill and blast construction method to the use of tunnel boring machines. The lining of the tunnels therefore changed from casting concrete in-situ to adopting pre-cast concrete segments. As such, a precast segment factory was now required for the Project.

Due to the limited space at Lobs Hole and the desire to limit the amount of clearing of non-disturbed areas of the Project, the segment factory would need to be located outside of Kosciuszko National Park. A number of options were investigated by the tenderers during the competitive tender phase, including:

- existing facilities as close to the Project site as possible;
- construction of a new facility close to the Project site; and
- overseas manufacturing of segments and sea and road transport to site.

Ultimately, local manufacture of the precast segments was selected due to the desire to provide local employment opportunities. Locating the segment factor close to a local community is considered to be an important factor as it provides an opportunity for people who have expressed interest in working on the Project to be employed who would otherwise have been unable to commit to living away from home and families and be accommodated in camps on the construction site.

3.11.3 Construction sites and adits

Rock Forest

As tunnels would be excavated by TBM and lined with concrete segments, therefore requiring greater transport of materials to and from site, it was determined that an intermediate site was required before entering KNP to allow for safe logistics and staging of transport of materials. This site was located at a private property just outside the boundary of the Park, named Rock Forest.

Initially the site was developed for logistics and accommodation, including:

- hardstand including truck parking, materials laydown, offices and facilities to allow logistics and staging of deliveries, in particular to manage traffic logistics, safety and severe weather; and
- contingency accommodation (up to 100 person camp) for workforce intensive periods or during adverse travel conditions.

Due to further development of construction delivery and the preferred option for local manufacture of segments, the scale of the site was significantly reduced by the Contractor, including removal of accommodation and materials handling at the site.

Mid-headrace adit

Throughout the Reference Design period of the Project, when the western half of the headrace tunnel was proposed to be constructed by drill and blast method, a mid-headrace access adit was proposed (shown on Figure 8). This adit provided access from the Plateau region of the Project to the headrace tunnel.

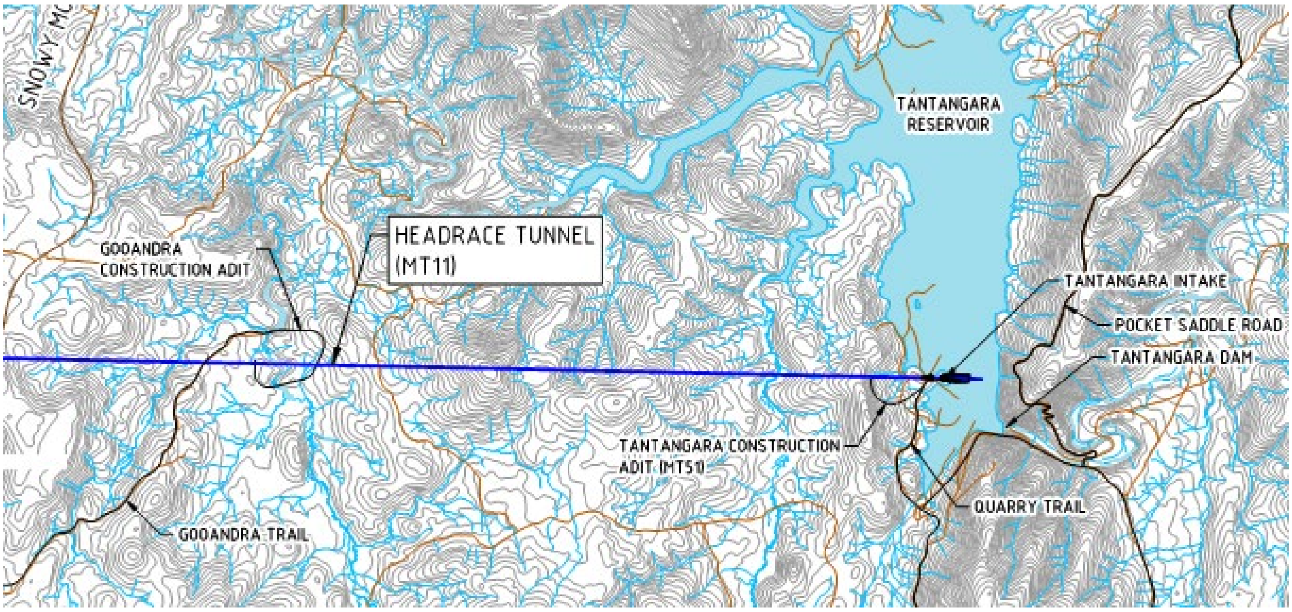


Figure 8: Reference design showing mid-headrace adit

The removal of this access adit eliminated the need for a construction road as well as tunnel portal and construction camp that would have been required in an environmentally sensitive area.

Marica adit

The Contractor’s initial tender design included an adit at Marica to aid construction of the pressure shafts. Following the change in design to an inclined pressure shaft, moving the power station location westward and shortening of the MAT and ECVT, there was no longer a need for the Marica adit. This had significant environmental, economic and schedule benefits.

Penstock guard valve access adit

The Contractor’s design provides for the guard valve for the isolation of the power station from the headrace tunnel to be located just upstream of the power station cavern rather than in a cavern immediately downstream of the headrace tunnel surge shaft. The removal of the guard valve cavern, access tunnel and portal has a significant reduction in excavation and spoil disposal volumes and a reduced surface impact.

3.11.4 Road reduction

During the design development process, the optimisation of the road design considered constructability, environmental impact and permanent operational requirements.

Marica West Road (Figure 9) links the headrace surge tank area and Marica Rd, to Lobs Hole and the MAT. Originally this road was intended to be a two-way road to provide both construction and permanent operations access between the two areas. However with an elevation difference of approximately 500 to 600 m, the road required significant earthworks and large cuts into the hillside to ensure that it had a final gradient that was suitable.

During the tender process, and after assessing the constructability of the road, it was reduced from a two-lane road to a single lane road only with the final gradient of road also increased. The road is now only required to provide the link for construction power and the communications cable from Lobs Hole to the Plateau area and across to Tantangara. This optimisation of the design has resulted in reduced surface disturbance impacts in an area of increased biodiversity value and reducing the final volume of excavated material that is required to be managed.

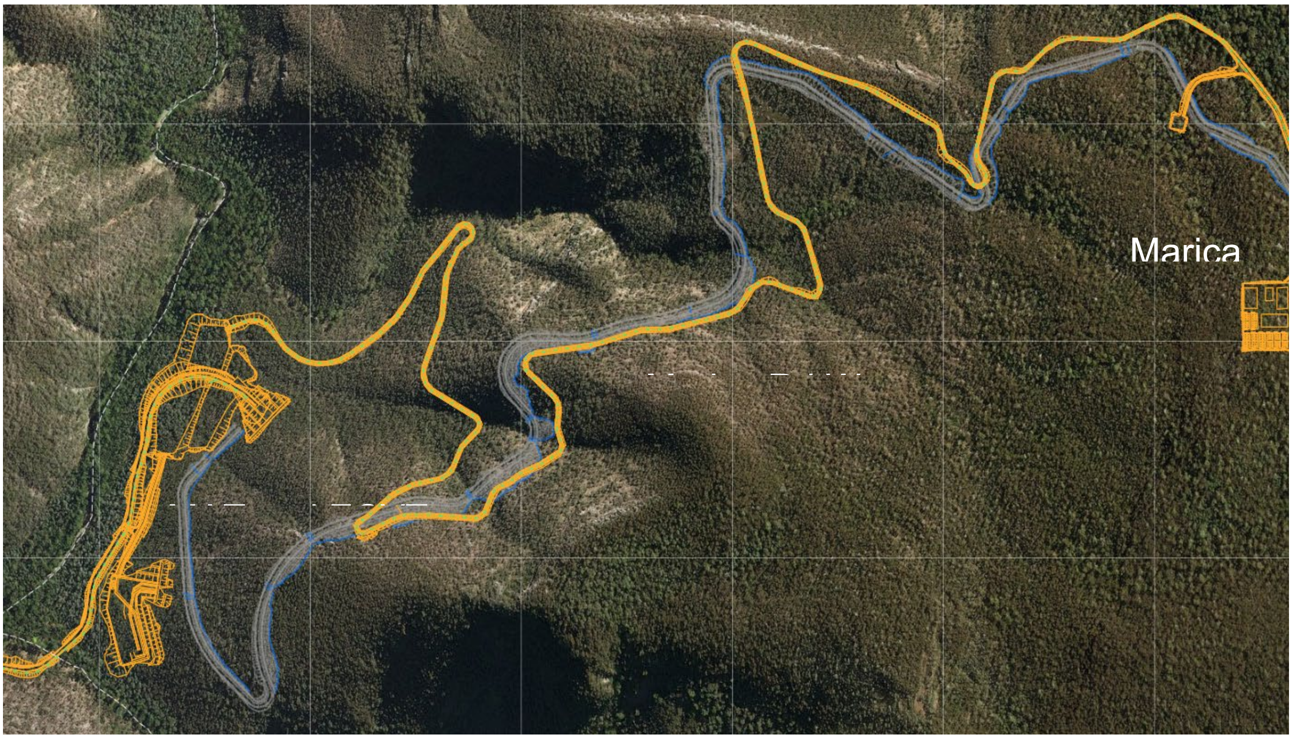


Figure 9: Change in design from Reference Design (grey/blue) to final Tender design (yellow)

3.11.5 Accommodation changes

The need for onsite accommodation is due to the remote site location of Snowy 2.0 and to minimise the impact on the surrounding community as much as possible. The reference design included two main camps, one at Lobs Hole and one at Tantangara. However, the Contractor during the tender phase identified the need for a third camp at Marica. This was to alleviate travel to and from the headrace surge shaft and vent shafts and create efficiency in the construction programme. The size of the camp was determined based on these activities.

3.12 Excavated rock management

Throughout the life of the Project, from the beginning of Feasibility Study, into the Reference Design and then into the competitive tender process, numerous options and alternatives have been investigated for the management of excavated material in the Project. These include:

- Barges with fall pipe (Reference design);
- Split-hopper barge placement (Tender design);
- Ravine Bay placement;
- Combined Ravine Bay placement and fall-pipe;
- All to land within the National Park;
- All to land out of the National Park; and
- Hybrid (combined reservoir and land).

Of these long list of options, some were discounted and others were carried forward for further assessment. In this chapter, only the options that have been discontinued and not adopted are outlined. The options that were carried forward for further assessment are discussed separately in the Main Works EIS excavated rock management options summary, attached to this document (refer Annexure A). As such, only the following are discussed:

- Split-hopper barge placement (Tender Design);
- Combined Ravine Bay and fall-pipe placement; and
- All to land out of the National Park.

3.12.1 Split-hopper barge placement (tender design)

This option was originally proposed and investigated during 2018 through the development of the Reference Design by Snowy Hydro, and then refined during the competitive tender evaluation process with input from the Contractor.

Method

Three subaqueous excavated rock placement locations, namely Cascade Bay, Plain Creek Bay, and Ravine Bay, were identified in the southern end of the Talbingo Reservoir for the excavated rock as outlined in Figure 10 below.

The key premise of the method is excavated material disposal in deep placement below the Minimum Operating Level (MOL) of the reservoir. This would be achieved through:

1. Transportation by vehicle (dump truck) from the tunnel portal to wharf infrastructure;
2. Loading of material onto large barges using on-shore conveyor systems, taking the material directly from the on-land stockpile to the barge;
3. Utilising large split-hopper barges only, instead of transport barges and disposal barges;
4. Three split-hopper barges would be utilised, rotating between the three disposal sites.
5. No deep fall-pipe placement; and
6. Silt curtains.

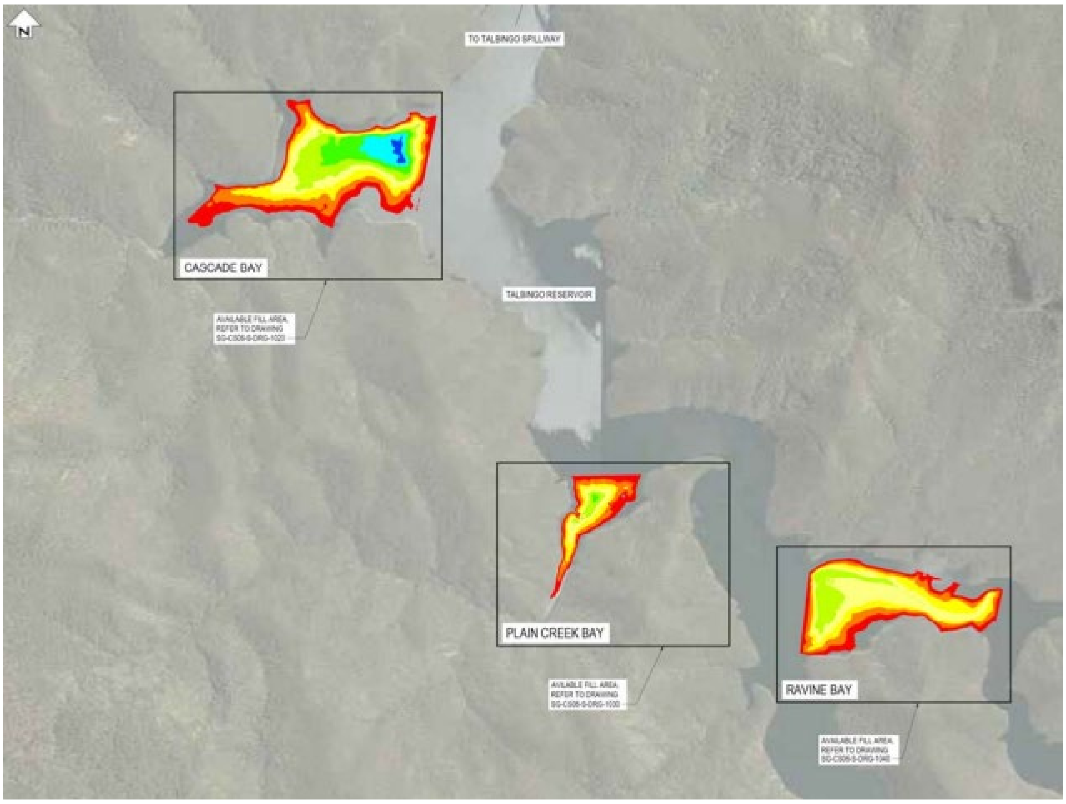


Figure 10: previous subaqueous rock placement locations in Talbingo Reservoir

Opportunities, challenges and risks

This option poses a number of key challenges and risks which as a result, make the final selection of this method unsuitable. The key challenges and risks are:

- Variability of water levels at Talbingo reservoir (fluctuates 9 m) due to the continuing Snowy Hydro operations throughout the project resulting in risk of delay to the inability to maintain a constant placement rate;
- Poor weather conditions such as high winds and foggy weather causing delays to placement rates;
- Mobilisation and movement of barges along Talbingo reservoir impacting recreational users and closure of the southern section of Talbingo Reservoir due to the movement of barges at all hours of the day for the 2.5 years of placement time;
- Slower rate of placement resulting in larger disturbance area required in Lobs Hole to temporarily store material as generation rate was greater than disposal rate;
- Large infrastructure required to be established at Talbingo spillway and in southern Talbingo to facilitate the movement of material onto the barges, as seen by Figure 11 and 12 below.

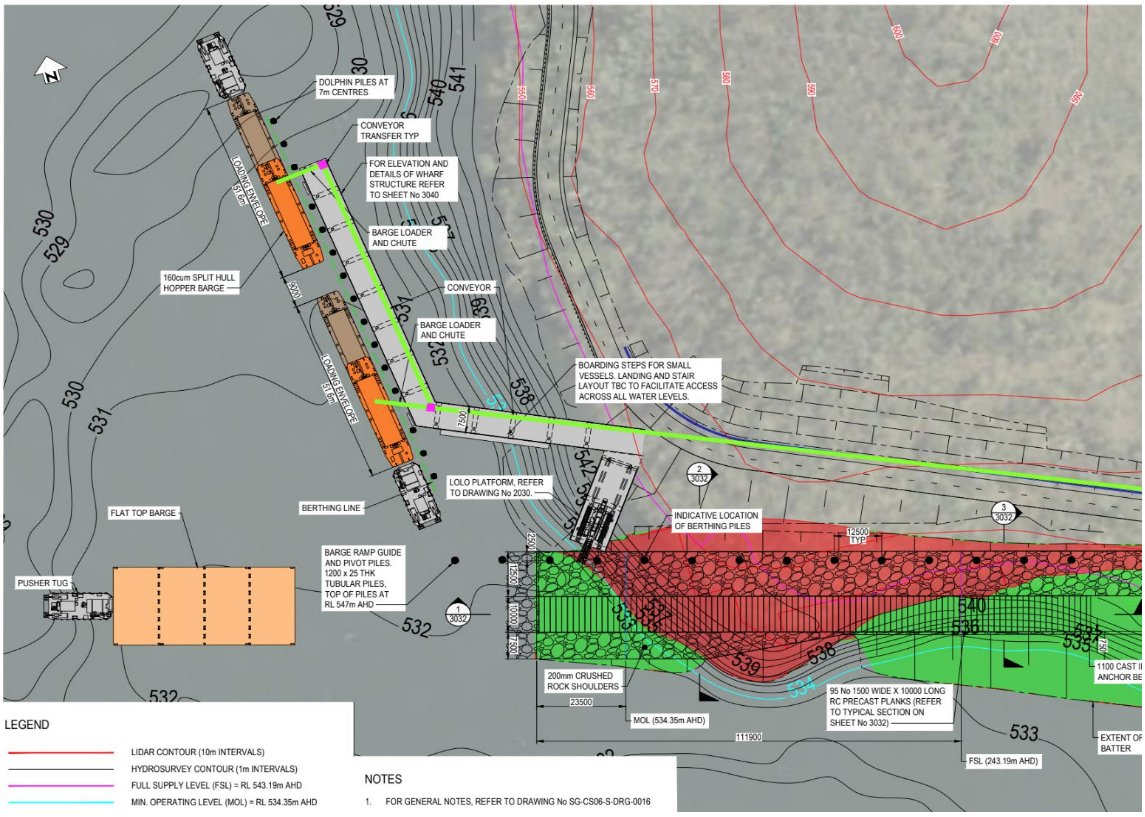


Figure 11: Infrastructure required for this method in southern Talbingo, including wharf structure, barge ramp and conveyor system

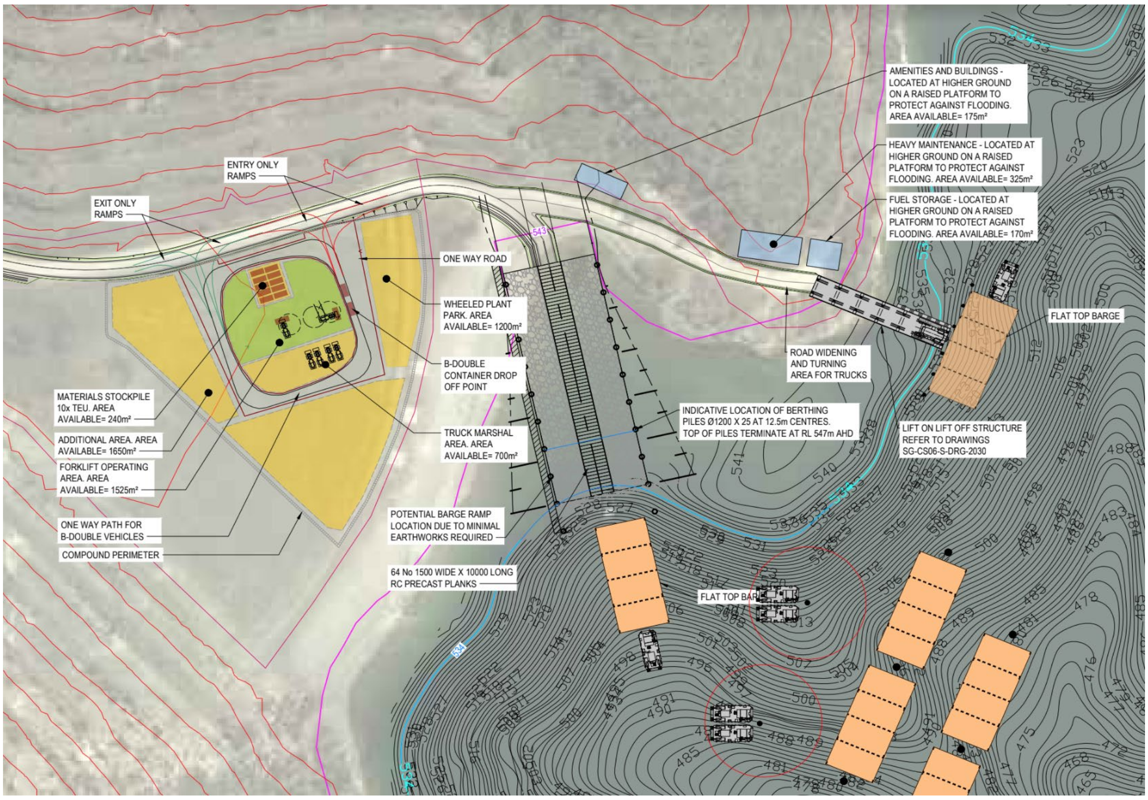


Figure 12: Required infrastructure for this method: including barge ramp, wharf structure and laydown area at Talbingo Spillway

3.12.2 Combined Ravine Bay and fall-pipe placement

The original method for sub-aqueous edge placement of the excavated rock disposal was proposed as an alternative to deep placement within the competitive tender process. During the later stages of the tender design optimisation and with the aim of investigating improvements to the water quality outcomes, a modification of the edge placement was proposed.

Method

The key fundamental difference of this method is the separation of coarse and fine material, with the placement of the coarse material as per the original sub-aqueous edge placement method, and the fine material through a static barge and fall-pipe.

The following sequence is used to achieve this methodology:

1. Construction of a new access road from Lobs Hole Ravine Road (North) to the disposal site at the confluence of the Yarrangobilly River and Tumut River arms of Talbingo Reservoir, see Figure 13;
2. Transportation of the material to a screening plant to separate aggregates >10mm for placement from the edge method and the remaining fines < 10mm will be placed through the fall-pipe;
3. Transportation by vehicle (dump truck) from the tunnel portal to the edge placement site;
4. For coarser material >10mm, the placement of material from the shoreline of Talbingo reservoir is by conventional earth-moving plant such as dump trucks and excavators on top of the fines deposit;
5. For finer material <10mm, the material is transported via a telestacker/conveyor from the shoreline to a barge located for placement using fall-pipe and placed within the placement area;
6. A nominal 1 m thick rock armor layer above MOL will be installed for the protection of spoil emplacement slope surface; and
7. A silt curtain will be established around the footprint of the proposed spoil emplacement site to manage the release of material into Talbingo reservoir.

Below is an indicative representation of the conveyor system used to transport the material to the barge for placement using a fall-pipe.

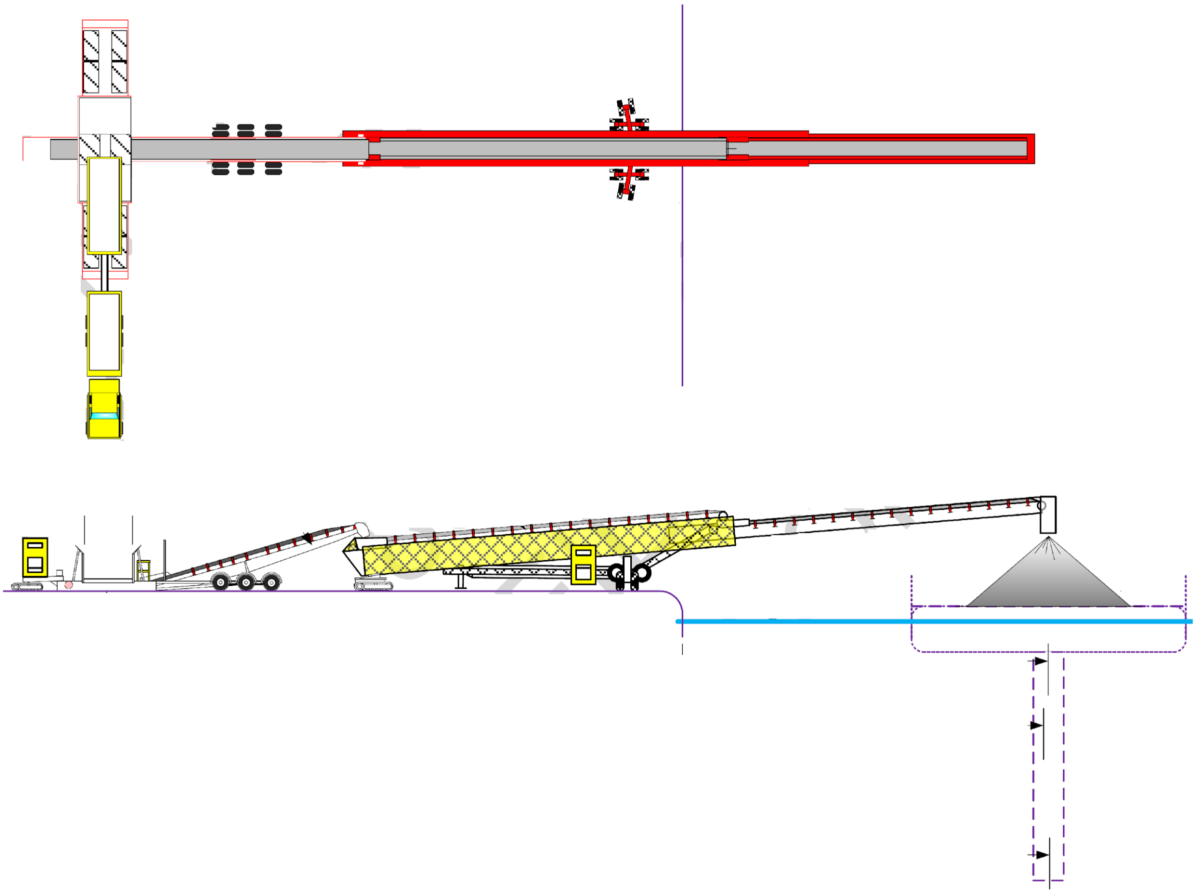


Figure 13: Indicative representation of conveyor system for placement

The final emplacement area will be established at least one metre above FSL to allow for long term rehabilitation of the area. Landforming of this final area will be undertaken to ensure natural drainage features are maintained and that it ties until the existing natural landform.

Opportunities, challenges and risks

This method presents many improvements compared to the split-hopper barge placement method. These are:

- Removal of the majority of barge infrastructure from Talbingo Reservoir (a barge or similar vessel will be required for placement of the silt curtain);
- Improved water quality outcomes compared with Ravine Bay Placement;
- Southern section of Talbingo no longer requires closing to recreational users as emplacement area isolated to the Yarrangobilly River arm; and
- Compaction of emplacement area material when above the water level to achieve greater placement volume within the equivalent footprint.

However, there are key challenges and risks with this method that have resulted in the method not being selected and carried forward. These are:

- Additional requirement of the conveyor and barge with fall-pipe for disposal of the finer material, compared with the original sub-aqueous edge placement method;
- Additional space required on-land for material separation plant and temporary storage of material; and

- Decreased economics of this option compared to the original edge placement method through primarily the additional equipment required of conveyors, barges and separation plant.

3.12.3 All to land out of the Kosciuszko National Park

Several excavated rock disposal methods for on-land disposal were considered throughout the design and construction development process. Originally on-land disposal within the National Park was not considered viable due to the concerns by NPWS over permanent excavated rock disposal sites on-land. This has recently been reconsidered, particularly as it removes all reservoir water quality risks. Disposal of material outside of the National Park was also considered throughout the process. Primarily this has been investigated at the Tantangara end due to original challenges of deep placement method in Tantangara Reservoir, and the increased material transport distance from the Talbingo end of the scheme making this option less-viable. However, both Tantangara and Talbingo out of the National Park excavated rock disposal methods have been investigated.

Method

For the Tantangara end, the option of transporting the excavated material to a site just outside of the National Park to the east was investigated. In order to facilitate this, a significant upgrade of an existing fire trail would be required from east of the Tantangara Dam wall to the selected site, approximately 14 km.

For the Talbingo end, the option of transporting the material to a site outside of the National Park towards Adaminaby was investigated. This site was preferred to areas West and North of the National Park due to the fact it utilises the main transport route to site and avoids the challenging and steep roads of the Elliot Way heading West from the site and Talbingo Mountain to the north on the Snowy Mountains Hwy.

Opportunities, challenges and risks

The key issue with transporting excavated material out of the National Park is the transport required. For the Talbingo end of the Project as an example, to transport the entire 2.8 million m^3 of material, and with a bulking factor on the material applied, approximately 210 truck and dog transport movements one way would be required a day for the duration of the two and half year placement period. With the existing traffic movements on the roads within KNP, it was deemed to be unfeasible to more than double these movements each day. For the Tantangara end, the large distance of upgraded road required and the visual and physical impacts that this would have on the ecological surroundings of the area were also a factor in why the disposal method was disregarded.

4 Design integration and assessment approach

As evident by the previous sections, there are several complexities requiring consideration in the design of Snowy 2.0 Main Works. A key consideration is the possible environmental impacts that may occur as a consequence of design, such as clearing required for the construction footprint. As such, an iterative and risk-based design and assessment process was adopted in identifying and assessing potential environmental impacts (the DIAA process, as shown in Figure 14). This process was undertaken to assist in assessment of options and development of design and construction methods that avoided or minimised environmental impacts where possible, and allowing for engagement with key stakeholders throughout the process.

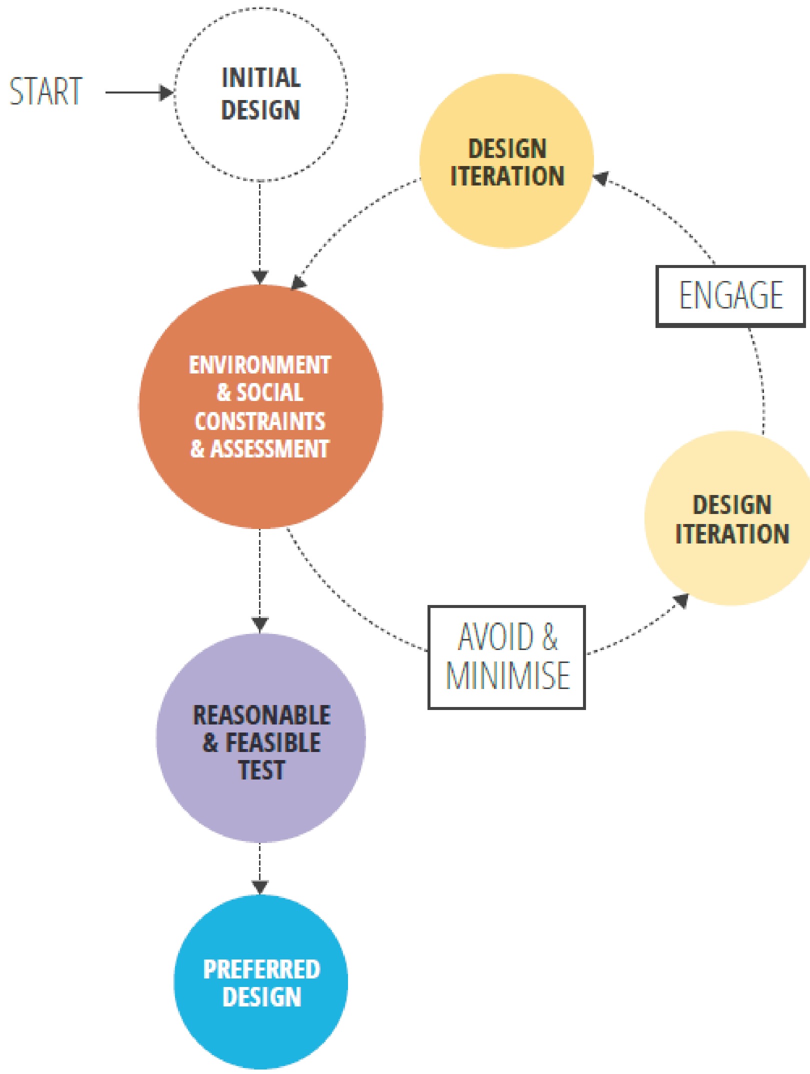


Figure 14: Design integration and assessment approach (DIAA) process

Implementation of the DIAA process to optimise the design resulted in some significant environmental improvements and outcomes. Primary design improvements with regard to the design information presented in Section 3 include:

- Discounting construction of a power station, and associated access adits, beneath the Plateau rather than Marica. This avoided significant impacts to threatened ecological communities, such as Alpine bogs and fens, and species, such as Alpine she-oak skink.
- Significant reduction in the disturbance footprint for the Marica West track down to Lobs Hole. There were further design improvements in this area through the removal of a construction adit and associated construction area to facilitate these excavations. Together, these improvements have avoided significant impacts to the critically endangered Smoky Mouse.
- Reduction in overall excavated materials due to revised tunnelling layouts and alignments, including removal of adits and relocation of the power station further west minimising the currently approved exploratory tunnel (which would be the MAT if Snowy 2.0 Main Works is approved). This reduced the volumes of materials to be handled and placed within the reservoirs.
- Removal of some construction areas and requirements from the footprint within KNP by choosing to construct a segment factory at Polo Flat in Cooma (subject to a separate application) which significantly reduced traffic volumes for the construction materials for these segments within KNP, and reduced the amount of land required to be cleared in the park by about 32 ha.
- Establish a logistics yard at Rock Forest, just outside the KNP (rather than within the project area), to store materials and manage traffic when required such as during adverse conditions. This improves Snowy Hydro’s ability to manage impacts to the road network and improves road user safety during adverse conditions.
- Reuse 1,000,000 m^3 of materials to landform and rehabilitate areas at Lobs Hole disturbed from construction, reducing the footprint volumes and timeframe of the Ravine Bay placement which reduces potential water quality impacts to Talbingo Reservoir.
- Reduction in barge infrastructure resulting in avoidance of areas being disturbed and longer term potential for disruption to the Talbingo community.
- Removal of an option to construct a road east of Tantangara Reservoir to a nearby private property, just outside KNP, to place excavated rock materials rather than in the reservoir. This avoided significant impacts to the critically endangered flora, Clover glycine.
- Reduction in excavated rock emplacement footprint within the reservoirs to focus on a single location within Talbingo Reservoir and within active (and dry during construction) storage at Tantangara Reservoir. This avoids direct impacts to previously proposed emplacement areas.
- Maintenance of the 50 m buffer around the Yarrangobilly River to protect its values and habitat to the endangered Booroolong frog.
- Reduction of access road works by some 20 km which avoids further environmental impacts through disturbance activities.
- Removal of the need to augment the existing Essential Energy transmission line for power for power to infrastructure at Tantangara Reservoir. This avoids further environmental impacts through disturbance activities.
- Avoidance of the Ravine cemetery within Lobs Hole which preserves the heritage values of this location.

5 Conclusion

Since the Feasibility Study was announced in March 2017, Snowy Hydro has undertaken a significant amount of due-diligence and optimisation of the design from all perspectives: engineering feasibility, construction feasibility, environmental impacts and economic outcomes.

Working from the original studies undertaken by Snowy Hydro in the past, the alignment of the power waterway (headrace and tailrace) and power station location has been optimised, with the proposed solution balancing out the engineering, construction and environmental outcomes. The tunnel alignment provides the best possible route between Tantangara and Talbingo as it avoids more challenging geology and terrain while maintaining the best hydraulic outcomes for the project.

The power station location, being located as far west as possible whilst still meeting the hydraulic requirements, has reduced the access tunnel lengths and ensured that is constructed in improved geological conditions compared to the original location. The geological investigation program that has been on-going since the Feasibility Study has confirmed this.

The final intake location and construction methodology has ensured that environmental impacts are minimised. All on-land construction of the intakes without the need for coffer dams has meant water controls are limited to only the final rock plug removal. The design of the intakes themselves have been optimised to reduce their final size, therefore reducing the visual impact.

Moving away from D&B construction methodology of the power waterway to TBM construction ensured that the mid-headrace construction adit, located in an environmentally sensitive area was no longer required. The TBM construction is able to manage the geotechnical risks in a more controlled manner and improves the safety of the workers involved when compared with D&B methodologies.

The decision to move to the single inclined pressure shaft has removed the need for an adit from Marica, as well as the significant underground guard valve chamber on top of the previous three vertical pressure shafts. These optimisations have reduced the amount of work required in the Marica area of the project, an area with environmental sensitivities and limited existing disturbance compared with Lobs Hole.

From a construction delivery point of view, there have been a number of optimisations and changes that have improved the way the project will be constructed. The move away from on-water access to site has effectively removed impacts to recreational users on Talbingo Reservoir. The optimisation of construction power from three individual supplied areas to only one area, and combining with the communications cable alignment, has reduced the amount of construction required and overall disturbance footprint.

Overall, a significant amount of design and construction optimisation of the Snowy 2.0 project has occurred since the commencement of the project. Snowy Hydro has always operated in an environmentally sensitive National Park and is therefore attuned to ensuring the design and final construction is optimised to deliver a project that enhances the energy market of Australia, whilst ensuring environmental impacts are minimised as much as possible.

Reference should be made to the Snowy 2.0 Main Works design, presented in Chapter 2 of the EIS Main Report for a summary of the final design carried forward for approval.

Annexure A – Main Works excavated rock management options summary

1 Executive Summary

This document provides an overview of the development of Snowy 2.0 excavated rock emplacement methodologies over the course of the Project and sets out the process in which the final preferred solution was ultimately selected.

Throughout the life of the Project, numerous options and alternatives have been investigated with respect to the management of excavated material for the Project. This included during the Feasibility Study, the Reference Design and development of Exploratory Works, and continued throughout the competitive tender process into the final Tender Design period. Consultation with key stakeholders and agencies has continued throughout this entire time period, and in particular has been a key focus area in the development of this Main Works EIS.

Throughout the development of the Project, the design has been optimised, resulting in a reduction in the total amount of excavated material generated. At the finalisation of the Reference and Tender Design stages, the volume generated was estimated to be approximately 10,210,000 banked cubic metres (bm^3), however following the optimisation of the design, this volume was reduced by 35% to 6,630,000 bm^3. Placement locations are determined based on the location the excavated rock is extracted along the Snowy 2.0 development. As a result, excavated materials will managed across three sites with the split being 2,830,000 bm^3, 2,800,000 bm^3 and 1,000,000 bm^3 for Talbingo, Tantangara and Lobs Hole respectively. The reduction in volume of material as a result of this design optimisation will significantly reduce environmental impacts and provides favourable outcomes for the Project.

Following an optimisation in the overall construction methodology, the final design submitted by the Contractor provides for, 1,000,000 m^3 of excavated material to be used in the construction pads within Lobs Hole. The key benefit of this is that material is not required to be imported to-site and allows for additional space to become available in Lobs Hole by creating level construction pads without needing to increase the disturbance footprint. This methodology is proposed because investigations have indicated that this fine material will not be suitable for reservoir placement. This new land formed area will open up new and exciting recreational opportunities that tie into the existing features that the Lobs Hole area offers.

The preference for the Project is to place all of the excavated material on-land and permanently landform and rehabilitate. However, based on the landowner's stated position of no excavated rock to be placed permanently on-land, the preferred method for the placement of the remaining excavated rock is edge placement from the shoreline of Talbingo and Tantangara reservoirs.

For the Talbingo end of the Project, the second preference is the hybrid option (drill and blast (D&B) material to be placed in reservoirs and tunnel boring machine (TBM) material to be placed on land) as it achieves goals of improved water quality, reduced quantity to land and reasonable constructability, however at a more expensive cost to the Project. The hybrid option achieves a balanced ecological and recreational outcome on completion of the Project.

The deep placement option, the original Reference Design option described as barges with fall pipe, has been assessed as being unsuitable nor practical for the Project at both Talbingo and Tantangara due to a combination of logistics challenges, increased infrastructure requirements (which has its own environmental impact), increased water quality risk and project construction risks.

For each of the final selected alternatives presented, the construction methodology, environmental outcomes, and opportunities and risks are discussed in order to demonstrate how the Project team, in consultation with the various agencies and key stakeholders along with the Contractor, determined the preferred solution.

The following options are presented, in order of preference, for Talbingo Reservoir:

1. Ravine Bay Placement - edge placement from the shoreline of Talbingo, from the reservoir bed to above full supply level of the reservoir, and rehabilitation of the land mass.
2. Hybrid option - combined reservoir and land, with drill & blast (D&B) material as per the Ravine Bay edge placement option, and the Tunnel Boring Machine (TBM) material on-land with landforming and rehabilitation.
3. All to Land - all material to-land within the Project boundary, landforming and rehabilitation.
4. Barges with fall pipe (Reference Design) - original deep placement method in Cascade Bay for the Project.

For Tantangara Reservoir, there is only one solution presented and that is edge placement from the shoreline of Tantangara.

Table of Contents

2 General Considerations

The following section provides an outline of the general principles that were key in the development of each excavated rock emplacement option, along with the final selection of the recommended excavated material emplacement location and methodology. The general principles can be broken down into two key areas; environmental assessment and engineering.

2.1 Environmental

Environmentally, there are a number of drivers that influence the development of each method for emplacement, and in-turn help direct the final selected option. These drivers can generally be broken up into two areas based on methodology: water placement and on-land placement.

Water placement

For placement methodologies investigated that are located within or near the reservoirs, the management of fines (being typically particles <63 μm) is the key to reducing impacts on water quality and aquatic ecology. Larger particles, e.g. sand sized and greater, are generally not an issue for turbidity and for ecology (except in direct placement area by potential smothering of habitat, of which impacts can be reduced by keeping the footprint relatively small). As such, the method development is focused on minimising the impact of fines materials, either through adjustments to the methodology and placement technique, refinements throughout detailed design, or through additional controls put in-place such as silt curtains.

On-land placement

Environmental controls for on-land placement are generally more straightforward to manage as they are an extension to construction work already occurring on-land such as development of site compounds and pads, portals and road upgrades. The controls therefore need to ensure seepage from the emplacement site, washing away from excessive rainfall and settlement of material overtime are managed.

The most important element of on-land placement environmentally however, is how the site will be rehabilitated and returned to National Parks and Wildlife Service (NPWS) as landowner. Significant design work, landforming and rehabilitation will be undertaken to ensure the shape of the placement site is designed to be amenable to users of the Kosciuszko National Park (KNP) post construction, and that it links back to the natural surrounding environment through sufficient quantities and appropriate selection of native flora.

2.2 Engineering

The engineering element of each option consists of a number of different components, each of which present feasible or not feasible gates. The main engineering elements include: capacity, methodology, schedule and operations. Each of these elements drives the emplacement method and is key to determining whether it is feasible or not.

Capacity

Adequate capacity and space to store the entire quantity of excavated material is required. Simply put, if there is not enough space in each placement location to hold the bulked volume of material required, then that site it is not feasible. Placement locations are determined based on the location the excavated rock is extracted along the Snowy 2.0 development, i.e. the Talbingo and Tantangara ends of the scheme. However, if multiple placement locations are selected at each end of the development, the environmental disturbance footprints extend over a larger area and mobilisation works increase for the Contractor as additional personnel, plant and machinery are required. Effort has therefore been made to find placement sites that maximise the storage volume of the final placement locations to minimise multiple smaller locations and additional transport impacts.

Re-use of material

Significant effort has been made to re-use as much of the material as possible for the construction of temporary and permanent portals, pads and access roads. This reuse results in a reduction in the volume of material required to be managed at the final placement site. Geochemical assessment has been undertaken on samples of the material from the Geotechnical Investigation Program (GIP), that has been on-going since mid-2017, to determine suitability for re-use as aggregates for concrete and base material for roads. A methodology for progressively sampling material to ensure that it is placed and or treated appropriately prior to placement has been developed and was approved for Exploratory Works. The same methodology is proposed for Main Works.

Methodology

There are a number of drivers that determine the feasibility of each method. Primarily, these are based on improving efficiency to ensure the schedule for the project is maintained and that there is no risk of delay.

The first of these drivers is to minimise the distance between the source of material (tunnel portals) and the final material placement location. This improves the rate of placement, reduces environmental impacts and reduces the transport requirements by requiring less plant to maintain the placement rate and reduces the number of interfaces with this plant and other elements of construction.

Secondly, maximising the efficiency of the material handling is equally important. Double handling of material increases the time to dispose of material, requires larger on-land temporary storage areas and therefore increases by the impact area and the cost of emplacement. The volume of fine material is also increased the more the material is handled and transported from one placement area to another.

Finally, the method itself needs to be able to maintain a rate of placement that is in-line with the extraction rates of material exiting the tunnels. It needs to be a method that is focused on mass production and the highest efficiency, in order to minimise temporary material storage sites and reduce delay risk to construction. The construction schedule needs to be maintained to ensure key Project milestones are completed on-time, with the ultimate aim of achieving first power out of Snowy 2.0 by late 2024 or early 2025 to help firm the increasing loads of intermittent renewable energy and underpin the decarbonisation of the National Electricity Market (NEM).

Operations

The Construction timeframe is relatively short compared to the overall operational timeframe of the Project. The placement method if within the reservoirs is required to be located, designed and constructed to minimise the risk of material transportation in perpetuity to ensure applicable water quality objectives are achieved. The placement location therefore is best to be located outside of the main course of water movement in reservoirs, as well as not directly in-line with the intakes. The method of placement of excavated material can also reduce the chance of remobilisation of fines by protecting the placement area with coarser rock.

3 Development of alternatives

The challenge of excavated material placement has been on-going since the beginning of the Snowy 2.0 Project in early 2017. The focus in development over the course of the Project through the Feasibility Study, Reference Design and competitive Tender Design stages of the Project has been around:

- reducing the volume of excavated material through optimisation of the design;
- construction optimisations and smarts through engaging an experienced Civil Contractor;
- maximising reuse opportunities (re-use of materials in road construction/upgrades, pads and gabions, maximising cut and fill balances through design, etc);
- environmental investigations on-site;

- engineering and scientific modelling of proposed solutions; and
- engagement with key stakeholders and agencies.

3.1 Optimisation of the design

Significant optimisation of the engineering design of the Project has been undertaken to ensure impacts are minimised and balances to ensure the most cost-effective and successful outcome for Snowy Hydro.

The following is a list of engineering developments and optimisations that has reduced the quantity of material to be disposed:

- movement of the power station 1.5 km further West, towards Lobs Hole, into more component rock, reducing the access tunnels length;
- changing from three vertical pressure shafts to one single inclined pressure tunnel;
- reduction in headrace and tunnel diameter due to the relaxation of head loss hydraulic requirements;
- extension of the headrace tunnel boring machine drive;
- removal of some construction adits around the power station cavern during construction;
- reduction of road width and volumes, for example reduction in size of Marica West Trail from two-way road to a single-lane construction road; and
- re-use of additional material, approximately 1,000,000 m^3 for construction camps and pads on-land and rehabilitate and retain permanently.

Table 3.1 demonstrates the reduction in volumes of material in bm^3 requiring placement throughout the development of the Project:

Table 3.1: Volumes of material proposed for placement during Project development

Area	November 2018	February 2019	April 2019
Talbingo	6,480,000 bm^3	3,550,000 bm^3	2,830,000 bm^3
Tantangara	2,370,000 bm^3	2,160,000 bm^3	2,800,000 bm^3
Construction pads Lobs Hole	1,000,000 bm^3	1,000,000 bm^3	1,000,000 bm^3
Totals	10,210,000 bm^3	6,710,000 bm^3	6,630,000 bm^3

For permanent pads, such as those required at the main access tunnel (MAT) and emergency egress, cable and ventilation tunnel (ECVT) tunnel portals and cabelyard, the volume of this material is not included in the above table.

4 Lobs Hole and Recreational Planning

For the four methods discussed herein, there is one commonality: landforming and permanent rehabilitation of the construction pads in Lobs Hole. In order for the Contractor to undertake the work to construct Snowy 2.0, they require sufficient space for a construction camp. This camp supplies and supports all aspects of the Project including: batching plants and laboratory, electrical and mechanical laydown areas, offices, fuel stations, workshops, explosive storages areas, steel yard and mechanical workshop. It is therefore a key component of the Project.

Approximately 1,000,000 m^3 of material is required to be used to develop level pads for all these facilities. It is the recommendation of the Project that this material remain in-place and be land formed and rehabilitated at the completion of the works for a number of key reasons discussed below:

- The material is the first material to be excavated on-site and as a result it is predominantly overburden material, such as from road and tunnel portal excavations. It is therefore material that is heavily weathered, clay rich (high quantity of fines) and high in iron oxide content. **Table 4.1** outlines the estimated particle size grading from geotechnical investigations undertaken on-site adjacent to the MAT tunnel portal.

Table 4.1: Particle size grading for material comprising the construction pads in Lobs Hole

Material	% total fines (< 63µm)	% clay (< 4µm)
Overburden	53	36
TBM	6	0.7
D&B	2	0.3

- Because of the high fines content and composition of this material, it is unsuitable to be placed within the reservoir as it would not settle easily, and likely cause higher surface turbidity for an extended period of time.
- Furthermore, if the material was to be placed in the reservoir through either the edge or deep placement method, there would be a delay of four years before this final placement could be undertaken. Placement of the material would not be able to commence until the Project is in the final commissioning and handover stages. The facilities that make use of the construction pads are necessary components of the Project and can not be decommissioned and demobilised until the electrical and mechanical fitout and commissioning of the power station has been completed. The scheduled time frame between final placement and decommissioning results in a period of approximately four years before the site area can be permanently rehabilitated.
- Finally, because of the 4- year timeframe between final placement of material and the final commissioning phase, it is anticipated that the new power station would be generating power at all capacities to ensure everything is working as designed. Higher flows through the Yarrangobilly River arm and subsequently Talbingo Reservoir would likely be present, going from natural inflows only to a peak of over 360 m^3/s exiting and entering the Talbingo intake. Placing material as per the water placement methods discussed during this period would result in significantly impact water quality.

The Project will therefore seek to retain these construction pads, and rehabilitate with permanent landforming and the development of key recreational areas in consultation with NPWS at the completion of the Project.

4.1 Landforming

As discussed, the Lobs Hole construction camp is key to the successful delivery of the Project. Below is an image that outlines an indicative layout of the construction camp.

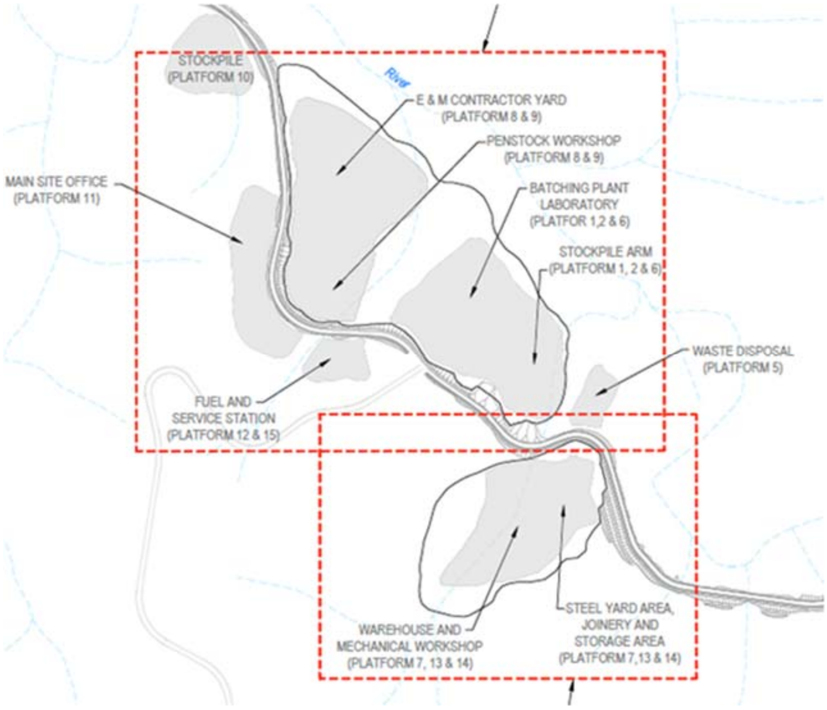


Figure 4.1: Indicative layout of the construction camp

On commencement of the demobilisation of the construction camp, the area will be transformed into a more natural final landform that will then be rehabilitated and revegetated. Below in **Figure 4.2** is an indicative design of how the final landforming of the site will appear. Flat areas have generally been retained along with natural drainage areas and the additional material has been sloped into the existing landform within Lobs Hole. **Figures 4.3** to **4.5** demonstrate how the land formed shape of the construction pads ties into the existing landmass within Lobs Hole.

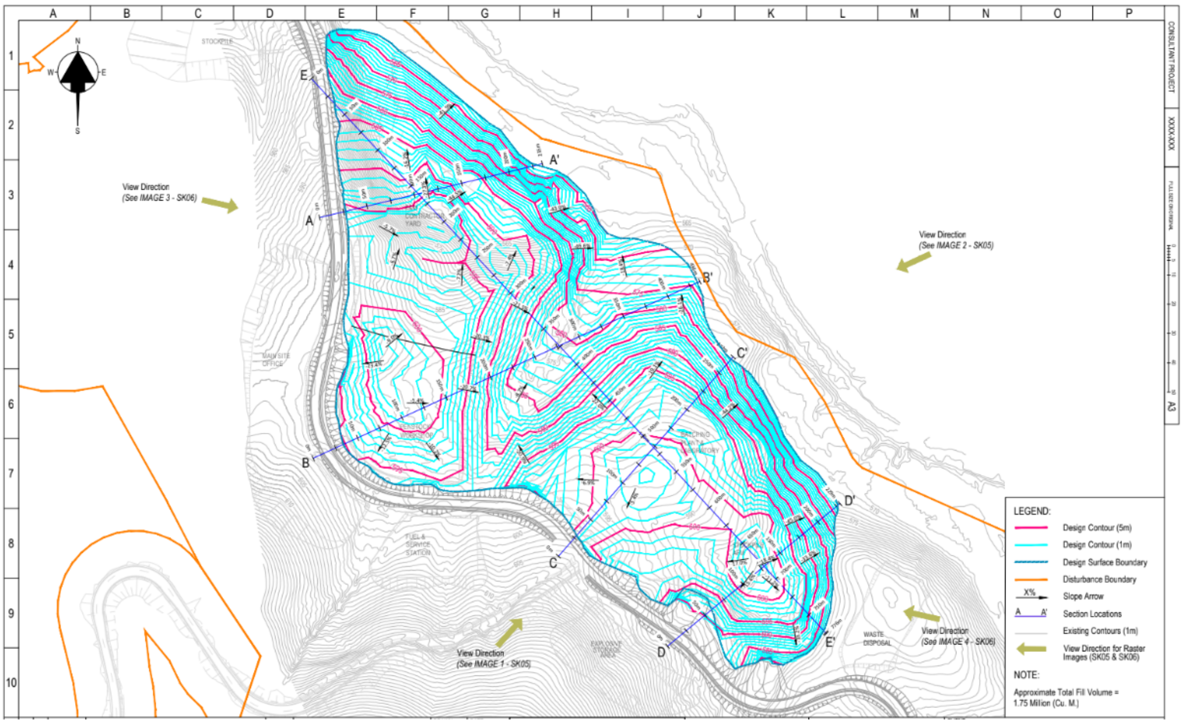


Figure 4.2: Outlining a general arrangement of the landforming of the construction pad site

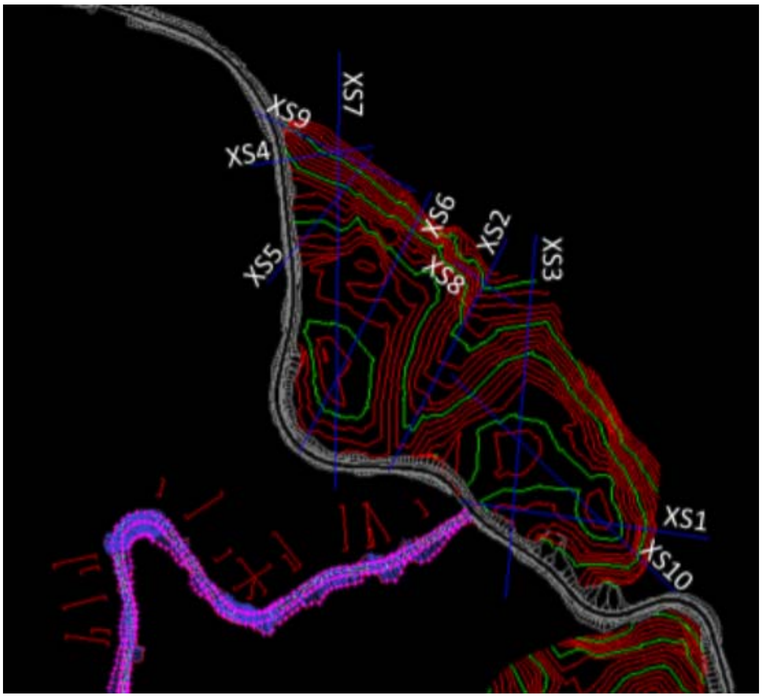
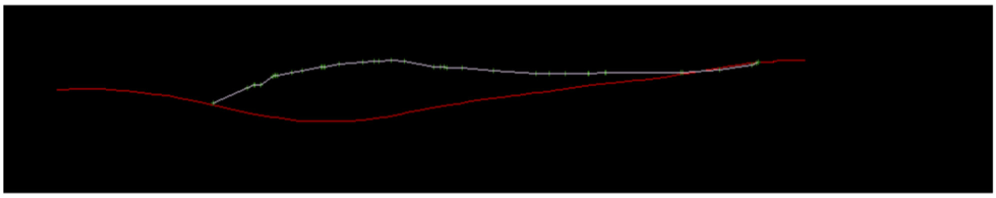


Figure 4.3: The engineering design of the land formed area

XS1



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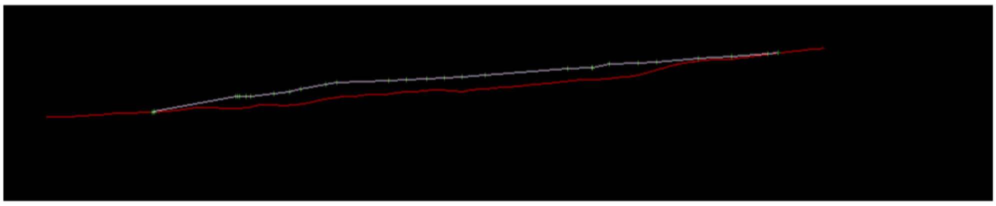

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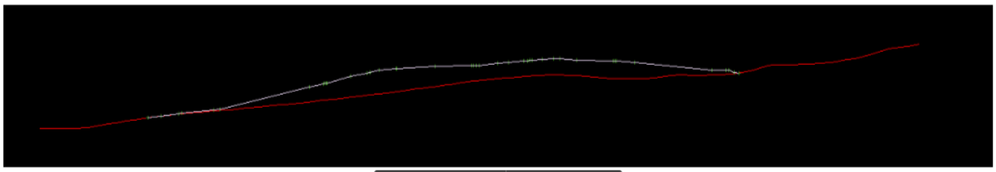

Figure 4.4: Multiple cross sections from the engineered landform design to show the existing (red) and the final landform level (white)

Figure 4.5: The above is an example of a similar cross section from the site with visuals added

4.2 Visuals

Figures 4.6 to **4.8** have been developed to illustrate the final rehabilitated landform of the emplacement area within Lobs Hole. The rehabilitation is illustrative of five years post completion of the Project. The key additional focus area for this landforming is what additional recreational opportunities would be available at the end of the Project.

Figure 4.6: Impression of Lobs Hole rehabilitated (5 years) with the Yarrangobilly River and multiple campsites

Figure 4.7: Lobs Hole rehabilitated (5 years) with an indicative image of one of the campsites on a high point of the land formed site.

Figure 4.8: Lobs Hole rehabilitated (5 years) with the campground at the lower end of the land formed site adjacent to the Yarrangobilly River.

4.3 Recreational Planning

4.3.1 Description

A key part of the landforming and rehabilitation strategy for the Lobs Hole construction pad site is around opening up new recreational opportunities within KNP. There are a number of key recreational opportunities to improve the current recreational experience which have been identified:

- Natural values and views (including waterways, waterfalls and mountainous view points);
- Existing recreational opportunities (including swimming holes and on-water activities);
- Access roads suitable for uplift opportunities (shuttle bus + trailer); and
- Great location for camping adjacent to Yarrangobilly River.

4.3.2 Plan Concept

Figure 4.9 is a plan concept of recreational opportunities that could be made available at the completion of the Project, utilising the on-land placement areas to create new recreational camping areas, lookouts and walking and/or biking trails, whilst opening up the existing features of the area

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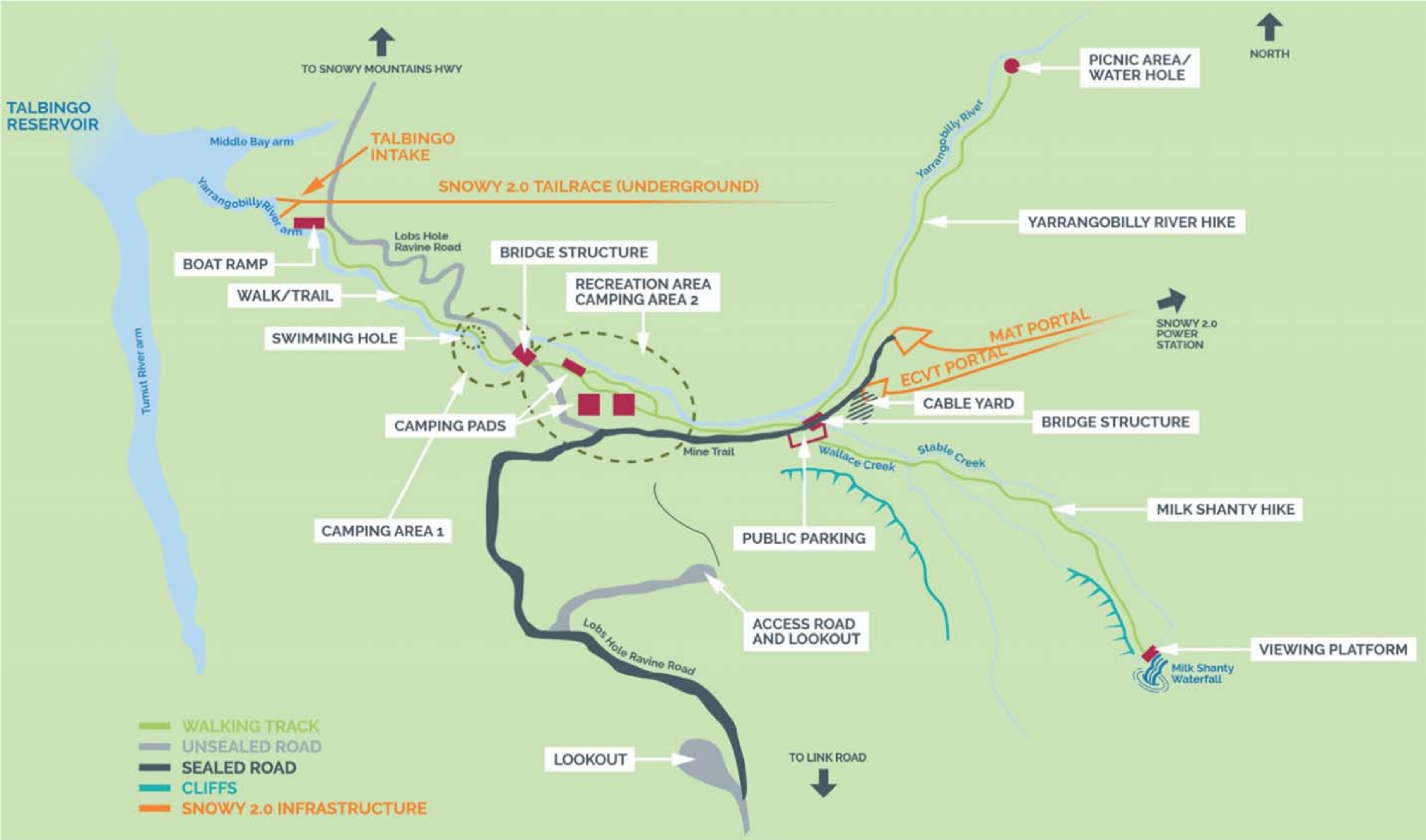


Figure 4.9: Concept recreational plan for Lobs Hole

4.3.3 Site Photos

Figures 10 and **11** are site photos taken to demonstrate the existing natural features that would be enhanced by the addition of new camping areas, hiking trails and bike paths within the Lobs Hole area.

Figure 4.10: Yarrangobilly River and Lobs Hole, along with the Yarrangobilly River swimming hole

Figure 4.11: Yarrangobilly River Swimming Hole and Stable Creek Waterfall

5 Tantangara Placement Method

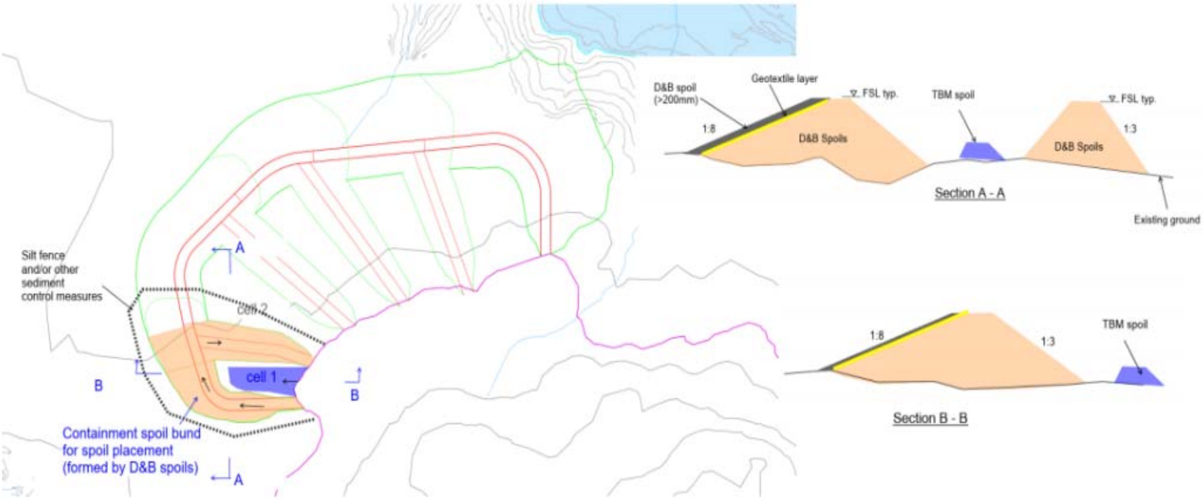
For Tantangara Reservoir, the placement into the reservoir from the edge is presented, along with justification as to why deep placement within the reservoir is not feasible. The edge placement is the preferred option for Snowy Hydro based on the landowner’s stated position of no excavated rock on-land and reasonable constructability.

5.1 Method

Placement of excavated material in Tantangara involves staged material placement predominantly within the active storage area of Tantangara Reservoir by conventional earth-moving plant, such as dump trucks and excavators. The final landform will be raised to at least 1 m above full supply level (FSL) to allow for the introduction of recreational facilities and rehabilitated areas that are to be agreed upon in further consultation with NPWS and other key stakeholders.

Placement of excavated material in Tantangara will be carried out in stages from the boundary of FSL towards the minimum operating level (MOL) area of the reservoir. To minimise the disturbed areas and unprotected excavated rock emplacement slope surface, staged containment excavated rock cells are proposed. The indicative construction staging is shown in **Figures 5.1** and **5.2**. Preliminary design drawings of the finished footprint and section of the excavated rock emplacement are shown **Figures 5.1** and **5.3**.

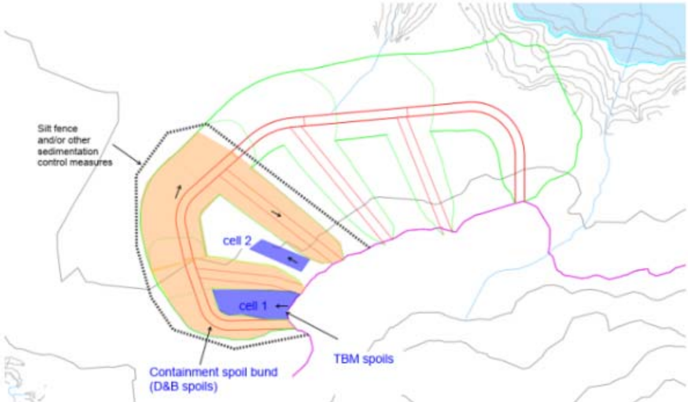
Stage 1: Install silt fence and/or other sediment control measures for construction of containment bund



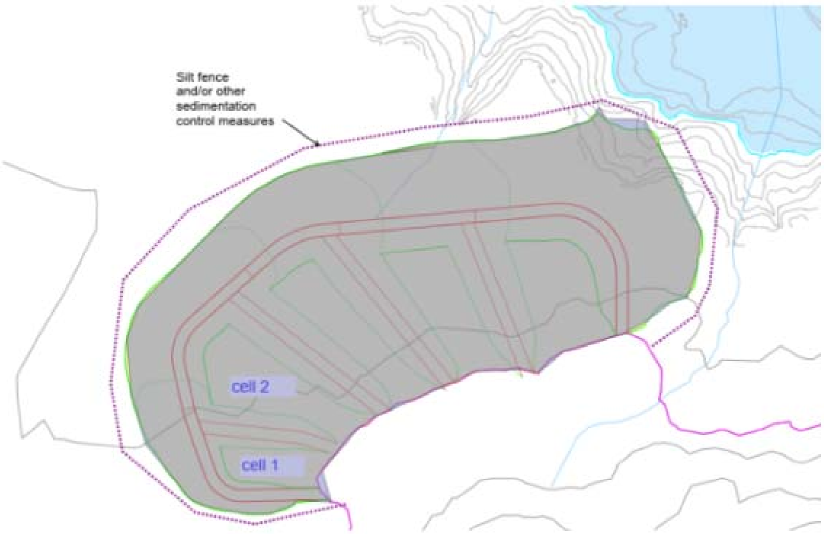
Stage 2: Push spoil from FSL boundary into active storage areas to construct cell 1 storage cell containment bund, and at the same time fill cell 1

Figure 5.1: Indicative construction staging

Stage 3: Continue pushing spoil into cell1, and install silt fence for construction of cell 2 spoil bund



Stage 4: Continue pushing spoil to fill cell 1;
construct cell 2 spoil containment bund for placement



Stage 5: Repeat the same construction staging until completion

Figure 5.2: Indicative construction staging

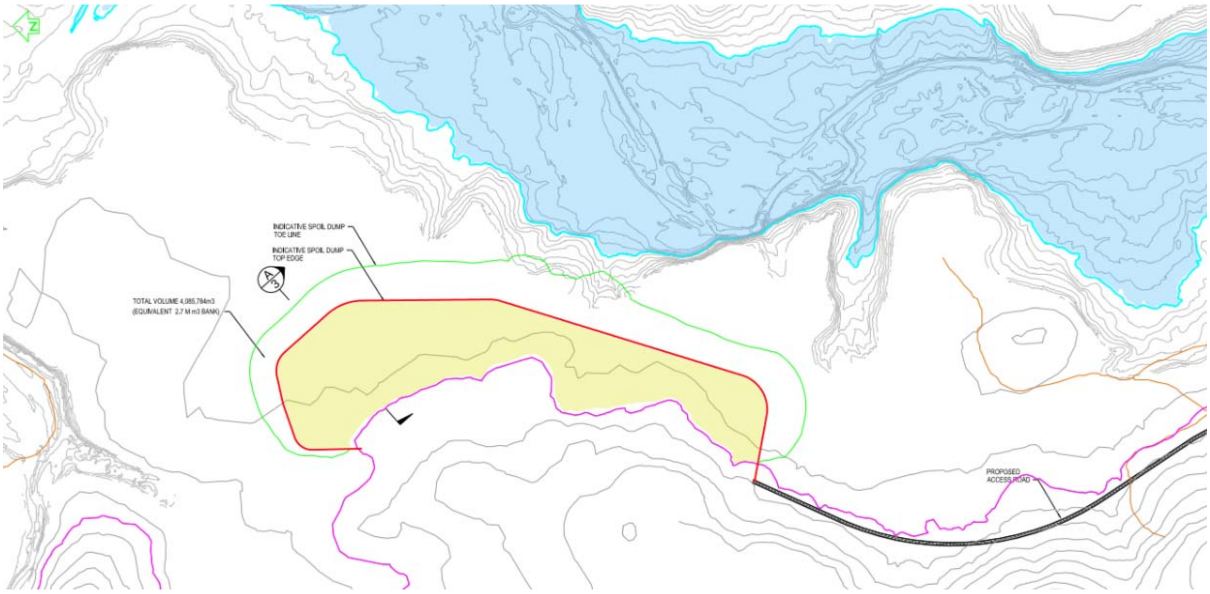


Figure 5.3: Tantangara finished excavated rock emplacement footprint

5.2 Visuals

Figures 5.4 and **5.5** have been developed to illustrate the final rehabilitated landform of the emplacement area within Tantangara Reservoir.

Figure 5.4: Tantangara Reservoir at FSL and optimised for recreational use of the rehabilitated emplacement area

Figure 5.5: Tantangara Reservoir at FSL with the emplacement area rehabilitated above FSL

5.3 Inclusions

The key elements that are included within this method are the following:

- Road construction and establishment of new road to placement site;
- Establishment of environmental controls including erosion and sediment controls;
- Transportation of material;
- Placement and compaction of material within the emplacement area; and
- Landforming and rehabilitation of the final area.

5.4 Opportunities, challenges & risk

Throughout the development of the Project, there have been various advancements in different engineering solutions that have been identified and each investigated in further detail in order to optimise outcomes for the overall Project.

Through initial design stages during the Reference Design development, it was identified that at Tantangara Reservoir approximately 3,000,000 m^3 of spare capacity was available at 1.3 m below the MOL. However during the competitive tender process, both Contractors initially proposed to use split hopper barges which require a larger draught of approximately 2.6 m. Larger clearance is therefore required to allow split hopper barge doors to open.

Taking into account the depth required for the split hopper barge and the buffer distance around the structures of Tantangara dam and the Snowy 2.0 intake structure to minimise remobilisation of materials during operation, the available capacity was reduced to approximately 1,500,000 m^3. It was determined that there was insufficient capacity to place all material subaqueously in deep placement within Tantangara Reservoir.

There was also reasonable concerns that due to the larger draught/clearance required by the split hopper barges, and that Tantangara Dam relies entirely on natural inflows, there was a real risk that there would be insufficient water to allow the barge movement to the northern areas of the reservoir for material placement.

The method of edge placement therefore presents many improvements when compared to barge placement within Tantangara Reservoir. These include:

- Removal of the majority of large barge infrastructure from Tantangara Reservoir (a smaller barge or similar vessel will be required for the removal of the rock plug at the intake location)
- Large section of Tantangara no longer required for closure to recreational users as emplacement area is on the western shore. It is envisaged that recreational users will therefore still be able to access most areas of Tantangara Reservoir;
- Ease of construction methodology as standard on-land earth moving equipment utilised;
- Compaction of emplacement area material to achieve greater placement volume within the equivalent footprint;
- Opportunity to establish a dedicated recreational area post construction;
- Reduced construction risk of delays due to the inability of sufficient water for placement;
- Significantly improved economics for the edge push method compared with the deep placement method.

6 Talbingo Options

For all the following options presented, the permanent landforming and rehabilitation of the construction pads within Lobs Hole is a common element to each option and is discussed in **Section 4**. Each method is then discussed in further detail.

6.1 Ravine Bay Placement

6.1.1 Method

The key principle of this method is the placement of materials within Talbingo reservoir from an edge based placement approach.

The following sequence is used to achieve this methodology:

1. Construction of a new access road from Lobs Hole Ravine Road (North) to the emplacement site on the northern shore of the confluence of the Yarrangobilly River and Tumut River arms of Talbingo Reservoir, see **Figure 6.1**;
2. Transportation by vehicle (dump truck) from the tunnel portal to the edge placement site;
3. Placement of material from the shoreline of Talbingo reservoir by conventional earth-moving plant such as dump trucks and excavators;
4. When there is sufficient material available, the material will be placed in stages at the emplacement site to better manage the release of fines, with drill and blast material placed on the outer edge, and in-filling with TBM material as per **Figure 6.2**;
5. A nominal 1 m thick rock armor layer above MOL will be installed for the protection of excavated rock emplacement slope surface;
6. A silt curtain will be established around the footprint of the proposed excavated rock emplacement site to minimise the release of fine material into Talbingo reservoir.

The final emplacement area will be established at least one metre above FSL to allow for long term rehabilitation of the area. Landforming of this final area will be undertaken to ensure natural drainage features are maintained and that the final landform ties into the existing natural landform.

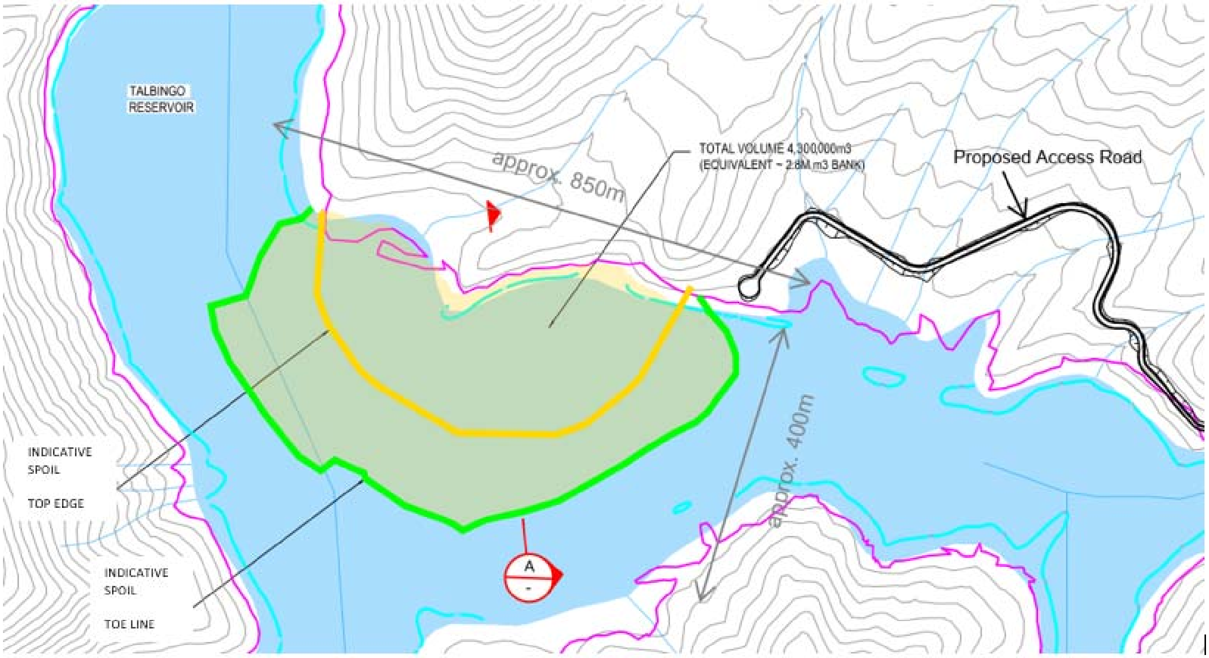


Figure 6.1: Staged Ravine Bay Placement of excavated material

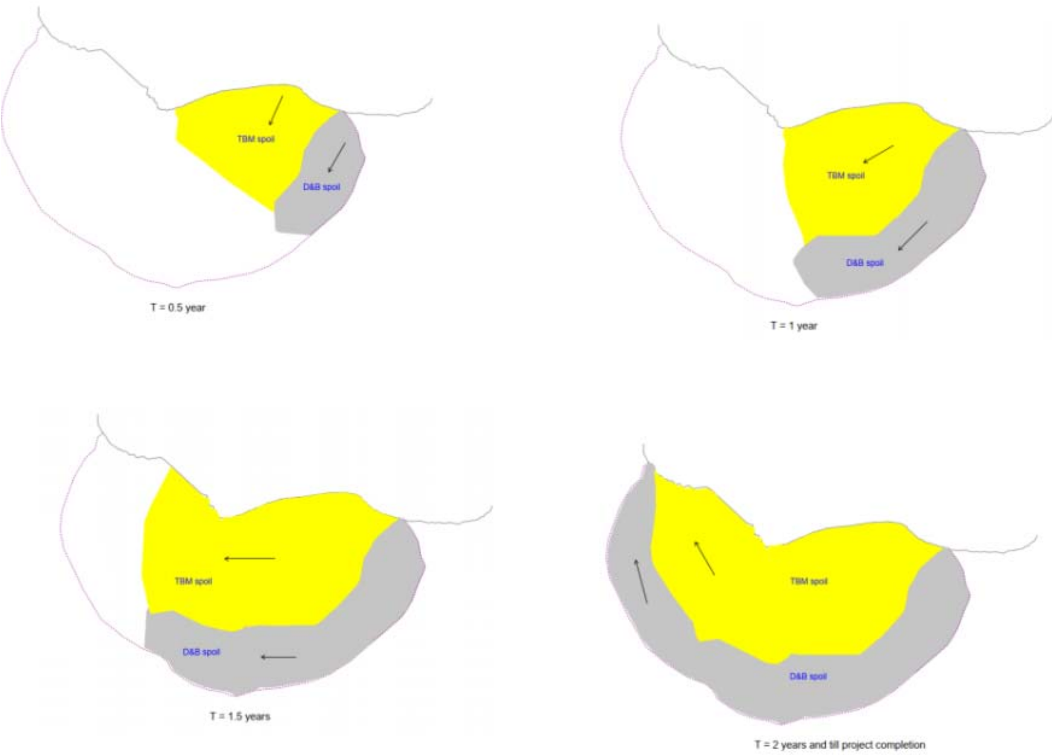


Figure 6.2: Indicative development of Talbingo excavated rock emplacement footprint versus time

6.1.2 Environmental Outcomes

Modelling has been undertaken by Royal Haskoning DHV (Royal Haskoning) to demonstrate the water quality outcomes from the placement method based on the transport of sediment through the reservoir using concentration of Total Suspended Solids (TSS). TSS has been identified as a primary indicator of impacts to the reservoirs based on visual amenity and potential effects on aquatic ecology. Some of the key inputs into the reservoir modelling undertaken included the following considerations:

- placement of 2,800,000 m^3 excavated rock;
- placement duration of 24 months;
- placement rate of 3,500 m^3/day;
- percentage of total excavated volume that will be fines;
  - 6% <63 μm for TBM;
  - 0.7% <4 μm for TBM;
  - 2% <63 μm for D&B; and
  - 0.3% <4 μm for D&B;
- source term:
  - 40% of the clay sized fraction would be released at the surface of the water column (i.e. when it is first discharged).
  - 60% of the clay sized fraction and 100% of the silt sized fraction would be released evenly through the water column (i.e. as the material moves down the slope).

For more detail on the modelling inputs, calibration and see the Excavated Rock Placement Assessment (EIS Appendix L)

Figures 6.3 to **6.5** demonstrate some of the key results of TSS modelling completed in relation to the placement of the excavated materials, projected through the entire duration of placement activities. Model result outputs of expected TSS levels at three key locations along the Talbingo Reservoir have been extracted.

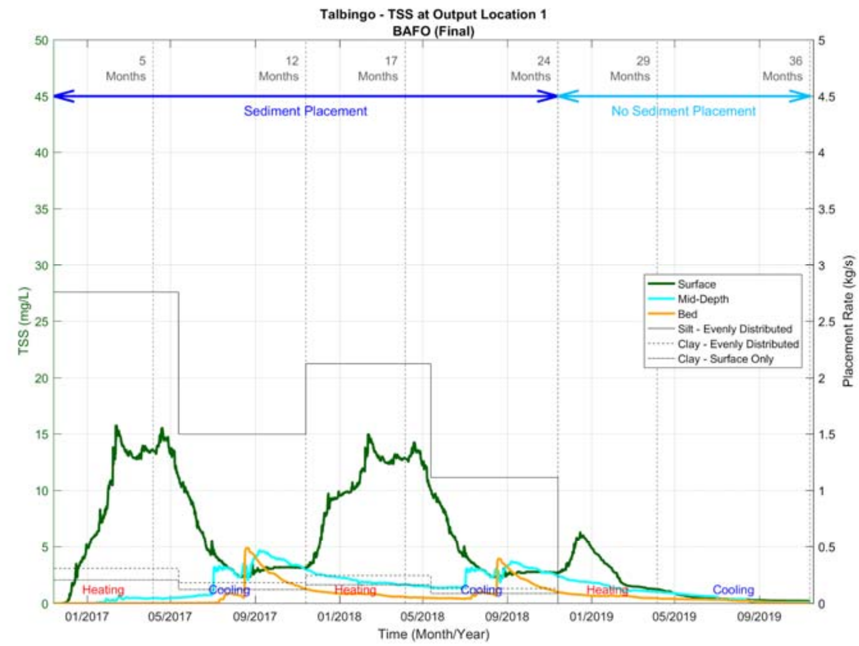


Figure 6.3: Modelled TSS levels at Talbingo Dam wall (Approximately 16 km from placement location)

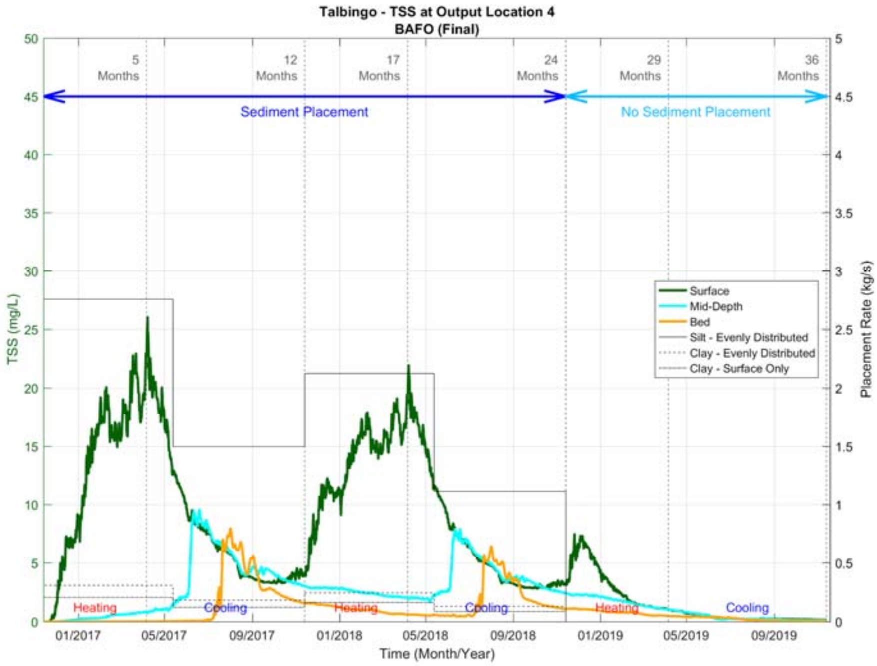


Figure 6.4: Modelled TSS levels mid-reservoir (Approximately 8 km from placement location)

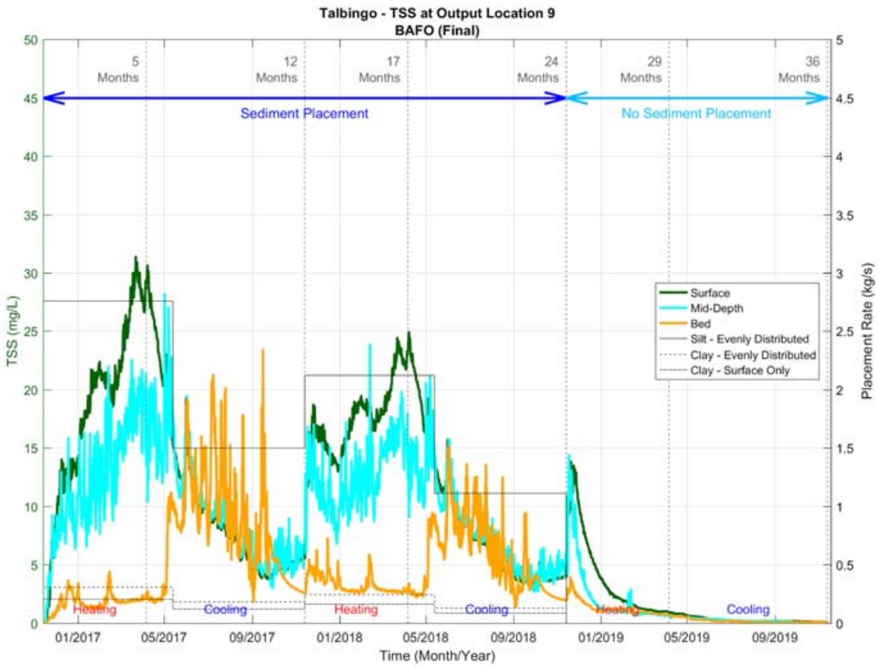


Figure 6.5: Modelled TSS levels near Ravine Bay (Approximately 1 km from placement location)

In general, the surface of the reservoir will contain the greatest concentration of TSS, with levels peaking during the summer months when Talbingo Reservoir is in a heating phase, resulting in a thermocline (a thermal layer within a water body where the warmer surface water conflicts with the colder deep water). During the cooling phase (during the winter months) the thermocline dissipates and fine material is able to settle, decreasing the concentration of TSS at the surface, and in turn, increasing the concentration at mid-depth and at the bed in the reservoir (mid-depth TSS concentrations in the reservoir are present in blue and bed TSS concentrations in the reservoir are presented in orange on the model result figures presented above).

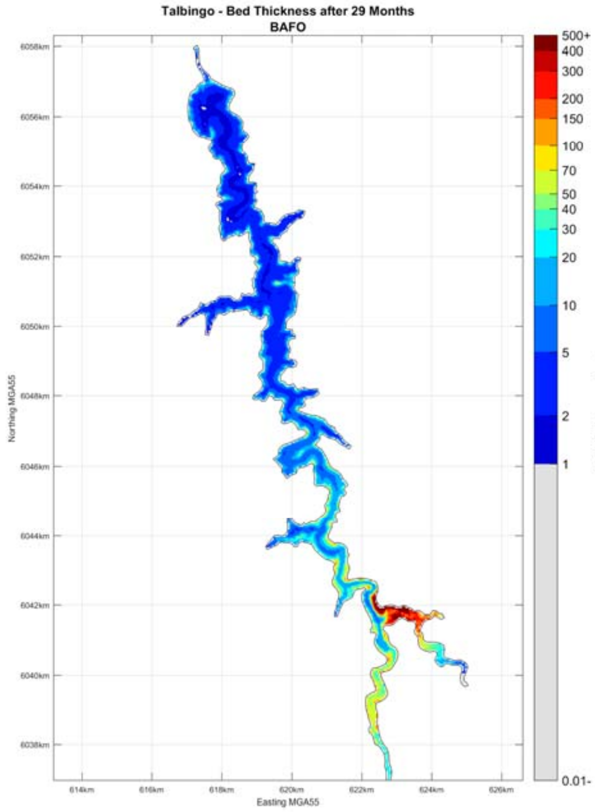
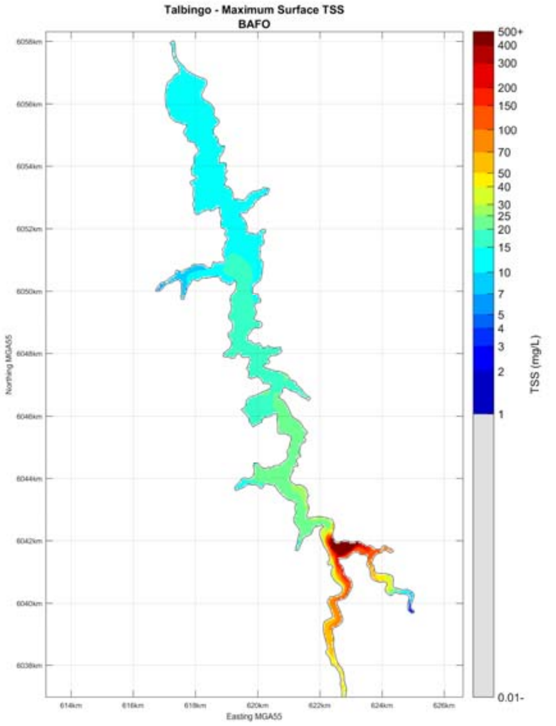


Figure 6.6: Sediment deposition 5 months after final excavated rock placement

The majority of the fine sediment deposition is contained to the placement area. However, after 24 months of placement and 5 months of no placement, the model results show sediment deposition of 100-150 mm in the Tumut Arm, upstream of Ravine Bay. This is due to the currents and temperature of the water flowing down the Tumut River displacing the surface of the thermocline resulting in sediment transport upstream.

Generally, after 24 months of placement and 5 months of no placement, the model results show sediment deposits are 20-30 mm on the banks of the reservoir, extending as far as the dam wall.



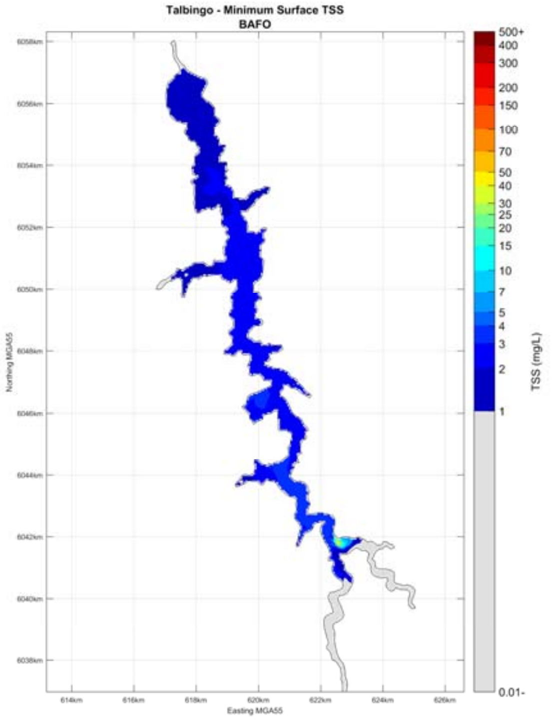


Figure 6.7: Maximum TSS concentration (mg/L) during the 24 months of placement

Figure 6.8: Minimum TSS concentration (mg/L) during the 24 months of placement

Figures 6.7 and **6.8** above show the maximum and minimum concentration of TSS (mg/L) over the 24 months of placement.

6.1.7 Visuals

The following images (**Figures 6.9** to **6.12**) were developed to illustrate the final rehabilitated landform of the emplacement area.

Figure 6.9: Existing condition of Ravine Bay emplacement area in Talbingo Reservoir

Figure 6.10: Talbingo Reservoir at a full supply level with the Ravine Bay emplacement area rehabilitated and landformed

Figure 6.11: Talbingo Reservoir at a typical operating level with the Ravine Bay emplacement area rehabilitated for recreational use

Figure 6.12: Talbingo Reservoir at FSL with the Ravine Bay emplacement area rehabilitated and landformed

6.1.8 Inclusions

The primary components included within this method are:

- road construction and establishment of approximately 6 km of new road;
- transportation of material;
- establishment of environmental controls including a silt curtain for the duration of the placement period;

- placement and compaction of material within the emplacement area; and
- landforming and rehabilitation of the final area, estimated at 240,000 m^2.

In terms of principal cost drivers, the loading and transportation of material is the key cost driver. Capital costs and mobilisation are less of a factor in this method as there is no requirement for wharf structures, nor multiple barges required. The material is transported directly from the tunnel portal to the emplacement site, removing any double handling of material. As as a result of the reduction in capital and mobilisation costs this option is significantly improved economically compared to the deep placement option.

6.1.9 Opportunities, challenges & risks

This method presents many improvements compared to the other options assessed. These include:

- Removal of the majority of barge infrastructure from Talbingo Reservoir (a smaller barge or similar vessel will be required for placement of the silt curtain);
- Southern section of Talbingo no longer requires closing to recreational users as emplacement area isolated to the Yarrangobilly River arm;
- Ease of construction methodology as standard on-land earth moving equipment utilised;
- Compaction of emplacement area material when above the water level to achieve greater placement volume within the equivalent footprint;
- Significantly improved economics for this method compared with the *Barges with fall pipe (Reference Design)* previous methodology.

Compared with the deep placement using a fall-pipe that places the excavated material deep within the reservoir, below the thermocline, this method is placing material at or near the surface of Talbingo reservoir. Therefore, the environmental outcomes of this method are increased suspended solids levels at the surface, reducing the water quality outcomes. The water quality outcomes however fluctuate throughout the placement period and improve seasonally when the water temperature is cooler in winter.

6.2 Hybrid (combined reservoir and land)

6.2.1 Method

This method focuses on delivering a balance between on land placement and water placement methodologies. The challenge with water placement methods is managing the fines content of the excavated rock, which is the key benefit of the *All to land option* as there is no water quality risk within the reservoir. However, for the on-land methodology, there is a strong desire to ensure that the final quantity of material is limited to minimise the disturbance and adjustments to the existing environment.

The hybrid method therefore finds a balance between the All to Land and Ravine Bay Placement options as it proposes to place the D&B material within the reservoir as per the Ravine Bay edge placement method, and to place the TBM material on-land. There is no change to the method proposed for each of these options previously, only a reduction in the volume for each, with the total excavated material split approximately evenly between the two options.

6.2.2 Environmental outcomes

The following modelling results (**Figures 6.13** to **6.15**) are for only the D&B material placed as per the *Ravine Bay Placement* method discussed in **Section 6.1**. Importantly the placement rate is reduced as only half of the excavated material coming from the tunnels and cavern is required to be placed as per this method, therefore:

- placement of 1,400,000 m^3 excavated rock;
- placement duration of 24 months;

- placement rate of 1,750 m^3/day;
- percentage of total excavated volume that will be fines are estimated as;
  - 2% <63 µm for D&B; and
  - 0.3% <4 µm for D&B;
- source term:
  - 40% of the clay sized fraction would be released at the surface of the water column (i.e. when it is first discharged).
  - 60% of the clay sized fraction and 100% of the silt sized fraction would be released evenly through the water column (i.e. as the material moves down the slope).

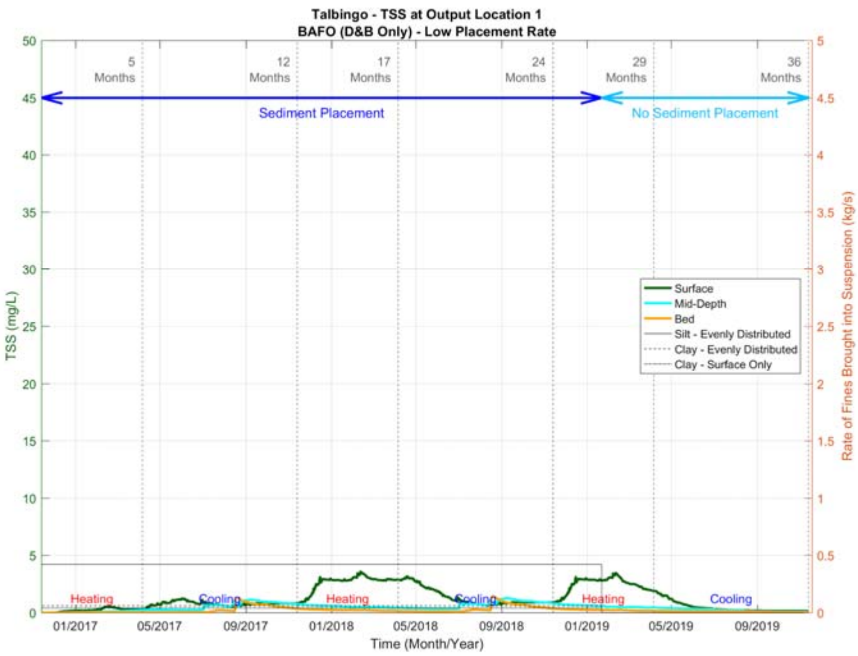


Figure 6.13: Modelled TSS levels at Talbingo Dam wall (Approximately 16 km from placement location)

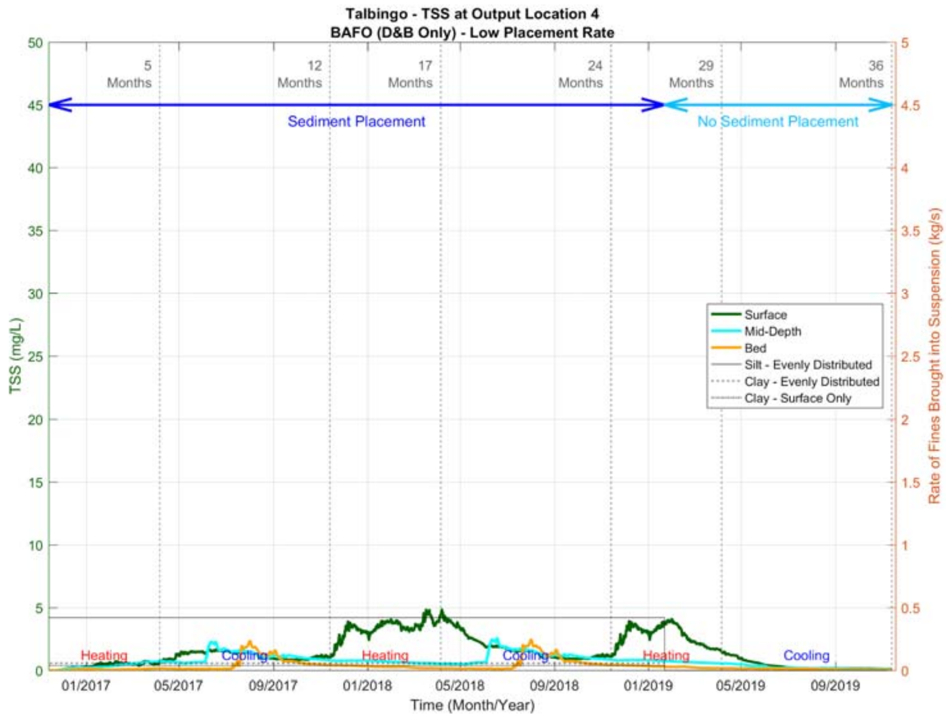


Figure 6.14: Modelled TSS levels mid-reservoir (Approximately 8 km from placement location)

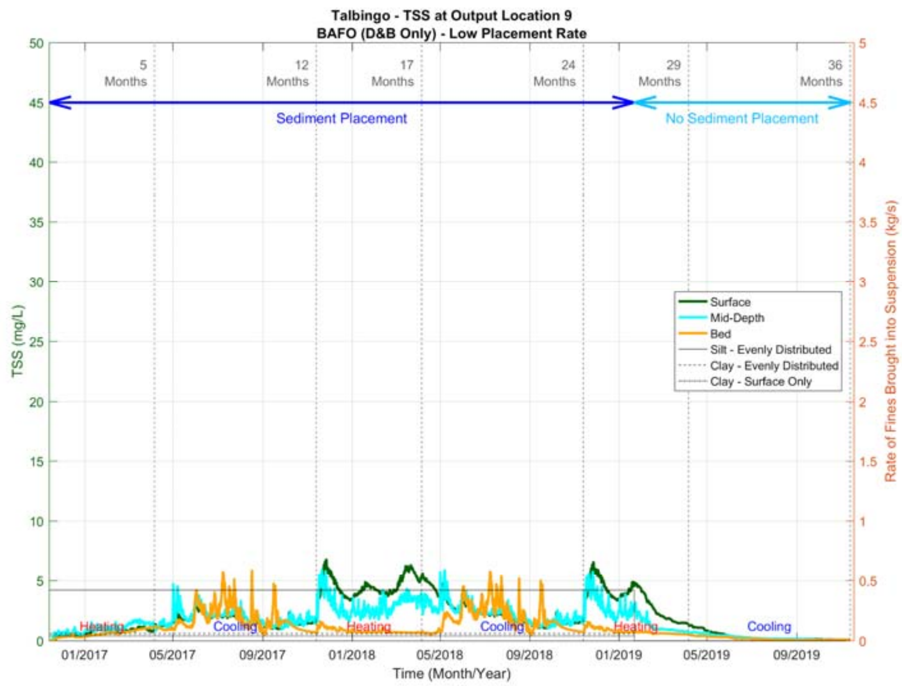


Figure 6.15: Modelled TSS levels near Ravine Bay (Approximately 1 km from placement location)

Similarly to Ravine Bay placement model results, surface TSS presented in green in **Figures 6.13** to **6.15** has the greatest concentration of TSS and is greater in during heating phase (summer) until the cooling phase (winter months) when the thermocline dissipates and fine material is able to settle. The main difference in the results of this model, the significantly lower TSS concentration, are due to the half the volume of material, and the significantly lower fines content in the material placed.

The model results show the majority of the fine sediment deposition is contained to the placement area with sediment deposits of 1-2 mm on the banks of the reservoir extending to the dam wall after 24 months of placement.

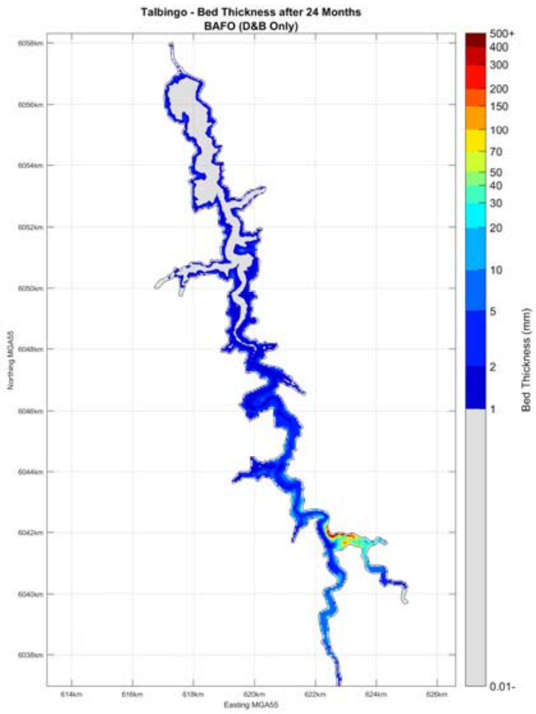
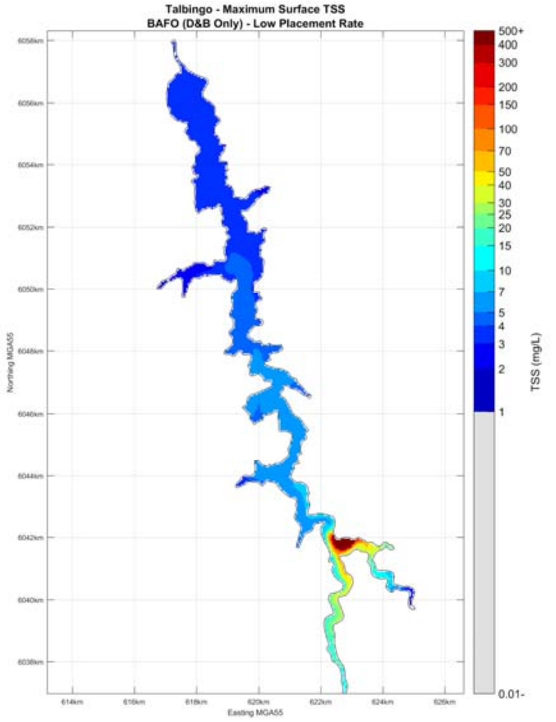


Figure 6.16: Sediment deposition after final excavated rock placement

Figures 6.17 and **6.18** show the maximum and minimum concentration of TSS (mg/L) over the 24 months of placement. Similarly to the results for Ravine Bay, the Figure showing the maximum TSS concentration is representative of placement in the heating phase (summer). **Figure 6.18** showing the minimum TSS concentration is representative of placement in the cooling phase (winter). The remaining time of a year would be a transition period between the two extremes.



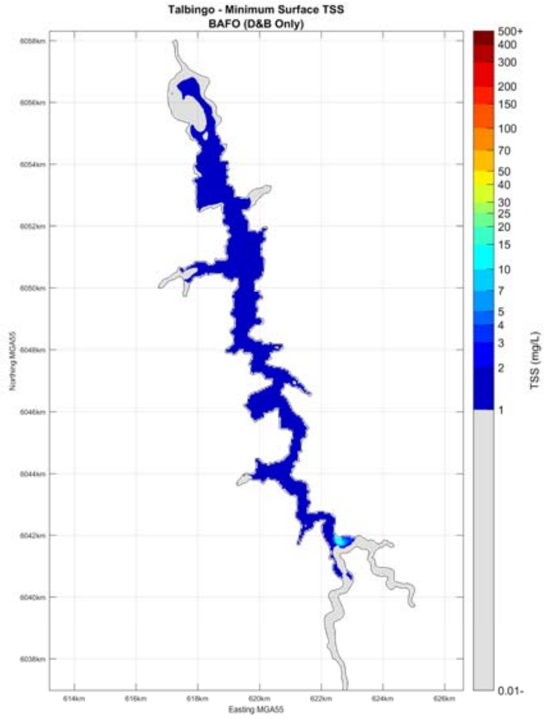


Figure 6.17: Maximum TSS concentration (mg/L) during the 24 months of placement

Figure 6.18: Minimum TSS concentration (mg/L) during the 24 months of placement

6.2.3 Visuals

The following images (**Figures 6.19** and **6.22**) have been developed to illustrate the final rehabilitated landform of the emplacement area. The rehabilitation is illustrative of five years post completion of the Project. Note that the volumes of material visualised below are approximately half of that which is outlined in the visual images for all to land option outlined in **Section 6.3**. This is due to the fact using the *Hybrid* methodology, a portion of material will be emplacemd within the reservoirs, leaving a lesser volume for on land placement.

6.2.3.1 Lick Hole Gully

Figure 6.19: The existing landform within Lick Hole Gully

Figure 6.20: Lick Hole Gully landformed and rehabilitated TBM material (Hybrid)

6.2.3.2 Cave Gully

Figure 6.21: The existing landform within Cave Gully

Figure 6.22: Cave Gully landformed and rehabilitated TBM material (Hybrid)

6.2.4 Inclusions

For the inclusions of this method, please refer to the previous discussion on the *Ravine Bay Placement* and *All to Land* methodologies in **Section 6.1** and **Section 6.3** respectively.

6.2.5 Opportunities, challenges & Risks

This method presents a compromise between the *Ravine Bay Placement* method and the *All to Land* method. The opportunities that it provides are:

- Significantly reduced water quality impact to Talbingo Reservoir with surface turbidity levels close to background levels;
- Significant reduction in required barge infrastructure on Talbingo Reservoir;

There are a number of key challenges and risks that are still present in the Hybrid method. Fundamentally these are:

- Risk of some water quality impacts is still in-place, for example if the fines content of the D&B is greater than assumed in the modelling;
- Highest disturbance footprint from all methods as the roads to the *Ravine Bay Placement* location and to the *All to Land* location are both required;
- Final landforming and rehabilitation of the *All to Land* placement area is still required;
- Reduced economics of the method due to the separation of two sources of material and corresponding two separate temporary laydown areas, as well as two construction fronts both requiring personnel and plant.

6.3 All to Land

6.3.1 Method

This method moves away from water placement and focuses on placing, landforming and rehabilitation of the excavated material on-land within the Project boundary. This option of *All to Land* placement and rehabilitation within KNP was originally ruled out by the Project during the early stages of the Feasibility Study based on feedback from the Landowner, NPWS. However, due to the challenges of achieving a water based placement method that meets both the water quality and economic requirements, the option of *All to Land* has been investigated further. The benefits to place the material on-land are due to the ease of construction, limited construction risks and improved water quality outcomes.

The following sequence outlines the general methodology, regardless of the final selected placement location:

- Establishment of construction access tracks to the placement site;
- Establishment of environmental and sediment management controls at the site, such as diversion of natural drainage systems;
- Removal of existing vegetation from the site;
- Transport by vehicle (dump truck) from the tunnel portal to the placement area;
- Material will be placed in layers, with benches established at a 1 to 4 batter slope;
- Reprofilling and landforming of the final layer will occur to ensure the natural landscape is maintained, and permanent natural drainage features exist; and
- Final rehabilitation of the site will occur.

The focus has been on selecting areas for on-land placement that have existing evidence of previous disturbance and are of low ecological significance. From a construction and schedule perspective, it is important to locate the placement area as close to the source of material as possible to reduce the transport requirements and improve the rate of placement to ensure that the tunnel excavation works are not delayed.

As such, two locations have been identified to-date, Lick Hole Gully and Cave Gully, identified in **Figure 6.23** as 'Area - 2' and 'Area - 1' respectively. Photos of the site are also provided in **Figure 6.24** below. By selecting more than one location, the final gradient of the placement area is able to be reduced which improves the rehabilitation and end use opportunities.

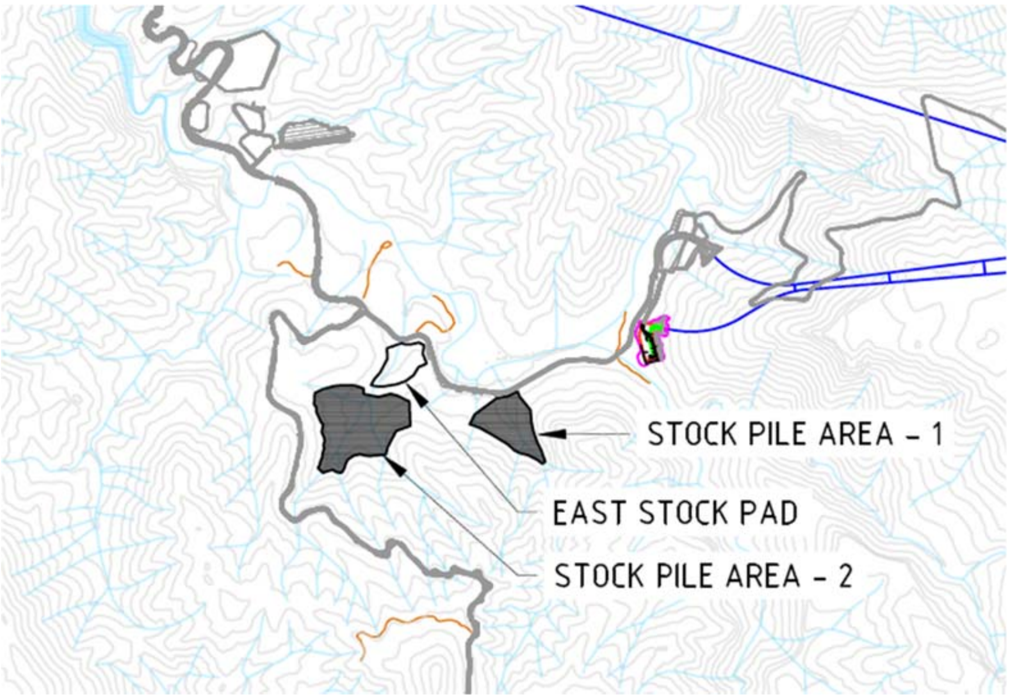


Figure 6.23: Indicative emplacement locations on-land, areas 1 and 2

Figure 6.24: Lick Hole Gully (Right) Cave Gully (Left)
Lick Hole Gully

6.3.2 Visuals

The following images have been developed to illustrate the final rehabilitated landform of the emplacement area. The rehabilitation is illustrative of five years post completion of the Project. The images showing the existing conditions of Cave Gully and Lick Hole Gully are provided in **Figures 6.21** and **6.19**, respectively.

6.3.2.1 Cave Gully

Figure 6.25: Cave Gully landformed and rehabilitated TBM material (All-to-Land)

6.3.2.2 Lick Hole Gully

Figure 6.26: Lick Hole Gully landformed and rehabilitated TBM material (All-to-Land)

6.3.3 Inclusions

The primary elements included in this method are:

- environmental controls including erosion and sediment controls;
- establishment of roads to the placement area;
- clearing and grubbing of the placement sites;
- transportation of material using truck and dog vehicle from source of material to placement area; and
- final landforming and rehabilitation of the site.

The key elements that drive the economics for this method are transporting material and management of the placement site.

6.3.4 Opportunities, challenges & risks

This method presents a number of improvements compared to the water based placement methods:

- reduced overall disturbance footprint with less roads required and temporary stockpile sites compared to the *Ravine Bay Placement* and *Barges with fall pipe* methods;
- no water quality risk for Talbingo Reservoir;
- highest placement rate, reducing construction risk delay;
- best commercial outcome for the Project.

The key challenge and risk for this method principally relates to achieving a natural final landform of the placement area that complements the existing topography, whilst ensuring that it still can be engineered and constructed effectively. Further engineering design and assessment would be required to ensure that final landforming can be achieved that is acceptable by the landowner, NPWS, and provides an equal or improved value to the site. A number of options are being explored to investigate how an on-land placement area could be incorporated into recreational opportunities for the area.

6.4 Barges with fall pipe (Reference Design)

This option was originally proposed and investigated during 2018 through the development of the Reference Design by Snowy Hydro. Royal Haskoning were engaged to develop a method of excavated rock emplacement for the Project.

6.4.1 Method

Three subaqueous excavated rock placement locations, namely Cascade Bay, Plain Creek Bay and Ravine Bay, were identified in the southern end of the Talbingo reservoir for the excavated rock (**Figure 6.27**).

The key premise of the method is excavated material emplacement in deep placement below the MOL of the reservoir. This would be achieved through the following sequence:

1. Transportation by vehicle (dump truck) from the tunnel portal to wharf infrastructure;
2. Loading of material onto large barges of capacity;
3. Transporting the barges from the wharf to the identified emplacement site;
4. Transferring material from the transfer barge to the stationary emplacement barge, containing a fall-pipe;
5. Placement of material through the fall-pipe to the reservoir bed using an excavator on the barge to move the material;
6. Utilising large coarse material to develop a bund at the reservoir bed; and
7. Silt curtains in place to reduce mobilisation of fines.

All material is placed in Cascade Bay by deep fall pipe for this methodology.

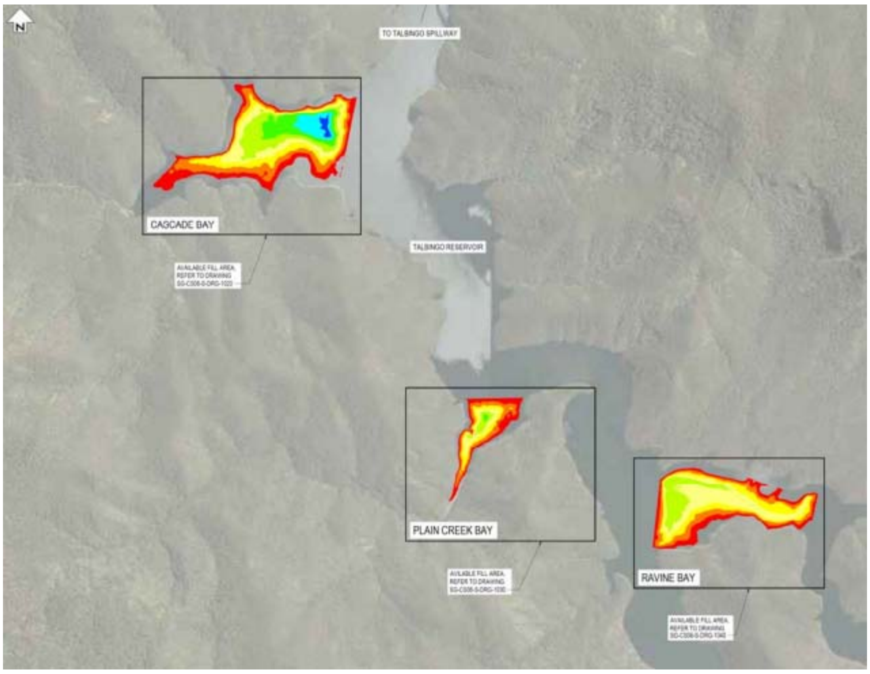


Figure 6.27: Reference Design subaqueous excavated rock placement locations

6.4.2 Environmental outcomes

Modelling has been undertaken by Royal Haskoning to demonstrate the water quality outcomes from the placement method. The following are the results undertaken from the modelling:

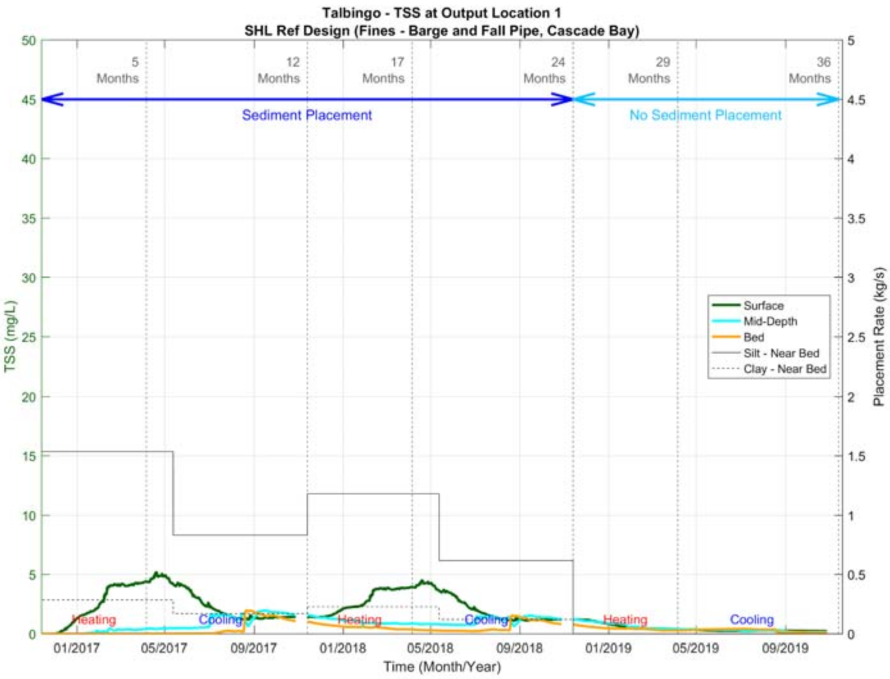


Figure 6.28: Modelled TSS levels at Talbingo Dam wall (Approximately 14 km from placement location)

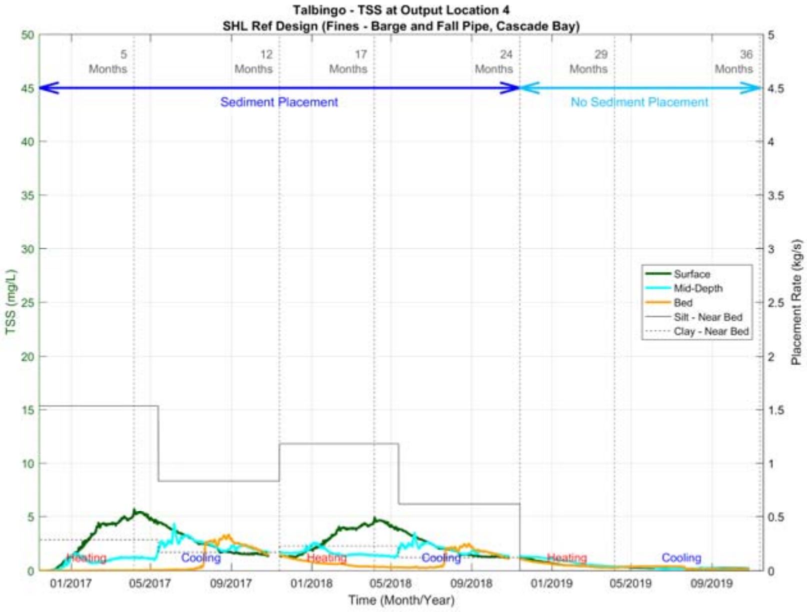


Figure 6.29: Modelled TSS levels mid-reservoir (Approximately 5 km from placement location)

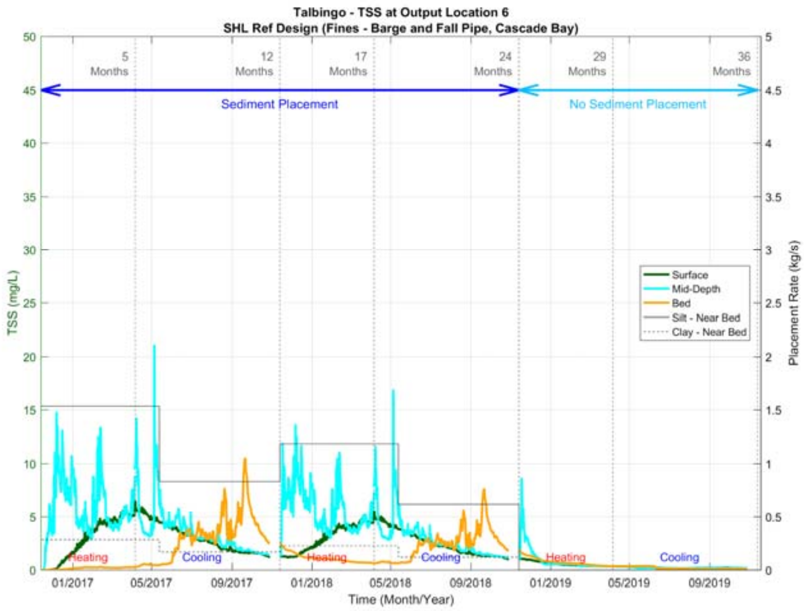


Figure 6.30: Modelled TSS levels near Cascade Bay (Approximately 1 km from placement location)

At the dam wall and mid reservoir, surface TSS (presented in **Figures 6.28** and **6.29**, has the greatest concentration of TSS, however closer to the placement location the concentration of TSS at mid-depth and the reservoir bed is greater than at the surface due to the deep placement. This would likely not be visible from the surface.

Surface TSS concentrations greater in during heating phase (summer) until the cooling phase (winter months) when the thermocline dissipates and fine material mixes with the surface water. While the thermocline is present, through the cooling phase (winter months), the TSS concentrations at mid-depth and the reservoir bed are greater than in the heating phase (summer) with greater distance from the placement area. However, at the reservoir bed, near placement the TSS concentrations are greater in the cooling phase (winter) due to sediment being trapped below the thermocline.

The model results (**Figure 6.31**) show the majority of the fine sediment deposition is contained to the placement area (modelled here as Cascade Bay) with sediment deposits of 1-5 mm on the banks of the reservoir extending to the dam wall 12 months after the completion of 24 months of excavated rock placement.

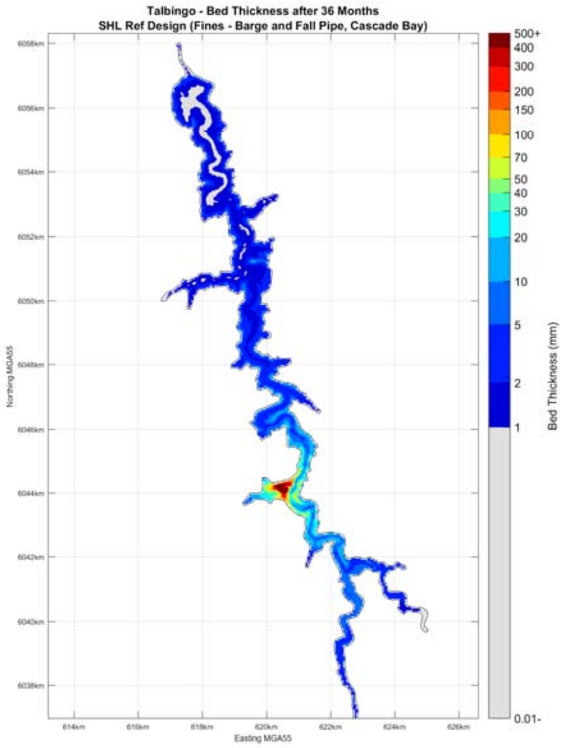
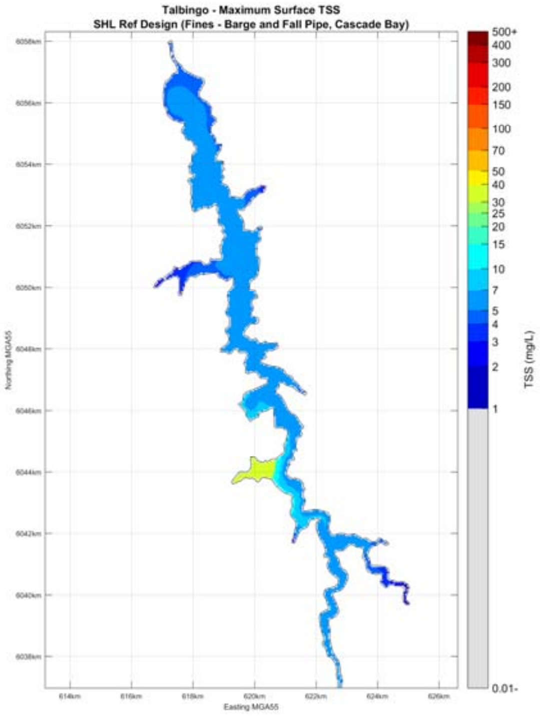


Figure 6.31: Sediment deposition after final excavated rock placement

Figures 6.32 and **6.33** show the maximum and minimum concentration of TSS (mg/L) over the 24 months of placement. Limited impacts are apparent upstream of the placement area in these modelling results. The Figures below show the maximum TSS concentration is representative of placement in the heating phase (summer) the minimum TSS concentration is representative of placement in the cooling phase (winter). The remaining time of a year would be a transition period between the two extremes.



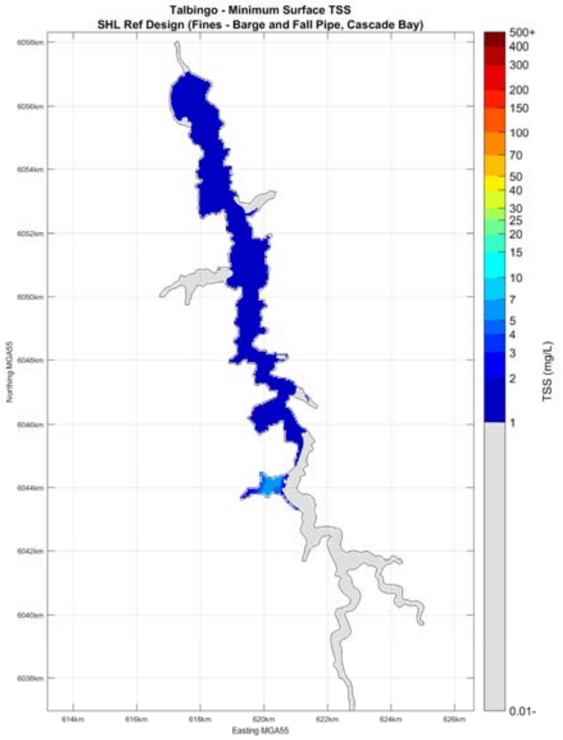


Figure 6.32: Maximum TSS concentration (mg/L) during the 24 months of placement

Figure 6.33: Minimum TSS concentration (mg/L) during the 24 months of placement

6.4.3 Inclusions

There are a number of components included within this method:

- Silt curtains in-place to reduce mobilisation of fines;
- Subaqueous placement within bund;
- Barges and fall-pipe;
- Wharf at Talbingo Spillway and southern end of Talbingo;
- Trucks to load points; and
- D&B material for underwater bunding.

The key elements that drive the economics can generally be broken into three main areas; capital costs and mobilisation, preparation and management of the material, and transportation of materials. For this method the high capital costs accounts for 70% to 80% of the total cost for this method. This includes items such as the multiple large barges required, the construction and establishment of the wharf structures, environmental controls required as well as all the equipment required for handling of the material.

6.4.4 Opportunities, challenges & risks

This option poses a number of challenges and risks which as a result, make the final selection of this method unsuitable. The key challenges and risks are:

- Variability of water levels at Talbingo reservoir (fluctuates 9 m) due to the continuing Snowy Hydro operations throughout the project resulting in risk of delay to the inability to maintain a constant placement rate;
- Poor weather conditions such as high winds and foggy weather causing delays to placement rates;
- Mobilisation and movement of barges along Talbingo reservoir impacting recreational users and closure of the southern section of Talbingo Reservoir due to the movement of barges at all hours of the day for the placement duration;
- Slower rate of placement resulting in larger disturbance area required in Lobs Hole to temporarily store material as generation rate would be greater than placement rate; and
- Insufficient rate of placement of material by the double handling of material and the slow placement method of utilising an excavator to push the material into the fall-pipe.

This option also requires dredging and establishment of a ramp structure within the Yarrangobilly River. In **Figure 6.34** the area highlighted in red required dredging to occur which is no longer required.

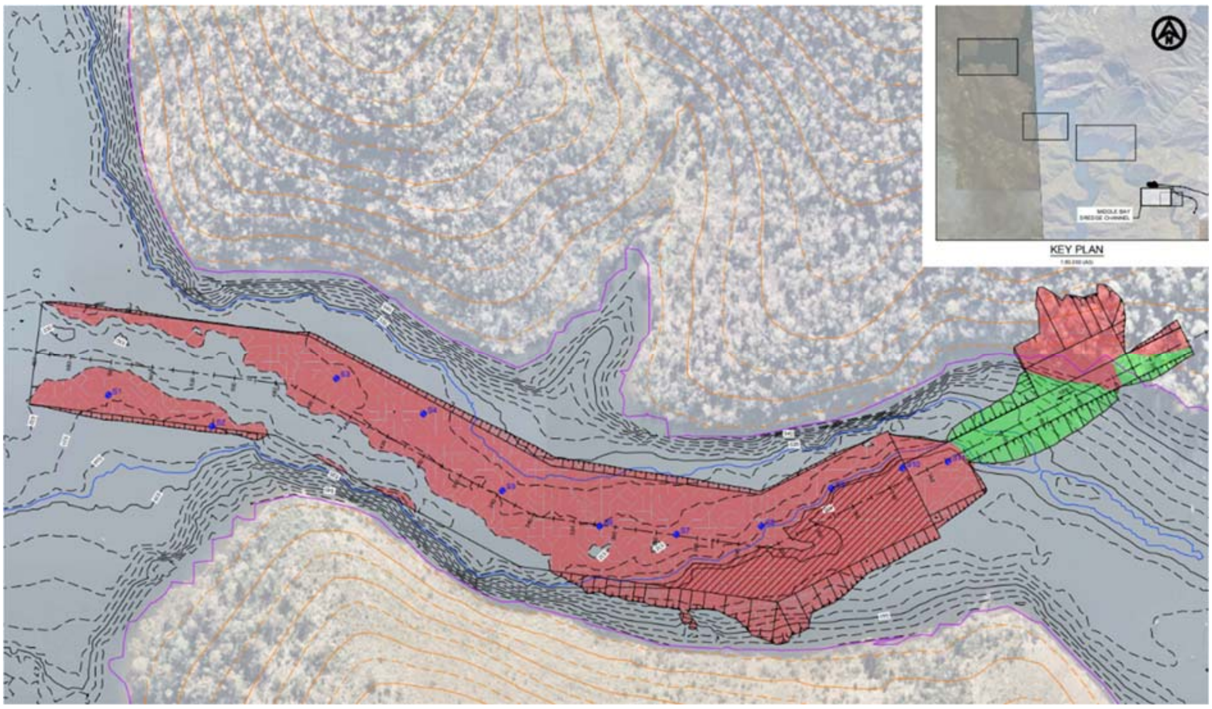


Figure 6.34: Dredging requirements for the barge ramp in the Yarrangobilly River

Furthermore, a large infrastructure setup would no longer be required at Talbingo spillway, with road construction upgrades of Spillway Road also not required. A significant amount of space and support logistics are required for the mobilisation, setup and then the operation of the barges as depicted in **Figures 6.35** and **6.36**.

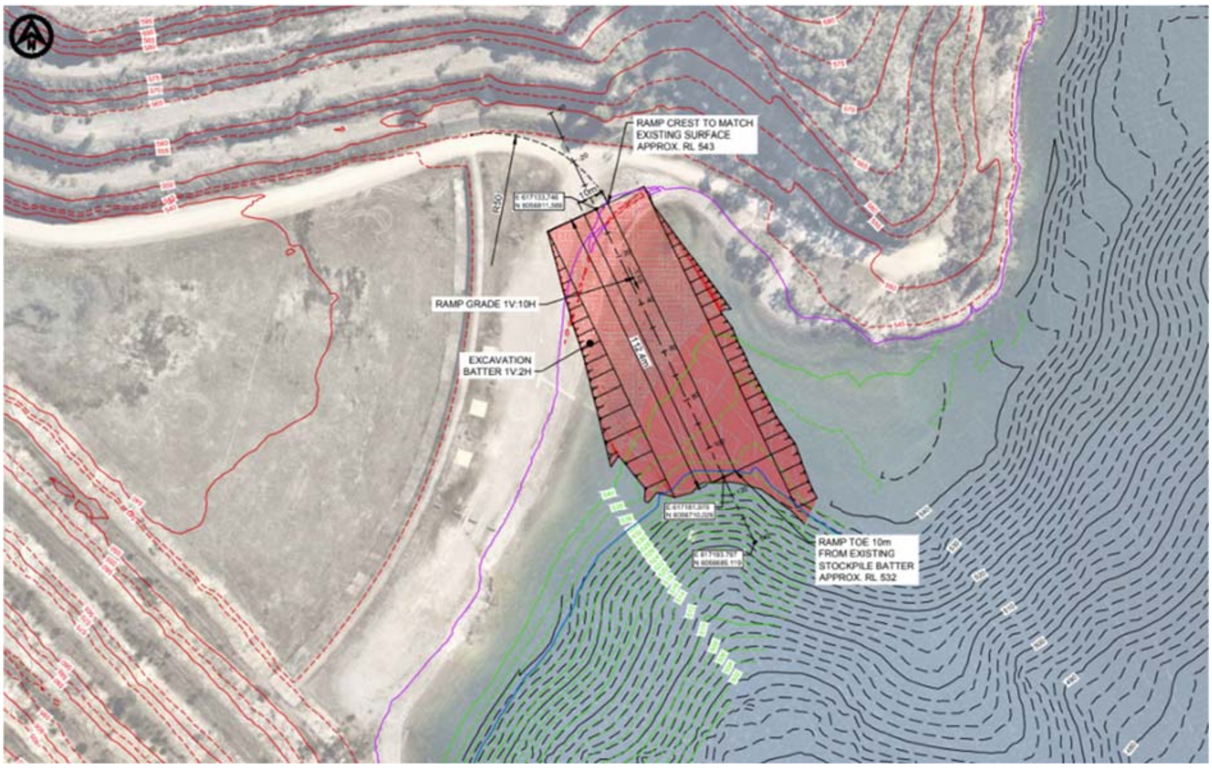


Figure 6.35: Barge ramp location in Talbingo Spillway

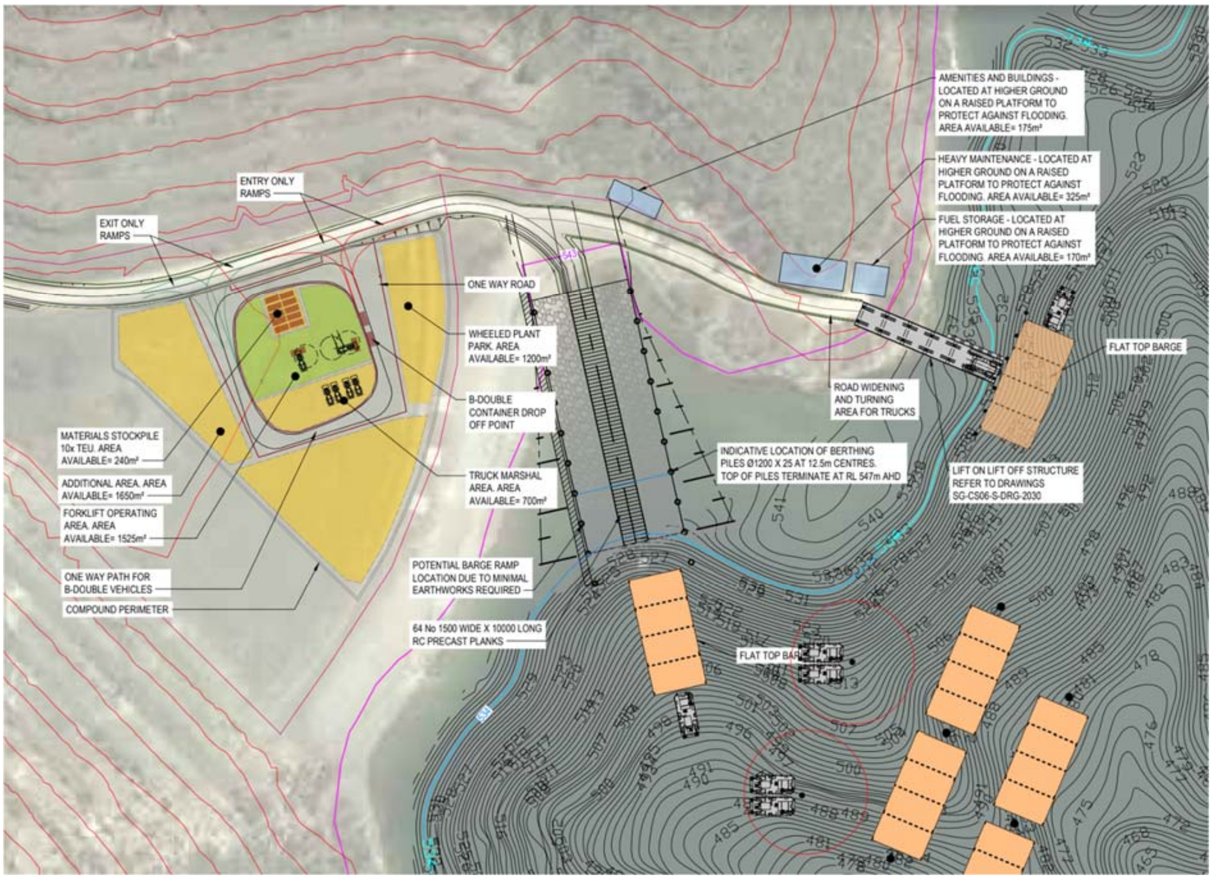


Figure 6.36: Indicative additional infrastructure required to support the barge operations, including laydown areas and mobilisation areas.

7 Conclusion

In summary, Snowy Hydro is confident that significant investigation has been undertaken in all options presented, from all perspectives for the project: constructability, environmental, water quality, cost and recreational aspects.

For the Talbingo end of the Project, the preferred method is *Ravine Bay placement*, with the second preference being the *Hybrid* (a *combination reservoir and land)* as it achieves goals of improved water quality, reduced quantity to land and reasonable constructability. The *Hybrid* option achieves a balanced ecological and recreational outcome on completion of the Project. This is followed by the *All-to-land* option. The *Barge with fall pipe* placement option is not deemed feasible.

For the Tantangara end of the Project, the preferred method of placement is the *Edge Placement* method. Engineering investigations and construction methodology advancements determined that there was insufficient capacity to place materials in deep placement within the Tantangara Reservoir, combined with a real risk that barge movements would not be possible along the northern sections of the reservoir. There is a favorable opportunity to utilise the final landform post construction to establish a new, dedicated recreational area at Tantangara.

Finally, the 1,000,000 m^3 used for construction pads within Lobs Hole is not suitable for reservoir placement and therefore the preference is to landform and rehabilitate this aspect of the Project. With further planning and investigation in consultation with NPWS, this new land formed area will open up new and exciting recreational opportunities that tie into the existing features the area offers.