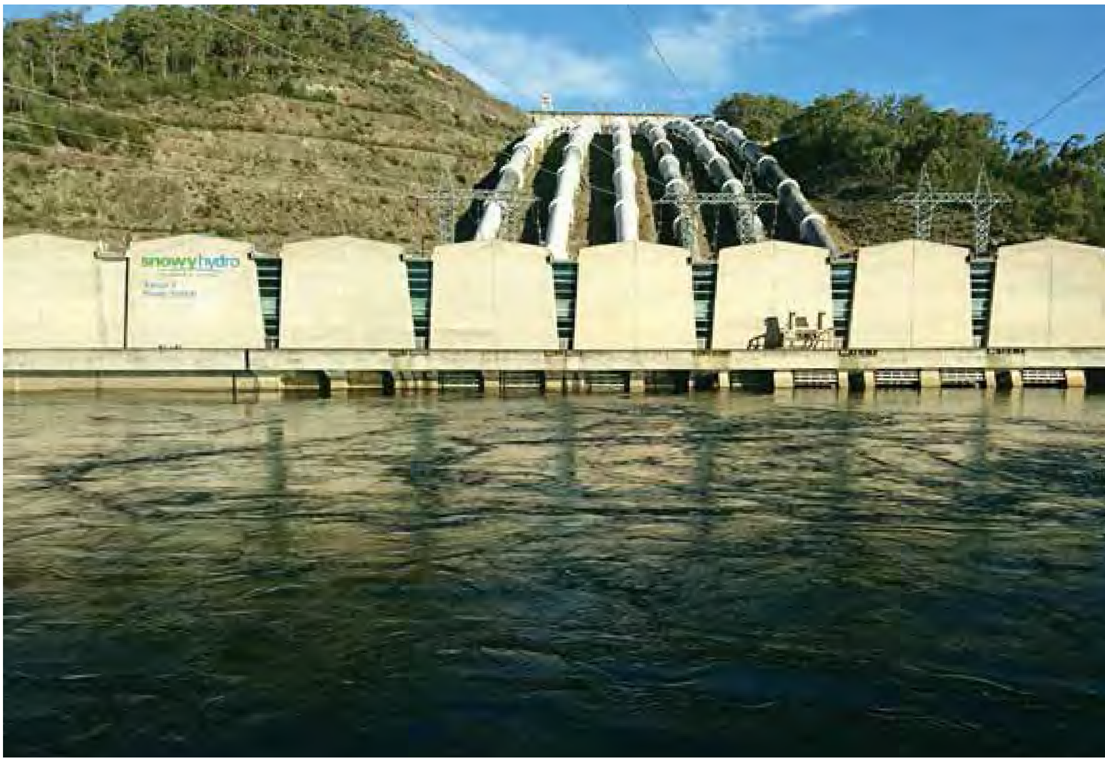
APPENDIX M

SURFACE WATER ASSESSMENT

Surface water assessment

Exploratory Works for Snowy 2.0

Prepared for Snowy Hydro Limited
July 2017



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Surface water assessment

Exploratory Works for Snowy 2.0

Prepared for SnowyHydro | 13 July 2018

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Surface water assessment

Final

Report Surface Water Assessment | Prepared for SnowyHydro | 13 July 2018

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Executive Summary

ES1 Overview

ES1.1 Exploratory Works

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 will link the existing Tantangara and Talbingo reservoirs within the Snowy Scheme through a series of underground tunnels and a hydro-electric power station.

Snowy 2.0 has been declared to be Critical State Significant Infrastructure by the NSW Minister for Planning under the provisions of the NSW *Environmental Planning and Assessment Act 1979* and is defined in Clause 9 of Schedule 5 of the *State Environmental Planning Policy (State and Regional Development) 2011.* Separate applications and environmental impact statements (EIS) for different phases of Snowy 2.0 are being submitted under Part 5, Division 5.2 of the EP&A Act. The application for Exploratory Works is the first application for Snowy 2.0.

The purpose of the Exploratory Works for Snowy 2.0 is primarily to gain a greater understanding of the conditions at the proposed location of the power station, approximately 850 metres (m) below ground level. Understanding factors such as rock conditions, ground temperature and stress conditions is essential to confirm the suitability of the site for the underground power station.

The Exploratory Works comprise:

- the establishment of an exploratory tunnel to the site of the underground power station for Snowy 2.0, portal and construction pad;
- the establishment of a portal construction compound;
- excavated rock management;
- the establishment of an accommodation camp;
- road establishment and upgrades providing access to the proposed construction areas;
- establishment of barge access infrastructure on Talbingo reservoir; and
- supporting power and communication.

ES1.2 Assessment overview

This surface water assessment supports the EIS for the Exploratory Works. The assessment has been informed by the reference design prepared for the Exploratory Works. The following aspects of the project are considered relevant to this assessment:

- Flood risk management associated with works proposed on flood prone land.

- Water management during construction of access roads, the accommodation camp, construction pad and other infrastructure.
- Water management during operation including:
  - stormwater runoff from the access roads, accommodation camp and construction pad;
  - water produced by and used by the proposed construction activities; and
  - waste water (ie sewage).
- Water management approach for rock and soil emplacement areas.

This assessment recommends controls to mitigate potential impacts. These controls will be considered in the detailed design of the Exploratory Works.

ES2 Existing environment

ES2.1 overview

The Exploratory Works will predominantly be in the Ravine region of the KNP. This region is located between Talbingo Reservoir to the north-west and the Snowy Mountains Highway to the east. Major infrastructure including the construction pad, accommodation camp and access roads will be located in Lobs Hole.

ES2.2 Yarrangobilly River

The Yarrangobilly River is a major regional watercourse that flows into the Talbingo Reservoir, downstream of Lobs Hole. The Yarrangobilly River catchment has an area of 271 km^2 that is wholly within the KNP. The catchment is characterised by a range of subalpine grasslands and woodlands and montane dry sclerophyll forests. Elevations range from 545 m AHD at Lobs Hole to more than 1,500 m AHD in the head water catchments. Median rainfall within the Yarrangobilly River Catchment ranges from 950 mm/year at Lobs Hole to 1,400 mm/year in the head water catchments. The spatial variation in median rainfall generally reflects the variation in topography within the catchment.

The majority of annual stream flows occur in late winter and early spring. Stream flows progressively reduce over summer and are at their lowest in late summer and generally remain low until the winter months. This is a typical regime for rivers in the Australian Alps.

Water quality monitoring was undertaken in the Yarrangobilly River on three occasions between February and April 2018. All samples were collected during base flow conditions, which are dominant in the summer months. The water quality during base flow conditions can be characterised as neutral to slightly alkaline, high carbonate levels, low salinity, low suspended solids and low levels of nutrients and metals.

Water quality during non base flow conditions is expected to have lower carbonate levels and potentially higher suspended solids and nutrient levels. Monitoring during elevated stream flow conditions will be undertaken in late winter and early spring 2018.

ES2.3 Wallaces Creek

Wallaces Creek is a major tributary to the Yarrangobilly River. The creek has a catchment area of 43.4 km^2, which extends to the south and forms the southernmost potion of the Yarrangobilly River Catchment.

Wallaces Creek has a similar stream flow regime and water quality characteristics to the Yarrangobilly River.

ES2.4 Local watercourses

There are numerous smaller watercourses in vicinity to the Exploratory Works. These watercourses are tributaries to the Yarrangobilly River, have catchment areas of up to 4 km^2 and typically have intermittent flow regimes.

ES2.5 Talbingo Reservoir

Talbingo Reservoir is an existing reservoir that forms part of the Snowy Scheme. Water is released from the reservoir through the Tumut 3 power station into Jounama Pondage, which releases water into Blowering Reservoir. Blowering Reservoir is operated by Water NSW and releases water into the Tumut River to supply the Murrumbidgee Irrigation Scheme. The Tumut 3 power station also has the ability to pump water from Jounama Pondage back into Talbingo Reservoir.

Average annual inflows (excluding pumping) into Talbingo Reservoir are 1,221 GL/year. The majority (86%) of inflows occur due to discharge from the Tumut 2 power station. Inflows from the Yarrangobilly River and ungauged catchments make up 8 and 6% of the total inflows respectively.

Comprehensive water quality monitoring was undertaken in March 2018. Water quality (at the time of sampling) can be characterised as having a neutral pH, low carbonate, low salinity, low levels of suspended solids and low nutrient levels. Elevated concentrations of copper and zinc were identified in most samples from the southern (upstream) portion of the reservoir. Elevated copper and zinc concentrations were not identified in either the Yarrangobilly or Tumut River inflow locations. Hence, the source of the elevated metal concentrations is unknown. This is not considered relevant to Exploratory Works but will be further investigated as part of the broader Snowy 2.0 project.

ES3 Flood risk assessment

A flood assessment has been undertaken as part of the EIS. The assessment is informed by modelling of flooding in the Yarrangobilly River, Wallaces Creek and minor tributaries that are in proximity to the Exploratory Works. The modelling has been undertaken in accordance with the methods recommended in Australian Rainfall and Runoff (Commonwealth of Australia, 2016). The flood model results have been used to establish flood characteristics within Lobs Hole for the 20%, 5%, 1%, 0.2%, 0.05% annual exceedance probability and probable maximum flood events.

The Exploratory Works avoid flood prone land where possible. However, the following infrastructure will unavoidably need to be constructed on flood prone land:

- bridge crossings over the Yarrangobilly River and Wallaces Creek;
- the western emplacement area; and
- the water management basin for the construction pad.

The flood model was applied to assess changes to the existing flooding regime associated with the infrastructure. This process concluded that the predicted changes to flood regimes will not impact infrastructure or items of heritage significance.

ES4 Water management

A water management system is proposed to manage both runoff from the Exploratory Works and water produced by and used by the proposed activities. The water management system has been categorised into eight focus areas. Table E.1.1 provides an overview of the management approach applied to each focus area.

Table E.1.1 Water management summary

Focus area	Management approach summary
Clean water management	• Where possible clean water will be diverted around or through water management areas.
Water management during construction (initial phase only)	• Erosion and sediment controls will be established to manage sediment laden runoff from construction disturbance areas.
Runoff from unsealed access roads	• Erosion and sediment controls will be established to manage sediment laden runoff from unsealed access roads.
Stormwater management: accommodation camp	• All pervious areas including batters will be vegetated with endemic native vegetation. • A stormwater management system will manage runoff from impervious areas.
Stormwater management: portal construction pad	• Activities that have the potential to contaminate stormwater runoff will be isolated from the stormwater system through the use of covering (ie by a building or roof) and bunding. • A stormwater management system will manage runoff from the portal construction pad. • The stormwater management system will be designed to contain any leak, spill or fire water runoff from the portal construction pad.
Process water management	• A process water management system will be established to manage water produced by and used by construction activities. • Any surplus process water will be treated and discharge into the Yarrangobilly River arm of Talbingo Reservoir. • Any additional water requirements will be sourced from Talbingo Reservoir.
Waste water management	• All waste water will be treated in a waste water treatment plant • Treated waste water will be discharged into the Yarrangobilly River Arm of Talbingo Reservoir.
Rock and soil emplacement water management	• Rock and soil emplacements will be designed to be physically and chemically stable landforms.

Chapter 6 of this report describes the water management risks, water management approach, expected impacts and monitoring and contingency measures for each of the water management focus areas. A summary of all controls proposed is provided in Appendix F.

ES5 Summary of impacts

Chapter 7 provides a summary of the identified potential and residual impacts of Exploratory Works on the surface water environment. Key residual impacts are summarised below.

ES5.1 Sediment laden runoff

Runoff from the construction areas (initial phase of the project only) and unsealed access roads will be laden with sediment. Sediment and erosion controls are expected to effectively remove coarse sediment but may provide limited removal of fine and dispersive sediments. Hence, some runoff containing fine and dispersive sediments may drain into receiving waters. It is expected that any runoff laden with fine and dispersive sediments that enters the Yarrangobilly River will be significantly diluted by river flows and will rapidly dissipate. Hence, no material change to the Yarrangobilly River water quality is expected.

ES5.2 Treated waste water discharge

Treated waste water will be discharged into the Yarrangobilly River arm of Talbingo Reservoir. During drought conditions, this discharge may result in the near-field concentration of phosphorus exceeding the trigger value for physical and chemical stressors that is provided in ANZECC 2000. No measurable near-field impacts are expected during non-drought conditions due to higher river inflows. Impacts to the greater reservoir are also not expected due to the high inflows associated with the existing operation of the Snowy Scheme.

ES5.3 Impacts to local watercourses

Some local watercourses will unavoidably be disturbed by the establishment of rock emplacement areas, bridge crossings and the accommodation camp.

ES6 Proposed Monitoring

A surface water monitoring program will be implemented over the duration of the Exploratory Works. The primary objectives of the monitoring program are to collect sufficient data to:

- continue to monitor baseline conditions;
- enable the effectiveness of water quality controls to be assessed;
- identify and quantify water quality impacts; and
- enable compliance with relevant consent and licence conditions to be assessed.

The monitoring program includes commitments to monitor weather, stream flows, process water quantity and quality, stormwater quality and receiving water quality.

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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). This would be achieved by establishing a new underground hydro-electric power station that would increase the generation capacity of the Snowy Scheme by almost 50%, providing an additional 2,000 megawatts (MW) generating capacity, and providing approximately 350,000 megawatt hours (MWh) of storage available to the National Electricity Market (NEM) at any one time, which is critical to ensuring system security as Australia transitions to a decarbonised NEM. Snowy 2.0 will link the existing Tantangara and Talbingo reservoirs within the Snowy Scheme through a series of underground tunnels and hydro-electric power station.

Snowy 2.0 has been declared to be State significant infrastructure and critical State significant infrastructure (CSSI) by the NSW Minister for Planning under the provisions of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) and is defined in Clause 9 of Schedule 5 of the *State Environmental Planning Policy (State and Regional Development) 2011* (SRD SEPP). Separate applications and environmental impact statements (EIS) for different phases of Snowy 2.0 are being submitted under Part 5, Division 5.2 of the EP&A Act. This technical assessment has been prepared to support an EIS for Exploratory Works to undertake investigative works to gather important technical and environmental information for the main Snowy 2.0 project. The main project will be subject of a separate application and EIS next year.

The purpose of Exploratory Works for Snowy 2.0 is primarily to gain a greater understanding of the conditions at the proposed location of the power station, approximately 850 metres (m) below ground level. Understanding factors such as rock conditions (such as stress conditions) and ground temperature is essential to inform decisions about the precise location of the power station cavern and confirm the cavern construction methods.

Exploratory Works comprises:

- an exploratory tunnel to the site of the underground power station for Snowy 2.0;
- horizontal and other test drilling, investigations and analysis in situ at the proposed cavern location and associated areas, and around the portal construction pad, access roads and excavated rock management areas all within the disturbance footprint;
- a portal construction pad for the exploratory tunnel;
- an accommodation camp for the Exploratory Works construction workforce;
- road works and upgrades providing access and haulage routes during Exploratory Works;
- barge access infrastructure, to enable access and transport by barge on Talbingo reservoir;
- excavated rock management, including subaqueous placement within Talbingo Reservoir;
- services infrastructure such as diesel-generated power, water and communications; and
- post-construction revegetation and rehabilitation, management and monitoring.

1.2 Purpose of this report

This surface water assessment supports the EIS for the Exploratory Works. It describes proposed flood risk and water management methods, monitoring and contingency measures and residual impacts.

1.3 Location of Exploratory Works

Snowy 2.0 and Exploratory Works are within the Australian Alps, in southern NSW. The regional location of Exploratory Works is shown on Figure 1.1. Snowy 2.0 is within both the Snowy Valleys and Snowy Monaro Regional local government areas (LGAs), however Exploratory Works is entirely within the Snowy Valleys LGA. The majority of Snowy 2.0 and Exploratory Works are within Kosciuszko National Park (KNP). The area in which Exploratory Works will be undertaken is referred to herein as the project area, and includes all of the surface and subsurface elements further discussed in Section 2.1.

Exploratory Works is predominantly in the Ravine region of the KNP. This region is between Talbingo Reservoir to the north-west and the Snowy Mountains Highway to the east, which connects Adaminaby and Cooma in the south-east to Talbingo and Tumut to the north-west of the KNP. Talbingo Reservoir is an existing reservoir that forms part of the Snowy Scheme. The reservoir, approximately 50 kilometres (km) north-west of Adaminaby and approximately 30 km east-north-east of Tumbarumba, is popular for recreational activities such as boating, fishing, water skiing and canoeing.

The nearest large towns to Exploratory Works are Cooma and Tumut. Cooma is approximately one hour and forty five minutes drive (95 km) south-east of Lobs Hole. Tumut is approximately half an hour (45 km) north of Talbingo. There are several communities and townships near the project area including Talbingo, Tumbarumba, Batlow, Cabramurra and Adaminaby. Talbingo and Cabramurra were built for the original Snowy Scheme workers and their families. Adaminaby was relocated to alongside the Snowy Mountains Highway from its original location (now known as Old Adaminaby) in 1957 due to the construction of Lake Eucumbene. Talbingo and Adaminaby provide a base for users of the Selwyn Snow Resort in winter. Cabramurra was modernised and rebuilt in the early 1970s and is owned and operated by Snowy Hydro. It is still used to accommodate Snowy Scheme employees and contractors. Properties within Talbingo are now predominantly privately owned. Snowy Hydro now only owns 21 properties within the town.

Other attractions and places of interest in the vicinity of the project area include Selwyn Snow Resort, the Yarrangobilly Caves complex and Kiandra. Kiandra has special significance as the first place in Australia where recreational skiing was undertaken and is also an old gold rush town.

The project area is shown on Figure 1.2 and comprises:

- **Lobs Hole:** Lobs Hole will accommodate the excavated rock emplacement areas, an accommodation camp as well as associated infrastructure, roads and laydown areas close to the portal of the exploratory tunnel and portal construction pad at a site east of the Yarrangobilly River;

- **Talbingo Reservoir:** installation of barge access infrastructure near the existing Talbingo Spillway, at the northern end of the Talbingo Reservoir, and also at Middle Bay, at the southern end of the reservoir, near the Lobs Hole facilities, and installation of a submarine cable from the Tumut 3 power station to Middle Bay, providing communications to the portal construction pad and accommodation camp. A program of subaqueous rock placement is also proposed;

- **Mine Trail Road** will be upgraded and extended to allow the transport of excavated rock from the exploratory tunnel to sites at Lobs Hole that will be used to manage excavated material, as well as for the transport of machinery and construction equipment and for the use of general construction traffic; and

- several sections of **Lobs Hole Ravine Road** will be upgraded in a manner that protects the identified environmental constraints present near the current alignment.

The project is described in more detail in Chapter 2.

1.4 Proponent

Snowy Hydro is the proponent for Exploratory Works. Snowy Hydro is an integrated energy business – generating energy, providing price risk management products for wholesale customers and delivering energy to homes and businesses. Snowy Hydro is the fourth largest energy retailer in the NEM and is Australia's leading provider of peak, renewable energy.

1.5 Assessment guidelines and requirements

This surface water assessment has been prepared in accordance with the Secretary's Environmental Assessment Requirements (SEARs) for Exploratory Works, issued on 17 May 2018, as well as relevant governmental assessment requirements, guidelines and policies, and in consultation with the relevant government agencies.

The SEARs must be addressed in the EIS. Table 1.1 lists the matters relevant to this assessment and where they are addressed in this report.

Table 1.1 Relevant matters raised in SEARs - Water

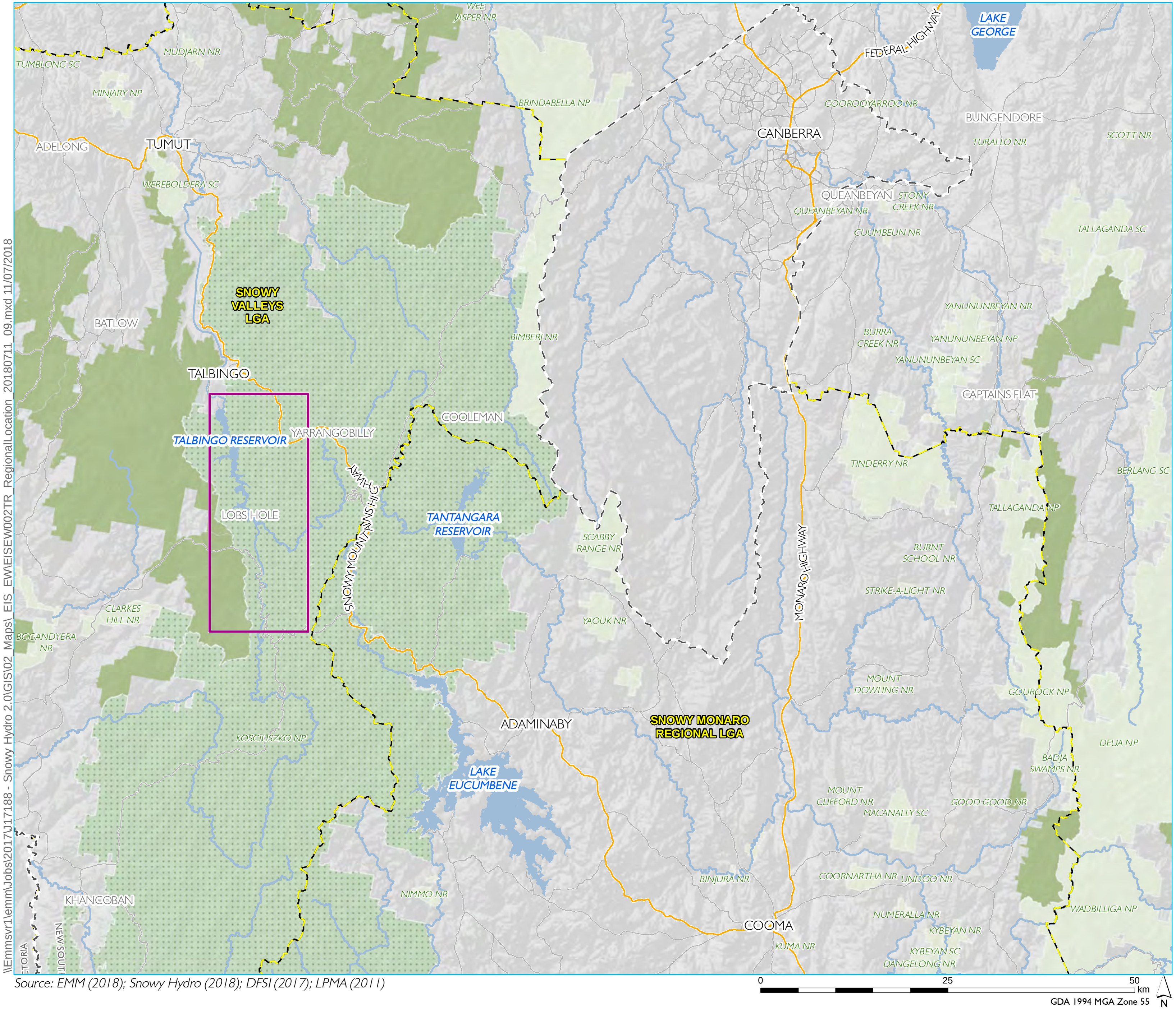
Requirement	Section addressed
An assessment of the impacts of the project on the quantity and quality of the region's surface water resources, including Yarrangobilly River, Wallaces Creek and Talbingo Reservoir.	Section 6 and 7
An assessment of the impacts of the project on groundwater aquifers and groundwater dependent ecosystems having regard to the NSW Aquifer Interference Policy and relevant Water Sharing Plans.	Refer to Groundwater Assessment (EMM, 2018b)
An assessment of the potential flooding impacts and risks of the project.	Sections 5 and 7
A detailed site water balance for the project, including water supply and wastewater disposal arrangements.	Section 6.7

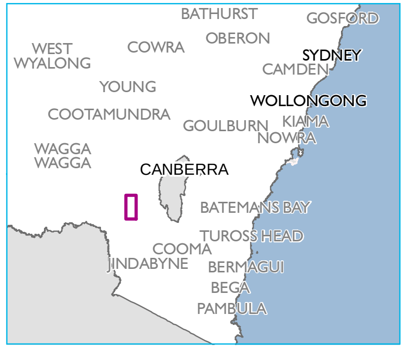
To inform preparation of the SEARs, the Department of Planning and Environment (DPE) invited relevant government agencies to advise on matters to be addressed in the EIS. These matters were taken into account by the Secretary for DPE when preparing the SEARs.

1.5.1 Other relevant reports

This Surface Water Assessment has been prepared with reference to other technical reports that were prepared as part of the Exploratory Works EIS. The other relevant reports referenced in this Surface Water Assessment are listed below:

- Excavated rock emplacement areas assessment (SGME 2018) – Appendix K of the EIS
- Groundwater assessment (EMM 2018) – Appendix N of the EIS
- Soils and land assessment (EMM 2018) – Appendix H of the EIS





KEY

- Exploratory Works project area
- Main road
- Local road
- Watercourse
- Waterbodies
- Kosciuszko National Park
- NPWS reserve
- State forest
- Local government area boundary
- State boundary

Source: EMM (2018); Snowy Hydro (2018); DFSI (2017); LPMA (2011)

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Regional location of Snowy 2.0 and Exploratory Works

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure 1.1

2 Project description

2.1 Overview

Exploratory Works comprises construction associated with geotechnical exploration for the underground power station for Snowy 2.0. The Exploratory Works elements are shown on Figure 2.1 and involve:

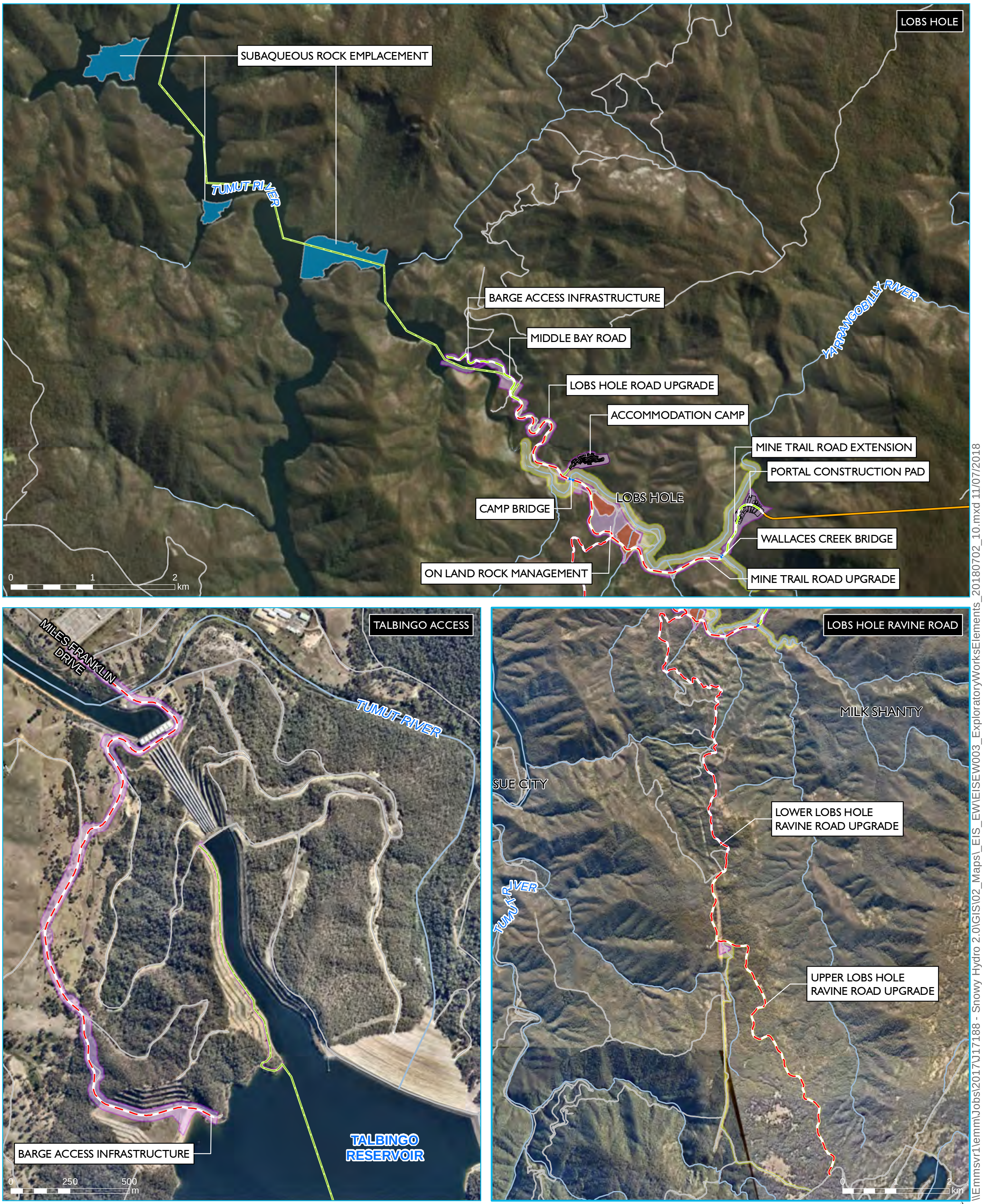
- establishment of an exploratory tunnel to the site of the underground power station for Snowy 2.0;
- horizontal and other test drilling, investigations and analysis in situ at the proposed cavern location and associated areas, and around the portal construction pad, access roads and excavated rock management areas all within the disturbance footprint;
- establishment of a portal construction pad for the exploratory tunnel;
- establishment of an accommodation camp for the Exploratory Works construction workforce;
- road works and upgrades providing access and haulage routes during Exploratory Works;
- establishment of barge access infrastructure, to enable access and transport by barge on Talbingo reservoir;
- excavated rock management, including subaqueous placement within Talbingo Reservoir;
- establishment of services infrastructure such as diesel-generated power, water and communications; and
- post-construction revegetation and rehabilitation, management and monitoring.

2.2 Exploratory tunnel

An exploratory tunnel of approximately 3.1 km is proposed to provide early access to the location of the largest cavern for the underground power station. This will enable exploratory drilling and help optimise the location of the cavern which, in turn, will optimise the design of Snowy 2.0.

The exploratory tunnel is proposed in the north-east section of Lobs Hole and will extend in an east-west direction with the portal construction pad to be outside the western end of the tunnel at a site east of the Yarrangobilly River, as shown on Figure 2.2.

The location of the proposed exploratory tunnel and portal construction pad is shown in Figure 2.2. The exploratory tunnel will be excavated by drill and blast methods and have an 8 x 8 m D-Shaped cross section, as shown on Figure 2.3.



Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017); LPMA (2011)

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KEY

- Exploratory tunnel
- Access road upgrade
- Access road extension
- Permanent bridge
- Portal construction pad and accommodation camp conceptual layout
- Communications cable
- Local road or track
- Watercourse
- On land rock management
- Subaqueous rock emplacement area
- Disturbance footprint
- Avoidance footprint

Exploratory Works elements

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 2.1

The drill and blast excavation process will be repeated cyclically throughout the tunnelling works, involving:

- marking up and drilling blast holes in a predetermined pattern in the working face of the tunnel;
- loading the blast holes with explosives, attaching detonators and connecting the holes into a blast sequence, and detonating the blast;
- ventilating the tunnel to remove blast fumes and dust;
- removing blasted rock;
- scaling and wash down of the tunnel roof and walls to remove loosened pieces of rock;
- geological mapping of the exposed rock faces and classification of the conditions to determine suitable ground support systems for installation;
- installing ground support; and
- advancing construction ventilation ducting and other utilities including power, water, compressed air and communications.

The exploratory tunnel will be shotcrete-lined with permanent anchor support, and incorporate a groundwater management system. The exploratory tunnel shape and dimensions are designed to allow two-lane traffic for the removal of excavated material, along with additional space for ventilation and drainage of groundwater inflows. Groundwater intersected during tunnelling will be contained and transferred to the portal for treatment and management. Areas identified during forward probing with the potential for high groundwater flows may require management through a detailed grouting program or similar.

The tunnel portal will be established at the western end of the exploratory tunnel and provide access and utilities to the exploratory tunnel during construction. The portal will house power, communications, ventilation and water infrastructure. The portal will also provide a safe and stable entrance to the exploratory tunnel.

It is anticipated that the exploratory tunnel will be adapted for multiple functions during construction of the subsequent stages of the Snowy 2.0 project. The exploratory tunnel will also eventually be utilized to form the main access tunnel (MAT) to the underground power station during the operational phase of Snowy 2.0, should it proceed.

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KEY

- Access road upgrade
- Access road extension
- Portal construction pad conceptual layout
- Exploratory tunnel
- Permanent bridge
- Communications cable
- Watercourse
- Contour (10m)
- Contour (100m)
- Disturbance footprint
- Avoidance footprint

Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); Robert Bird (2018); SMEC (2018); DFSI (2017)

Exploratory tunnel location

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 2.2

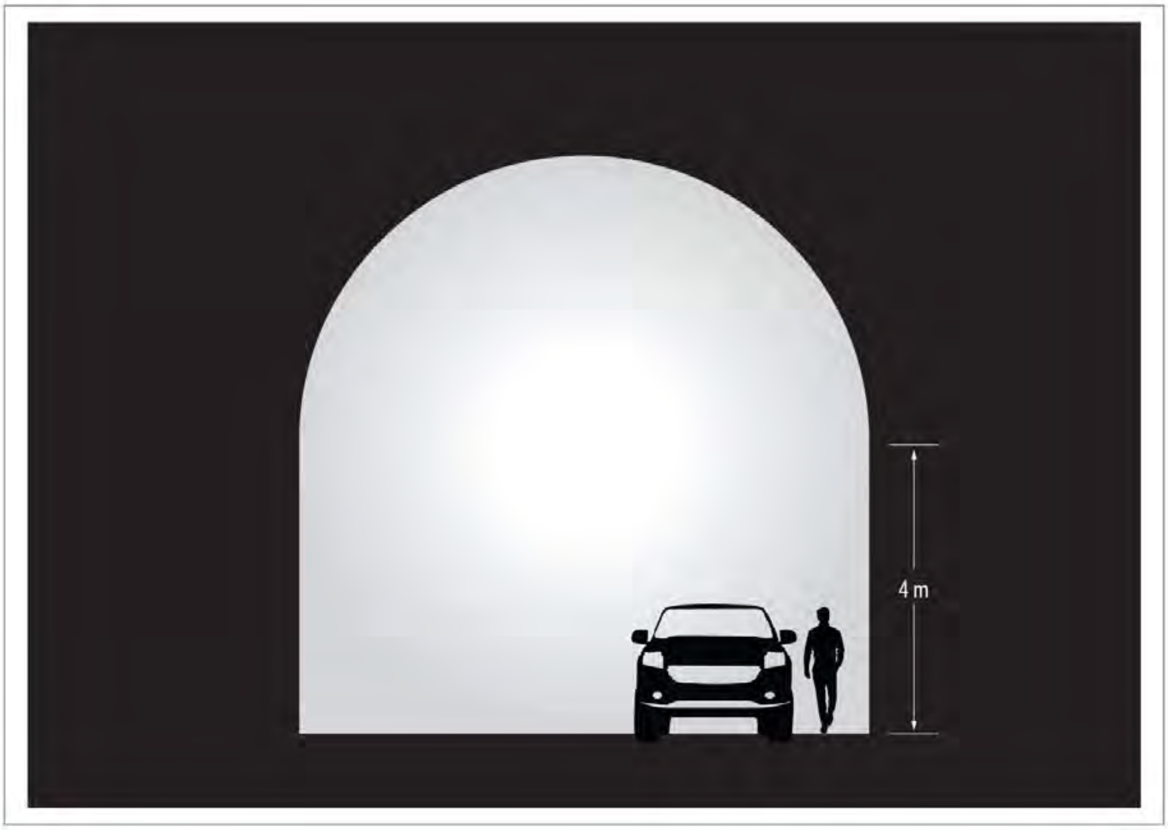
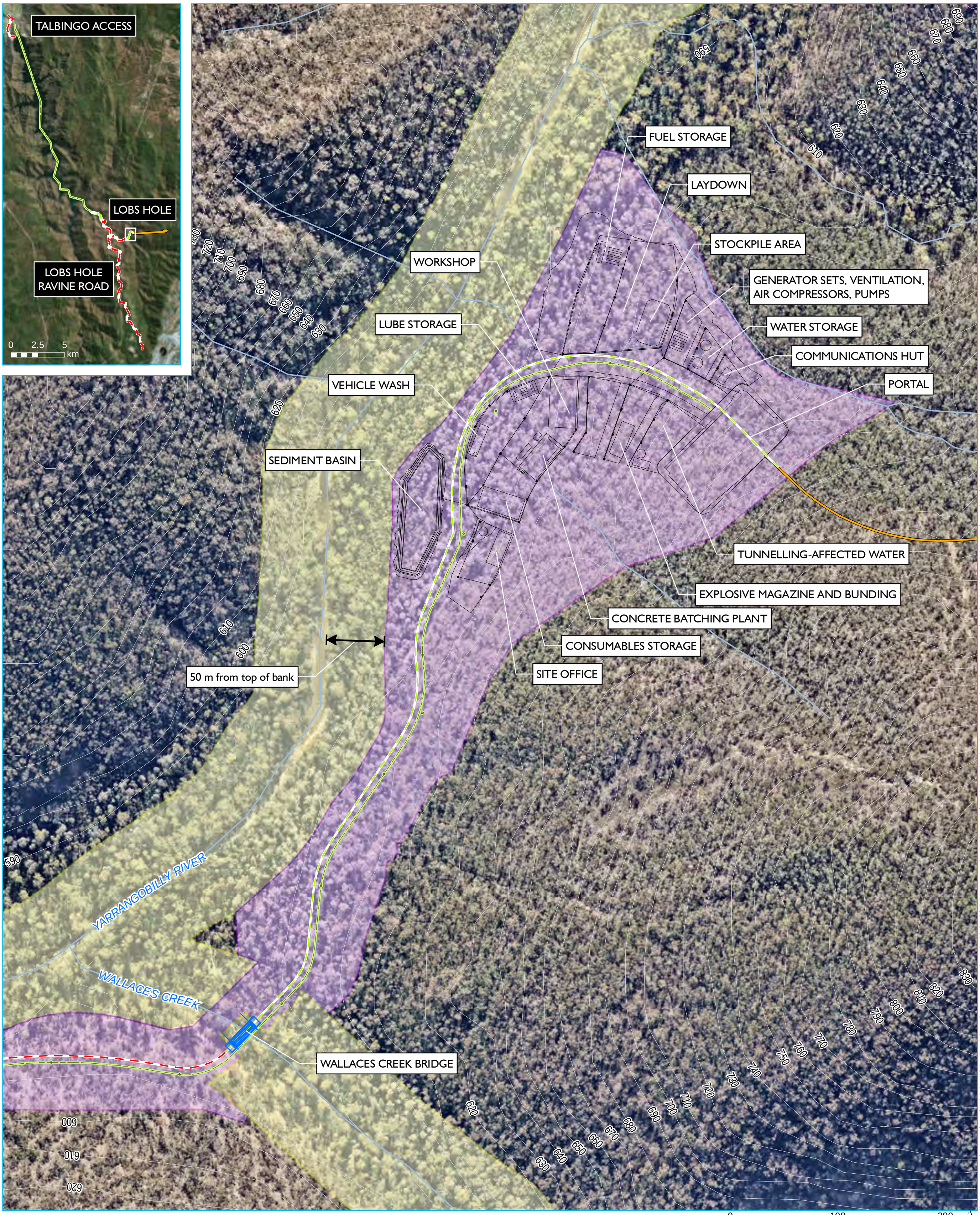


Figure 2.3 Exploratory tunnel indicative cross section

2.3 Portal construction pad

A portal construction pad for the exploratory tunnel will provide a secure area for construction activities. Infrastructure at the portal construction pad, shown in Figure 2.4, will primarily support tunnelling activities and include a concrete batching plant and associated stockpiles, site offices, maintenance workshops, construction support infrastructure, car parking, equipment laydown areas. Stockpile areas will allow for around two to three months supply of concrete aggregate and sand for the concrete batching plant to ensure that the construction schedule for the proposed access road works do not interfere with the exploratory tunnel excavation schedule. A temporary excavated rock stockpile area is also required to stockpile material excavated during tunnel construction prior to its transfer to the larger excavated material emplacement areas.

The portal construction pad will be at the western end of the exploratory tunnel. The portal construction pad will be excavated to provide a level construction area with a near vertical face for the construction of the portal and tunnelling. The area required for the portal construction pad is approximately 100,000 m^2.



Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017)

KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable
- Watercourse
- Contour (10m)
- Disturbance footprint
- Avoidance footprint

Conceptual layout – portal construction pad

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 2.4

2.4 Excavated rock management

It is estimated that approximately 750,000 m^3 of bulked materials will be excavated, mostly from the exploratory tunnel and portal construction pad with additional quantities from road upgrade works. Subject to geochemical testing of the rock material, excavated rock will be placed either on land or subaqueously within Talbingo Reservoir.

2.4.1 On land placement

Excavated materials will be placed in one of two rock emplacement areas at Lobs Hole as shown on Figure 2.5.

The strategy for excavated rock management is for excavated material to be emplaced at two areas with the final placement of excavated material to be determined at a later date.

Consultation with NPWS throughout the design process has identified an opportunity for the eastern emplacement area to form a permanent landform that enables greater recreational use of Lobs Hole following the completion of Snowy 2.0's construction. It is envisaged that the excavated rock emplacement area will provide, in the long-term, a relatively flat final landform suitable for camping and basic recreational facilities to be confirmed in consultation with NPWS.

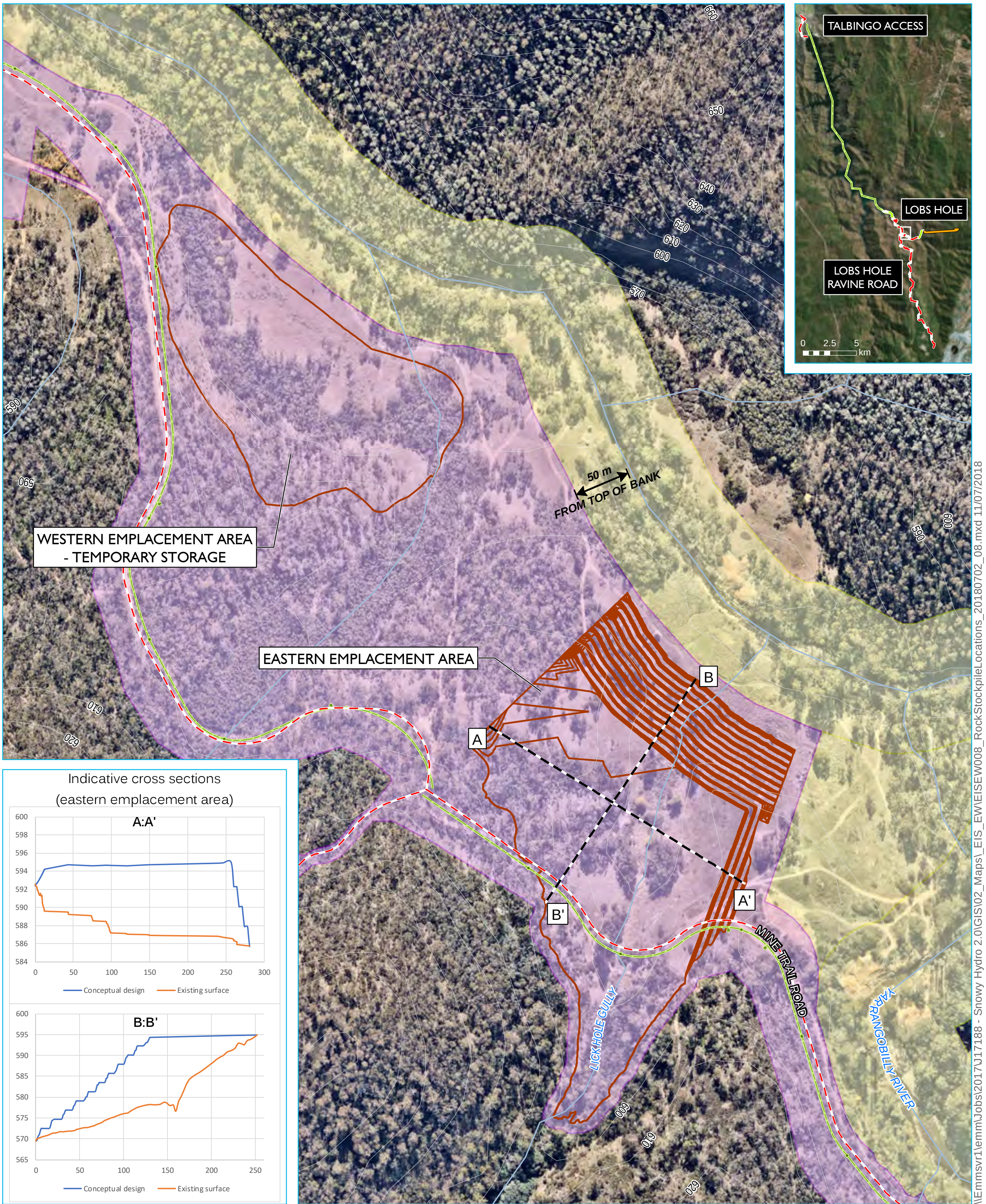
The eastern emplacement area has a capacity of up to 600,000 m^3 of material. It will be approximately 25 m maximum depth and will be benched down to the northern edge of the emplacement which is setback 50 m from the Yarrangobilly River.

The western emplacement area will be used to store excavated material should it not be able to be placed within the eastern emplacement area. It is envisaged this emplacement area will be used to store excavated materials suitable for re-use within the construction of Exploratory Works or for use by NPWS in KNP maintenance activities. All remaining material placed in this emplacement area will be removed following the completion of Exploratory Works.

The guiding principles for the design, construction method and management of emplacement areas undertaken for Exploratory Works have been as follows:

- reducing potential for acid rock drainage from the excavated rock emplacement area entering the Yarrangobilly River or forming groundwater recharge;
- avoid known environmental constraints; and
- manage existing surface water flows from Lick Hole Gully.

The design and management of the emplacement areas have not yet been finalised due to the need for further investigations to determine the likely geochemical characteristics of the excavated material. Following further investigation and prior to construction of Exploratory Works a management plan will be prepared and implemented.



Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); DFSI (2017)

KEY

- Cross-section
- Exploratory tunnel
- Access road upgrade
- Access road extension
- Communications cable
- On land rock management
- Watercourse
- Contour (10m)
- Disturbance footprint
- Avoidance footprint

Conceptual layout – excavated material emplacement areas

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 2.5

2.4.2 Subaqueous placement

An intial program for the placement of excavated rock within Talbingo Reservoir also forms part of Exploratory Works. The program will be implemented in an appropriate section of Talbingo Reservoir in accordance with a detailed management plan based on an engineering method informed through the materials' geochemistry and reservoir's characteristics. The purpose of the program is to confirm the suitability of the emplacement method for future excavated rock material from the construction of Snowy 2.0, should it proceed.

The rock for subaqueous placement will be taken from the excavated rock emplacement areas as described above. Testing of the rock would be conducted during excavation to assess geochemical properties. Any rock assessed as unsuitable for subaqueous placement based on the prior geochemical and leachability testing would be separately stockpiled and not used in the program. Suitable (ie non-reactive material) would be transported and loaded to barge, for placement at the deposition area. Suitable placement locations have been identified for Exploratory Works and are shown indicatively on Figure 2.6.

All placement within the reservoir would occur within silt curtains and would be subject to a detailed monitoring regime including survey monitoring of pre-placement and post-placement bathymetry, local and remote background water quality monitoring during placement with a structured management response to monitoring results in the event of an exceedance of established triggers. The management, mitigation and monitoring measures would be refined following the ongoing investigations.

2.5 Accommodation camp

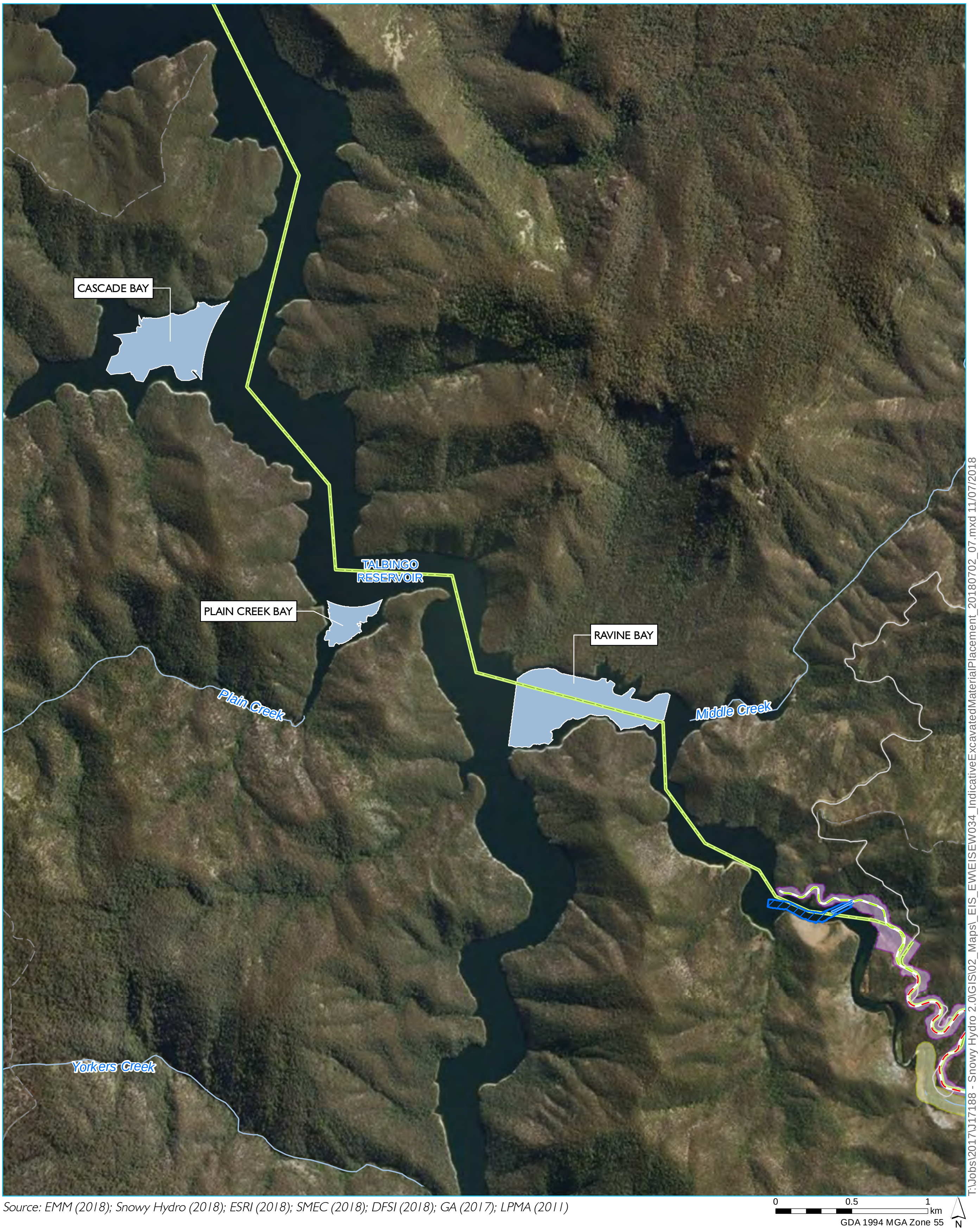
An accommodation camp is proposed to provide accommodation and supporting services for workers in close proximity to the exploratory tunnel. The accommodation camp layout is shown on Figure 2.7 and includes ensuite rooms surrounding central facilities including a kitchen, tavern, gym, admin office, laundry, maintenance building, sewage and water treatment plants and parking that will service the Exploratory Works workforce. The accommodation camp access road will connect to the north side of Lobs Hole Road at Lobs Hole. The conceptual layout of the accommodation camp is shown on Figure 2.7.

2.6 Road and access provisions

Existing road and access will need to be upgraded to a suitable standard to:

- provide for the transport of excavated rock material between the exploratory tunnel and the excavated rock emplacement areas;
- accommodate the transport of oversized loads as required; and
- facilitate the safe movement of plant, equipment, materials and construction staff to the portal construction pad.

Given the topographic constraints of the area, the standard of the existing roads and the environmental values associated with KNP, the option of barging larger and oversized loads to the site is available. This is discussed further at Section 2.7.



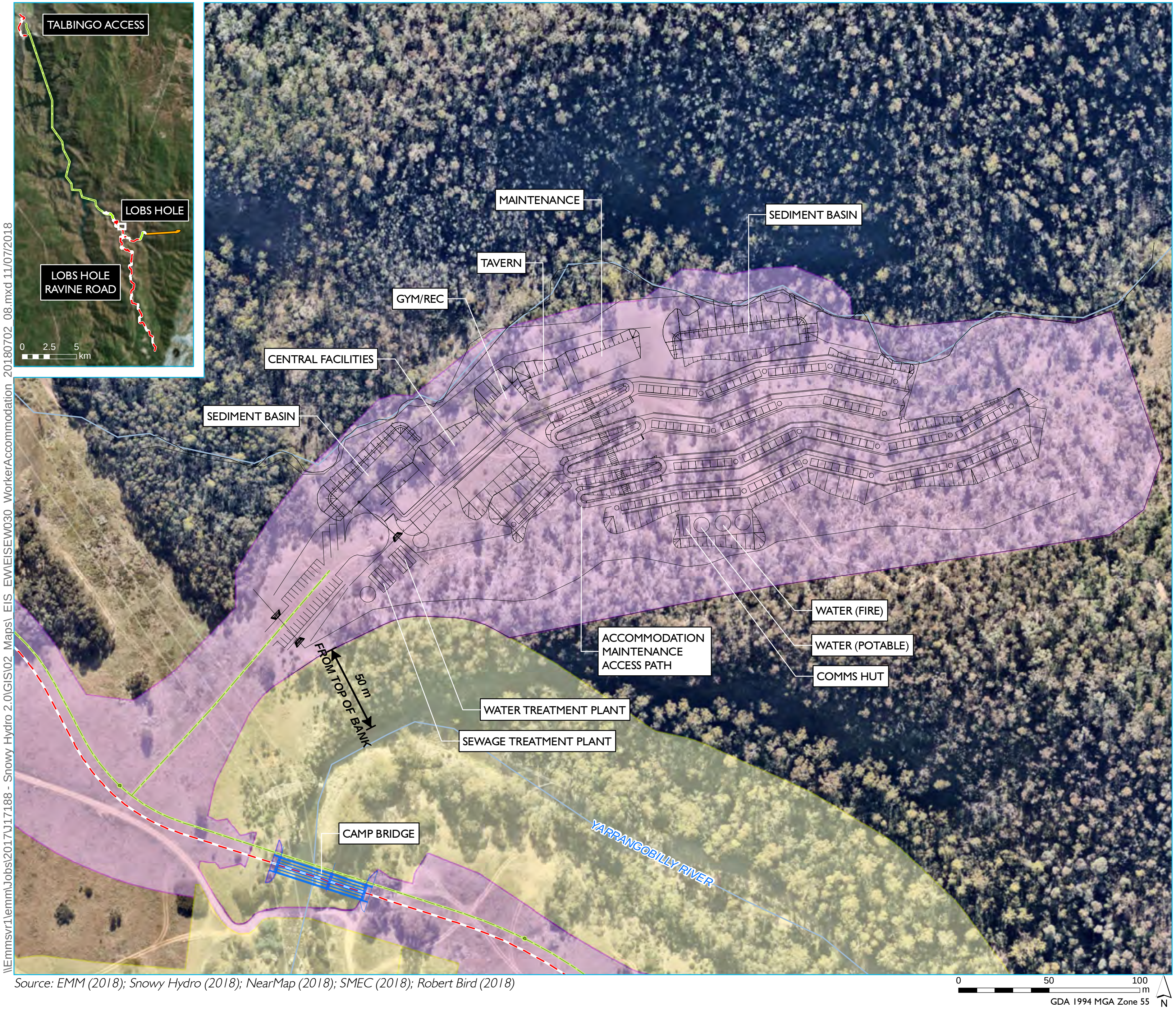
Source: EMM (2018); Snowy Hydro (2018); ESRI (2018); SMEC (2018); DFSI (2018); GA (2017); LPMA (2011)

KEY

- Access road upgrade
- Access road extension
- Communications cable
- Subaqueous rock emplacement
- Major watercourse
- Local road
- Track
- Middle Bay barge access
- Disturbance area - barge infrastructure
- Disturbance footprint
- Avoidance footprint

Subaqueous excavated rock placement

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 2.6



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KEY

- Exploratory tunnel
- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Communications cable
- Watercourse
- Disturbance footprint
- Avoidance footprint

Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018)

Conceptual layout – accommodation camp

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 2.7

2.6.1 Access road works

The access road upgrades will be designed based on access for a truck and dog trailer. The proposed road works are shown in Figure 2.8 and described in Table 2.1. It is expected that the majority of materials and equipment will travel along the Snowy Mountains Highway, Link Road and Lobs Hole Ravine Road, with some required to travel on Miles Franklin Drive via Talbingo to Talbingo Dam Wall and be transferred via a barge to site. The primary haul routes for construction material on site are provided in Figure 2.9. Where existing roads are replaced by new access roads or road upgrades, the existing roads will be removed and rehabilitated in line with the rehabilitation strategy for Exploratory Works.

Table 2.1 Access road works summary

Roadwork area	Overview
Upper Lobs Hole Ravine Road upgrade	Minor upgrades to 7.5 km section of existing road. Only single lane access will be provided. No cut and fill earthworks or vegetation clearing will be undertaken.
Lower Lobs Hole Ravine Road upgrade	Upgrades to 6 km section of existing road involving cut and fill earthworks in some sections. Only single lane access will be provided.
Lobs Hole Road upgrade	Upgrade to 7.3 km section of existing road providing two-way access.
Mine Trail Road upgrade	Upgrade to 2.2 km section of existing track to two-way access.
Mine Trail Road extension	Establishment of a new two-way road providing access to the exploratory tunnel portal.
Middle Bay Road	Establishment of a new two-way road to the proposed Middle Bay barge ramp.
Spillway Road	Upgrade of a 3 km section of existing road to provide two-way access to the proposed Spillway barge ramp.

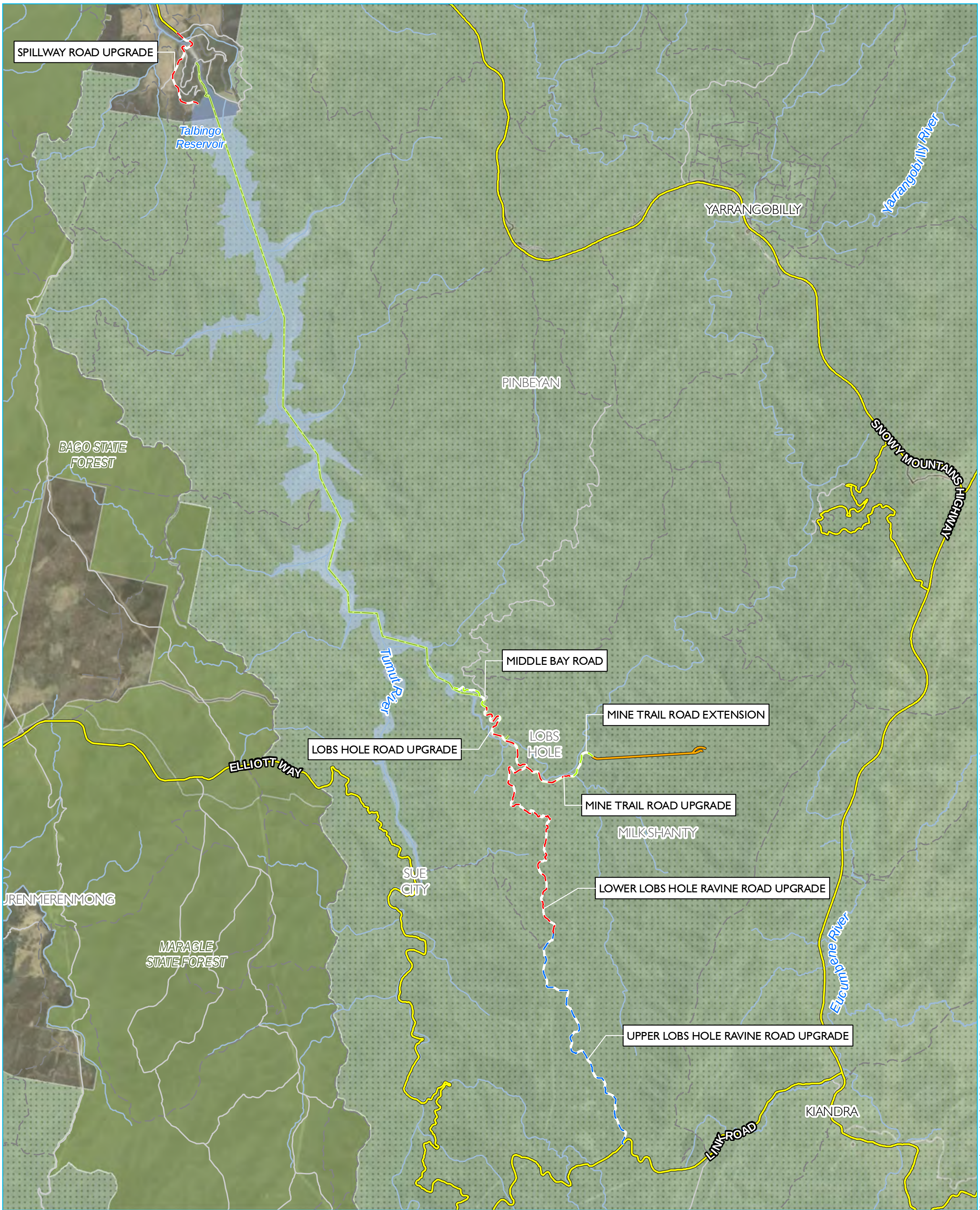
While no cut and fill earthworks or vegetation clearing is proposed along Upper Lobs Hole Ravine Road, a laydown area is proposed within and adjacent to the existing transmission line easement. This area will be used to store materials required for the road works to the lower section of Lobs Hole Ravine Road.

2.6.2 Watercourse crossings

Bridge construction will be required at two locations as described in Table 2.2. The locations of proposed bridge works are shown in Figure 2.9.

Table 2.2 Watercourse crossing summary

Bridge works area	Overview
Camp bridge	An existing crossing on Yarrangobilly River will be used as a temporary crossing while a new permanent bridge is built as part of Lobs Hole Road upgrade. The existing crossing will require the crossing level to be raised with rocks to facilitate vehicle passage. The rocks used to raise the crossing level will be removed and the crossing no longer used once the permanent bridge has been constructed. The new bridge (Camp Bridge) will be a permanent crossing and used for both Exploratory Works and Snowy 2.0 main works, should it proceed.
Wallaces Creek bridge	Establishment of a new permanent bridge at Wallaces Creek as part of the Mine Trail Road extension. Establishment of this bridge will require an initial temporary pre-fabricated 'Bailey bridge' to be constructed, which will be removed before the end of Exploratory Works.



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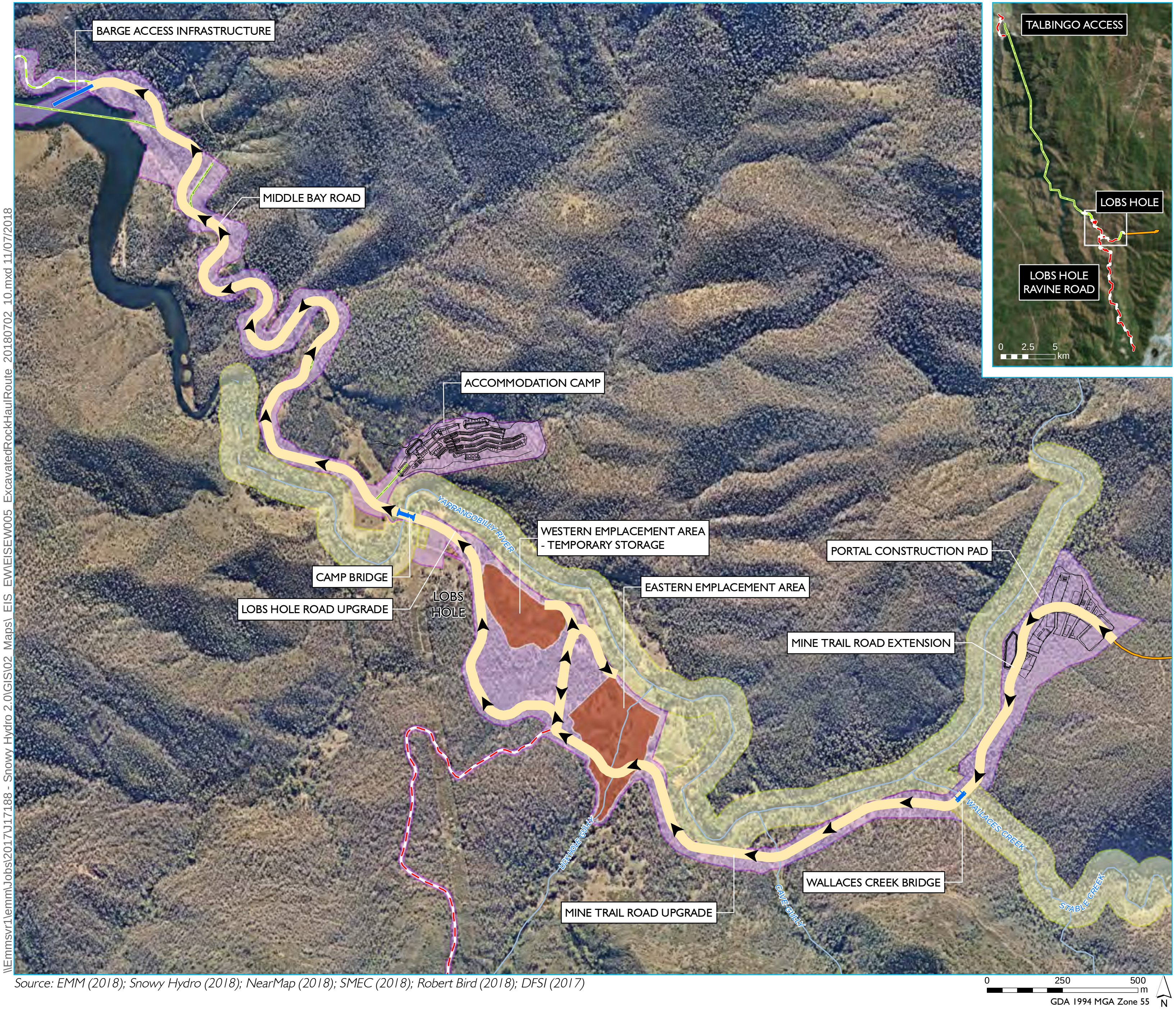
Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); DFSI (2017); GA (2015); LPMA (2011)

KEY

- Access road upgrade - without widening
- Access road upgrade - with widening
- Access road extension
- Exploratory tunnel
- Communications cable
- Main road
- Local road
- Vehicular track
- Perennial watercourse
- Scheme storage
- Kosciuszko National Park
- State forest

Access road upgrades and establishment

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 2.8



Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017)

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Excavated material haul route

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 2.9

The design for permanent bridges at both crossings will consist of steel girders with a composite deck. This is the most common type of permanent bridge constructed in and around the existing Snowy Scheme. Lightweight steel girders are easy to transport and will therefore allow for efficiencies in the construction schedule and permit the use of smaller-scale lifting equipment at the construction site.

2.7 Barge access infrastructure

To provide an alternative to road access, a barge option is proposed, not only for bulky and heavy equipments but for materials and also in case of emergency. During Exploratory Works, barges will be loaded at the northern barge ramp (Talbingo barge ramp), travel about 18 km along Talbingo Reservoir and be unloaded at the southern barge ramp (Middle Bay barge ramp) before returning to the north. Some loads may also be transported in the reverse direction.

Barge access infrastructure will comprise two dedicated barge ramps at Middle Bay and Talbingo Spillway, with a slope of approximately 1 vertical to 10 horizontal (1V: 10H) at each location. A navigation channel is also required adjacent to the Middle Bay barge ramp. Construction will involve:

- geophysical and geotechnical investigation of the barge access area to inform detailed design;
- site establishment and excavation of barge access area;
- installation of precast concrete panels at the ramp location;
- installation of bollards for mooring lines;
- removal of trees and debris to establish a navigation channel allowing barge access; and
- minor dredging to allow barge access at the reservoir minimum operating level.

To facilitate construction, laydown areas are proposed adjacent to the Middle Bay barge ramp and adjacent to the water inlet pipeline. Laydown will also be used within the footprint of the Talbingo barge ramp.

Dredged material will be placed as part of the subaqueous placement program or within one of the designated on land rock emplacement areas. The infrastructure proposed for the Talbingo Spillway barge ramp and Middle Bay barge ramp is provided in Figure 2.10.

2.8 Services and infrastructure

The Exploratory Works will require additional power and communication infrastructure. Water services are also needed and include a water services pipeline and water and waste water (sewage) treatment facilities. A summary of services required is provided at Table 2.3.

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Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); DFSI (2017); LPMA (2011)

GDA 1994 MGA Zone 55

N

KEY

- Exploratory tunnel
- Access road upgrade
- Access road extension
- Communications cable
- Main road
- Local road or track
- Perennial watercourse
- Middle Bay barge access
- Disturbance area - barge infrastructure
- Disturbance footprint
- Avoidance footprint

Barge access locations

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 2.10

snowy 2.0 EMM

Table 2.3 Summary of services and infrastructure

Services infrastructure	Description
Power	Power will be provided at the portal construction pad and accommodation camp by diesel generators, with fuel storage provided at the portal construction pad.
Communication	Communication will be provided via fibre optic link. The fibre optic service has been designed to incorporate a submarine cable from Tumut 3 power station across Talbingo Reservoir to Middle Bay, and then via a buried conduit within the access roads to the accommodation camp and the portal construction pad.
Water and waste water (sewage)	A water services pipeline is proposed for the supply and discharge of water for Exploratory Works which will pump water between Talbingo Reservoir and the exploratory tunnel portal, portal construction pad and accommodation camp.
	A package water treatment plant is proposed at the accommodation camp to provide potable water to the accommodation camp and portal construction pad facilities and will be treated to a standard that complies with the Australian Drinking Water Guidelines. The accommodation camp water supply will be pumped via the water pipeline from Talbingo Reservoir at Middle Bay.
	A package waste water (sewage) treatment plant (STP) is proposed at the accommodation camp for Exploratory Works waste water. The STP will produce effluent quality comparable to standard for inland treatment facilities in the region (eg Cabramurra). Following treatment waste water will be discharged to Talbingo reservoir via the water services pipeline connecting the accommodation camp to Talbingo Reservoir. Waste water from the exploratory tunnel and concrete batching plant will be either re-used on site or sent to the waste water treatment plant for treatment prior to discharge.

2.9 Construction and schedule

2.9.1 Geotechnical investigation

To assist the design development for the portal construction pad, accommodation camp, Middle Bay Road, Spillway Road, and Lobs Hole Ravine Road, further survey of ground conditions is required. A program of geotechnical investigations including geophysical survey, construction of test pits, and borehole drilling within the disturbance footprint, will be undertaken as part of construction activities. Excavation of test pits in areas where information on relatively shallow subsurface profiles is required, or where bulk sampling is required for laboratory testing. Borehole drilling is required to facilitate the detailed design of cuttings, bridge foundations, retaining wall foundations, and drainage structures.

2.9.2 Construction activities

A disturbance footprint has been identified for Exploratory Works. The extent of the disturbance footprint is shown on Figure 2.1 and shows the area required for construction, including the buildings and structures, portal construction pad, road widening and bridges, laydown areas, and rock emplacement areas. Typical construction activities that will occur within the footprint are summarised in Table 2.4.

Table 2.4 Construction activities

Activity	Typical method
Geophysical and geotechnical investigation	Geophysical surveys will generally involve: • laying a geophone cable at the required location and establishing seismic holes; • blasting of explosives within seismic holes; and • in-reservoir geophysics surveys will use an air gun as the seismic source. Geotechnical surveys will generally involve: • establishing a drill pad including clearing and setup of environmental controls where required; • drilling a borehole to required depth using a tracked or truck mounted drill rig; and • installing piezometers where required for future monitoring program. Geophysical and geotechnical investigation within Talbingo Reservoir will be carried out using barges and subject to environmental controls.
Site establishment for portal construction pad, accommodation camp, rock placement areas and laydown areas	Site establishment will generally involve: • identifying and flagging areas that are to be avoided during the Exploratory Works period; • clearing of vegetation within the disturbance footprint, typically using chainsaws, bulldozers and excavators; • civil earthworks to create a stable and level area suitable for establishment. This will involve a cut and fill approach where required to minimise the requirement for imported material; • installing site drainage, soil erosion and other permanent environmental controls where required; • surface finishing, compacting only existing material where possible, or importing additional material. Where suitable, this material will be sourced locally (eg from upgrade works to Lobs Hole Ravine Road); and • set up and commissioning of supporting infrastructure, including survey marks.
Road works	Upgrades of existing tracks (no widening) will generally involve: • identifying and flagging areas that are to be avoided during the Exploratory Works period; and • removing high points, infilling scours, levelling of rutting, and compacting surfaces. Extension or widening of existing tracks will generally involve: • identifying and flagging areas that are to be avoided during the Exploratory Works period; • installing site drainage, soil erosion and other permanent environmental controls where required; • clearing and earthworks within the disturbance footprint; and • placing road pavement material on the roadway.
Bridge works	Establishment of permanent bridges will generally involve: • installing erosion and sedimentation controls around watercourses and installing scour protection as required; • establishing temporary diversions within the watercourse where required, including work to maintain fish passage; • establishing temporary bridges to facilitate permanent bridge construction; • constructing permanent bridges including piling, establishment of abutments and piers; and • removal and rehabilitation of temporary bridges and diversions.
Barge access works	Establishment of barge access infrastructure will generally involve: • installing sediment controls; • excavating and dredging of barge ramp area and navigation channel; • installing precast concrete planks and bollards; and • set up and commissioning of supporting infrastructure.

Table 2.4 Construction activities

Activity	Typical method
Exploratory tunnel construction	The drill and blast excavation process will be repeated cyclically throughout the tunnelling works, involving: • marking up and drilling blast holes in a predetermined pattern in the working face of the tunnel; • loading the blast holes with explosives, attaching detonators and connecting the holes into a blast sequence, and detonating the blast; • ventilating the tunnel to remove blast fumes and dust; • removing blasted rock; • scaling and wash down of the tunnel roof and walls to remove loosened pieces of rock; • geological mapping of the exposed rock faces and classification of the conditions to determine suitable ground support systems for installation; • installing ground support; and • advancing construction ventilation ducting and other utilities including power, water, compressed air and communications.

2.9.3 Ancillary construction areas

Ancillary facilities and laydown areas have been identified within the conceptual layout for the portal construction pad and accommodation camp. A number of other indicative construction and laydown areas have also been identified to support Exploratory Works. A summary of these sites are:

- Upper Lobs Hole Ravine Road laydown area;
- rock emplacement area laydown, storage and ancillary uses;
- barge access infrastructure laydown areas at Talbingo and Middle Bay; and
- other minor laydown areas as needed during site establishment of watercourse crossings.

All laydown areas are within the disturbance footprint identified for Exploratory Works.

In addition, an area near Camp Bridge has been identified to be used for a plant nursery and organic stockpile area.

2.9.4 Construction workforce requirements

i Staffing levels

It is currently expected that workforce for Exploratory Works will be approximately 200 people in total at peak construction. Workers are anticipated to work a ‘swing’ shift, for example two weeks on and one week off. These workers will be accommodated within the accommodation camp at Lobs Hole when rostered on.

The majority of the workforce will work on a fly-in fly-out and drive-in drive-out basis. It is expected that the majority of workers will fly in and out of either Cooma Airport or Canberra Airport and then travel to site via bus.

During construction of the accommodation camp, workers will be accommodated at Cabramurra. Some workers may also be accommodated at Snowy Hydro existing accommodation units at Talbingo during construction of the Talbingo barge ramp. No accommodation will be required outside of Cabramurra, the construction accommodation camp or Talbingo for the Exploratory Works workforce.

ii Hours of operation

It is expected that construction of the exploratory tunnel and haulage of rock material between the tunnel and excavated rock stockpile locations at Lobs Hole will be 24 hours a day, seven days a week for the duration of the tunnel drilling and blasting operation. Other construction activities, including the establishment works, road and infrastructure works, will normally work a 12 hour day, seven days a week.

The transport of materials along the haul route from Snowy Mountains Highway, Link Road and Upper Lobs Hole Ravine Road will only occur during day time hours (except during emergency), to avoid impacts to threatened species (Smoky Mouse). Transport by barge will be 24 hours a day, seven days a week.

2.9.5 Timing and staging

Exploratory Works are expected to take about 34 months, with the exploratory tunnel expected to be completed by late 2021.

It is expected that the construction works will be completed largely in parallel. However, road and access works are expected to be completed within the first six months from commencement. The proposed staging of construction activities are highlighted in Figure 2.11.

Figure 2.11 Indicative timing of Exploratory Works elements

2.10 Site rehabilitation

All Exploratory Works align with components of the main works for Snowy 2.0. However, should Snowy 2.0 not be approved or not progress, the project area will need to be rehabilitated, and project elements decommissioned in consultation with NPWS. Anticipated rehabilitation activities are summarised in Table 2.5.

Table 2.5 Planned Exploratory Works rehabilitation activities

Exploratory Works element	Indicative rehabilitation activities
Exploratory tunnel	Tunnel to remain open, and allowed to flood in lower portion provided groundwater impacts are negated.
Exploratory tunnel portal area	Permanent portal facade to be constructed, portal to be sealed from entry.
Portal construction pad and associated infrastructure	To be demobilised and all infrastructure removed. Site to be revegetated and returned to “original state”.
Excavated rock emplacement areas	Emplaced excavated rock in the western emplacement area to be removed offsite and area to be revegetated and returned to “original state”. The eastern emplacement area could remain in-situ and the landform rehabilitated as agreed with NPWS.
Accommodation camp	To be demobilised and all infrastructure removed. Site to be revegetated and returned to “original state”.
Road access works	No remediation required as works are to be designed to be permanent.
Barge access infrastructure	No remediation works required as wharf and loading ramps are designed as permanent. Wharf can be removed if desired.
Services and infrastructure	To be demobilised and all infrastructure removed. Site to be revegetated and returned to “original state”.

2.11 Decommissioning

Should Snowy 2.0 not proceed following the commencement or completion of Exploratory Works, elements constructed are able to be decommissioned and areas rehabilitated. Given works are within KNP, Snow Hydro will liaise closely with NPWS to determine the extent of decommissioning and types of rehabilitation to be undertaken. This approach will be taken to ensure that decommissioning allows for integration with future planned recreational use of these areas and to maintain the values of KNP.

2.12 Key aspects relevant to surface water assessment

The assessment has been informed by the reference design prepared for the Exploratory Works. The following aspects of project are considered relevant to this assessment:

- Flood risk management associated with the following works that are proposed on flood prone land:
  - Camp and Wallaces Bridges;
  - the western rock and soil emplacement area; and
  - the water management basin for the construction pad.
- Water management during construction of access roads, the accommodation camp, construction pad and other infrastructure.
- Water management during operation including:
  - stormwater runoff from the access roads, accommodation camp and construction pad;
  - water produced by and used by the proposed construction activities; and
  - waste water (ie sewage).

- Water management approach for rock and soil emplacement areas.

This assessment recommends controls to mitigate potential impacts. These controls will be considered in the detailed design of the Exploratory Works.

3 Regulation and Guidelines

This section describes assessment requirements and government regulation, plans and guidelines that have been considered in this assessment.

3.1 NSW regulatory framework

Water (both supply and discharge) will be used throughout the construction of Exploratory Works. The primary water related statutes that apply to Exploratory Works are the *NSW Water Management Act 2000* (WMA 2000), *Water Act 1912 (*WA 1912*), Protection of the Environment Operations Act 1997* (POEO Act), and their attendant regulations (including water sharing plans under the WMA 2000).

3.1.1 Water Act 1912

The WA 1912 is gradually being repealed and replaced by the WMA 2000 as water sharing plans (WSPs) are developed for water sources across NSW, and as new regulations are made. However, some aspects of the WA 1912 are still operational across all of NSW. Licences for monitoring bores greater than 40 m in depth are the only expected commitment under the WM 1912 for the Exploratory Works.

3.1.2 NSW Water Management Act 2000

The WMA 2000 is the relevant statute for the regulation water take from surface and alluvial water sources. The act provides for water sharing between different water users, including environmental, basic rights or existing water access licence (WAL) holders and provides security for licence holders. The licensing provisions of the WMA 2000 apply to those areas where a Water Sharing Plan (WSP) has commenced.

i Water Sharing Plans

WSPs are statutory documents that apply to one or more water source areas. They contain the rules for sharing and managing the water resources within water source areas. WSPs describe the basis for water sharing, and document the water available and how it is shared between environmental, extractive, and other uses. The WSPs then outline the water available for extractive uses within different categories, such as local water utilities, domestic and stock, basic rights and access licences.

The *Water Sharing Plan for the Murrumbidgee unregulated and alluvial water sources (2012)* applies to surface and alluvial water sources within the Exploratory Works project area. The Exploratory Works are located within the Upper Tumut water source which covers all contributing catchment areas to Blowering Reservoir. Existing surface water allocations within the Upper Tumut water source are shown in Table 3.1.

The dominant use of water in the Upper Tumut water source is for town water supply, with the past three water years (ie 2015/16 to 2017/18) reporting usage of between 12.2 and 67.5 ML/yr, significantly below the total annual share component of 153 ML/yr.

Table 3.1 Water rights and allocations in the unregulated WSP for the Murrumbidgee unregulated and alluvial water sources 2012 – Upper Tumut

Surface water source	Unit	Upper Tumut
Basic landholder rights		
Domestic and stock	ML/day	nd
Native title	ML/yr	0
Harvestable rights		nd
Water access licences		
Domestic and stock licences	ML/yr	7
Local water utility licences	ML/yr	153
Unregulated river access licences (tradeable)	Unit shares	45

Notes: nd - volume not defined based on an entire water source.

3.1.3 Protection of the Environment Operation Act 1997

The POEO Act establishes the NSW environmental regulatory framework and includes licensing requirements for certain activities. EPLs for water discharge and waste water treatment systems are administered by the NSW Environment Protection Authority (EPA) under the POEO Act.

3.2 Snowy Hydro Corporatisation Act 1997

The NSW *Snowy Hydro Corporatisation Act 1997* (SHC Act) came into effect on 28 June 2002. The Act enabled the corporatisation of the former Commonwealth Snowy Mountains Hydro-Electric Authority to Snowy Hydro Limited, and entitled Snowy Hydro to a number of key operating instruments to enable the continued operation of the existing Snowy Scheme.

Part 4 and 5 of the SHC Act relates to water. Part 4 sets out the terms and timing for the Snowy Water Inquiry which was to examine environmental issues arising in rivers and streams from the operations of the Snowy Scheme. Part 5 established the entitlement of Snowy Hydro to the Snowy Water Licence and prescribes the basic rights and obligations that are to be contained in the licence.

The Snowy Water Licence embodies the operating and accounting principles of the Snowy Scheme. The Snowy Water Licence confers the following rights on Snowy Hydro:

- to collect all water from the rivers, streams and lakes within the Snowy Water Catchment;
- to divert that water;
- to store that water;
- to use that water to generate electricity and for purposes that are incidental or related to the generation of electricity; and
- to release that water from storage.

Snowy Hydro's rights are subject to the rights of certain other occupiers to take and use water (eg local councils). In addition to these rights, the Snowy Water Licence also sets out Snowy Hydro's water related obligations, in particular, release obligations.

3.3 Relevant Guidelines

The following guidelines are referenced in this assessment.

3.3.1 Guidelines for controlled activities on waterfront land

The WMA 2000 defines waterfront land as the bed of any river, lake or estuary and any land within 40m of the river banks, lake shore or estuary mean high water mark. Controlled activity approvals are generally required for works on waterfront land. Guidelines for controlled activities have been prepared by the NSW Department of Industry – Water (DoI –Water). These guidelines provide information on the design and construction of a controlled activity, and other ways to protect waterfront land.

The Exploratory Works are categorised as CSSI under section 89J (1) (g) of the EP&A Act 1979. Should approval be granted, a controlled activity approval to undertake work on waterfront land will not be required.

3.3.2 Australian Rainfall and Runoff

Australian Rainfall and Runoff (Commonwealth of Australia, 2016) is a national guideline document, data and software suite that can be used for the estimation of design flood characteristics in Australia. This guideline is referred to as ARR2016 in the remainder of this document.

3.3.3 Floodplain Development Manual

The NSW Floodplain Development Manual is a document published in 2005 by the NSW Government. The document details flood prone land policy which has the primary objective of reducing the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods. At the same time, the policy recognises the benefits from occupation and development of flood prone land.

3.3.4 Erosion and Sediment Control Guidelines

The following NSW government guidelines have been referred to when developing erosion and sediment control strategies for the project:

- Managing Urban Stormwater: Soils and Construction – Volume 1 (Landcom, 2004);
- Managing Urban Stormwater: Soils and Construction – Volume 2C – Unsealed roads (DECC, 2008); and
- Managing Urban Stormwater: Soils and Construction – Volume 2D – Main road construction (DECC, 2008).

3.3.5 Bunding and Spill Management Guidelines

The following NSW Government guidelines detail best practice storage, handling and spill management procedures for liquid chemicals:

- Liquid Chemical Storage, Handling and Spill Management: Review of Best Practice Regulation (DECC, 2005); and
- Storing and Handling Liquids: Environmental Protection: Participant's Manual (DECC, 2007).

3.3.6 Australian Guidelines for Water Quality Monitoring and Reporting – ANZECC, 2000

The Australian and New Zealand Environment Conservation Council (ANZECC) published the revised Australian and New Zealand guidelines for fresh and marine water quality in 2000. These guidelines provide a framework for:

- assessing and managing water quality for environmental values;
- establishing water quality objectives; and
- establishing protection levels, water quality indicators and trigger values.

4 Existing surface water environment

This section provides a description of the existing surface water environment in the vicinity of the Exploratory Works and is structured as follows:

- Section 4.1 describes the general setting at Lobs Hole where most of the construction activities will occur;
- Section 4.2 describes rainfall and evaporation characteristics;
- Section 4.3 provides a summary of soil characteristics;
- Section 4.4 describes the catchments, flow regimes and key features of the Yarrangobilly River and its tributaries;
- Section 4.5 describes Talbingo Reservoir and its operating regime; and
- Section 4.6 describes the water quality in the Yarrangobilly River, Wallaces Creek and Talbingo Reservoir.

Existing flood characteristics are discussed separately in Chapter 5.

4.1 Setting

The Exploratory Works will predominantly be in the Ravine region of the KNP. This region is between Talbingo Reservoir to the north-west and the Snowy Mountains Highway to the east. Major infrastructure including the construction pad, accommodation camp and access roads will be in Lobs Hole.

The Yarrangobilly River is the defining feature of Lobs Hole. The river initially flows in a southerly direction before turning to the west, towards Talbingo Reservoir. The river's floodplain levels range from 545 m AHD at the river's interface with Talbingo Reservoir to approximately 585 m AHD adjacent to the construction pad. There are some areas of relatively flat and open terrain within or adjacent to the floodplain, which ranges in width between 100 to 350 m. The floodplain is generally bound by steep topography which rises up to mountain ranges that have peak elevations ranging from 800 to 1,500 m AHD.

Former mine workings including shafts and spoil piles are located on the Yarrangobilly River floodplain and immediate areas. These works are remnant from copper mines that operated intermittently between 1874 and 1919.

4.2 Weather

Lobs Hole is within the western extent of the Australian Alps. The climate of the Australian Alps is influenced by three features of the general circulatory system affecting south-eastern Australia (Brown and Millner, 1988):

- the latitudinal position of the westerly airstream that encircles the southern hemisphere;
- the influence of depressions lying off the east coast of NSW; and
- the occasional intrusion of moist tropical air masses from northern Australia.

In general, in winter and spring there is a predominance of westerly weather that results in regular precipitation on the western slopes. Precipitation depths increase in the alpine areas due to orographic effects. From late autumn to early spring, precipitation at the higher elevations predominantly occurs as snow. Snow cover usually begins to form in the highest areas in late autumn. By the middle of June areas above 1500 m AHD are usually covered. Snow cover usually peaks in August and begins to melt in late winter through to early spring (Brown and Millner 1988).

Summer and autumn are generally drier with the weakening of the westerly circulation. However, there are occasional intrusions of moist air which results in thunderstorm activity that tends to favour the eastern slopes. Summer rainfall is generally of higher intensity and of shorter duration than winter rainfall (Brown and Millner 1988).

The following sections provide further information on rainfall and evaporation characteristics at Lobs Hole.

4.2.1 Rainfall

This section describes rainfall characteristics within the Yarrangobilly River catchment using available information from regional Bureau of Meteorology (BoM) rainfall gauges and rainfall maps that are also produced by BoM. Rainfall characteristics within the catchment are relevant to understanding the Yarrangobilly River flow regime, while rainfall characteristics at Lobs Hole are relevant to water management for Exploratory Works. It is noted that some rainfall will occur as snowfall and should correctly be referred to as precipitation. However, the term rainfall has been used to maintain consistency with other sections of the EIS.

The following rainfall gauges are within the proximity to the Yarrangobilly River catchment and provide the best available information on rainfall within the catchment:

- Talbingo (72131) – this gauge is within the township of Talbingo, approximately 3.5 km to the north of the Tumut 3 Power Station and 26 km to the north-west of Lobs Hole. The gauge elevation is 395 m AHD, which is approximately 150 to 200 m lower than levels at Lobs Hole (550 to 600 m AHD).

- Cabramurra SMHEA AWS (72161) – this gauge is approximately 8 km to the south-west of the head waters of Wallaces Creek, which is a major tributary to the Yarrangobilly River catchment. The gauge elevation is 1,482 m AHD.

- Yarrangobilly Caves (72141) – this gauge is centrally in the Yarrangobilly River catchment. The gauge elevation is 980 m AHD.

Figure 4.1 locates these three gauges relative the Yarrangobilly River Catchment and the Exploratory Works. Median annual rainfall depth contours that were sourced from BoM's online climate maps are also shown. Table 4.1 presents key information and statistical data from the three gauges.

Table 4.1 Rainfall statistics[1]

Rainfall[2] Statistics (annualised)		Talbingo (72131)	Cabramurra SMHEA AWS (72161)	Yarrangobilly Caves (72141)
Rainfall record		1997 - present	1996 - present	1906 – 1919 1978 - present
Distance from Lobs Hole	(km)	25 km to the north west	15 km to the south	15 km to the north-east
Elevation (m AHD)	(m AHD)	395	1482	980
Average rainfall	(mm/year)	952	1178	1169
Lowest rainfall	(mm/year)	361	567	552
5th percentile rainfall	(mm/year)	663	877	818
10th Percentile rainfall	(mm/year)	771	992	905
Median rainfall	(mm/year)	946	1202	1158
90th percentile rainfall	(mm/year)	1220	1386	1511
95th percentile rainfall	(mm/year)	1313	1427	1535
Highest rainfall	(mm/year)	1343	1634	1902

Notes: *1.Data sourced from BoM website (climate data online)*

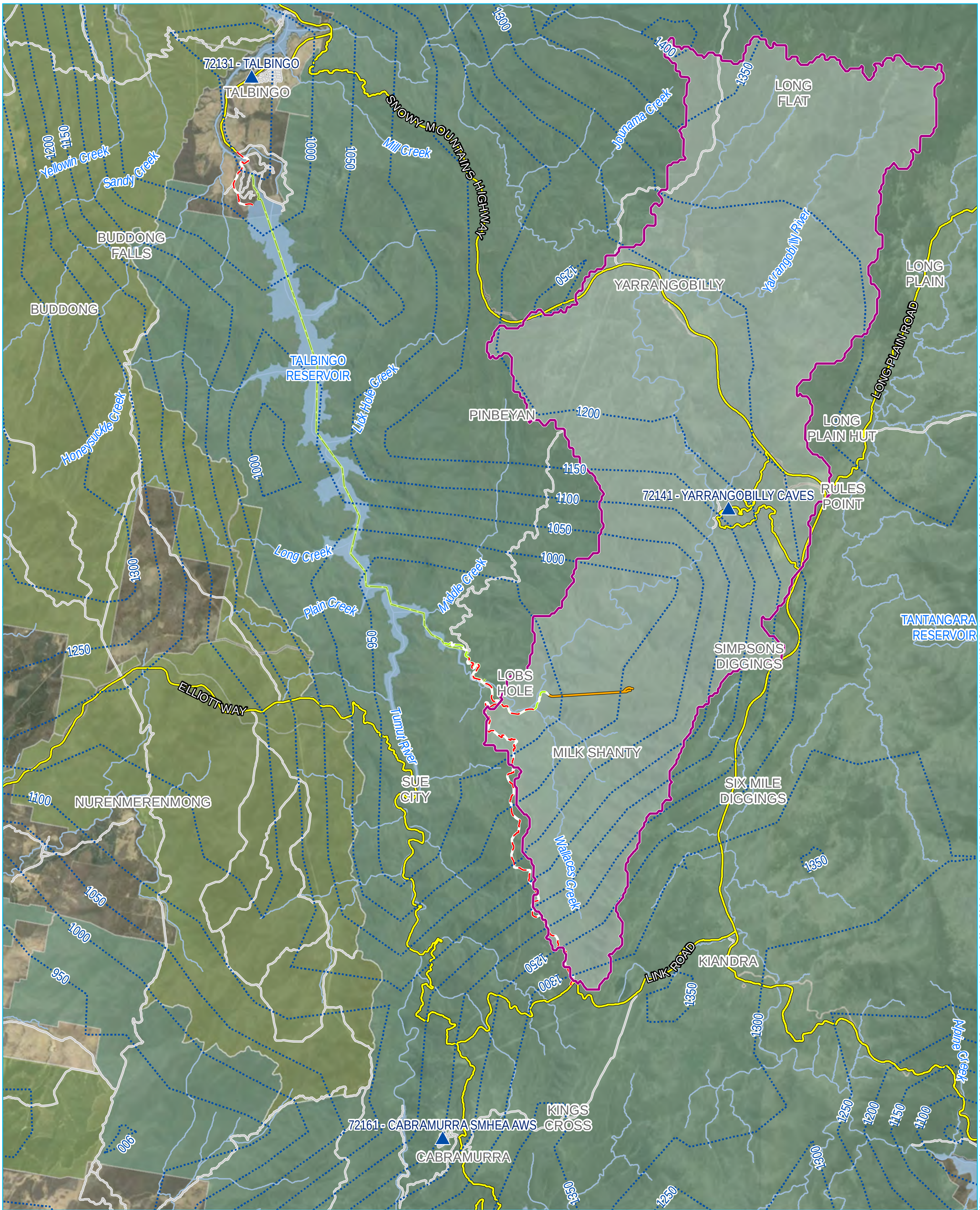
2. Some precipitation will occur as snow fall but has been referred to as rainfall to maintain consistency with other sections in the EIS.

The median annual rainfall depth contours shown in Figure 4.1 indicate that median rainfall within the Yarrangobilly River catchment ranges from 1,400 mm/year in the head water catchments to the 950 mm/year at Lobs Hole. The spatial variation in median rainfall generally reflects the variation in topography within the catchment. The median annual rainfall depth contours are consistent with median values from the three rainfall gauges. This information indicates that:

- Stream flows in the Yarrangobilly River are likely to be primarily influenced by runoff from the headwater catchments that receive higher rainfall, rather than runoff from lower portions of the catchment around Lobs Hole.

- The median annual rainfall depth contours shown in Figure 4.1 indicate that the median annual rainfall at Lobs Hole is similar to median annual rainfall at Talbingo. This indicates that rainfall characteristics at Lobs Hole and Talbingo are likely to be similar. Accordingly, the Talbingo rainfall gauge (72131) record is considered to be the most reliable representation of rainfall characteristics at Lobs Hole. This rainfall record has been applied to stormwater management calculations that are presented in subsequent sections of this report.

Figure 4.2 plots the 10th, 50th and 90th percentile monthly rainfall depths that have been calculated by BoM from the Talbingo (72131) gauge record. This information indicates that the highest and most consistent rainfall occurs in winter to early spring. Rainfall in summer is more variable with significant differences between the 10th and 90th percentile monthly rainfall depths.



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Source: EMM (2018); Snowy Hydro (2018); DFSI (2017); GA (2015); LPMA (2011)

KEY

- Rainfall gauge
- Median rainfall contour (50 mm)
- Exploratory tunnel
- Access road upgrade
- Access road extension
- Communications cable
- Main road
- Local road
- Perennial watercourse
- Yarrangobilly River catchment area
- Scheme storage
- NPWS reserve
- State forest

Rainfall in the Yarrangobilly River catchment

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 4.1

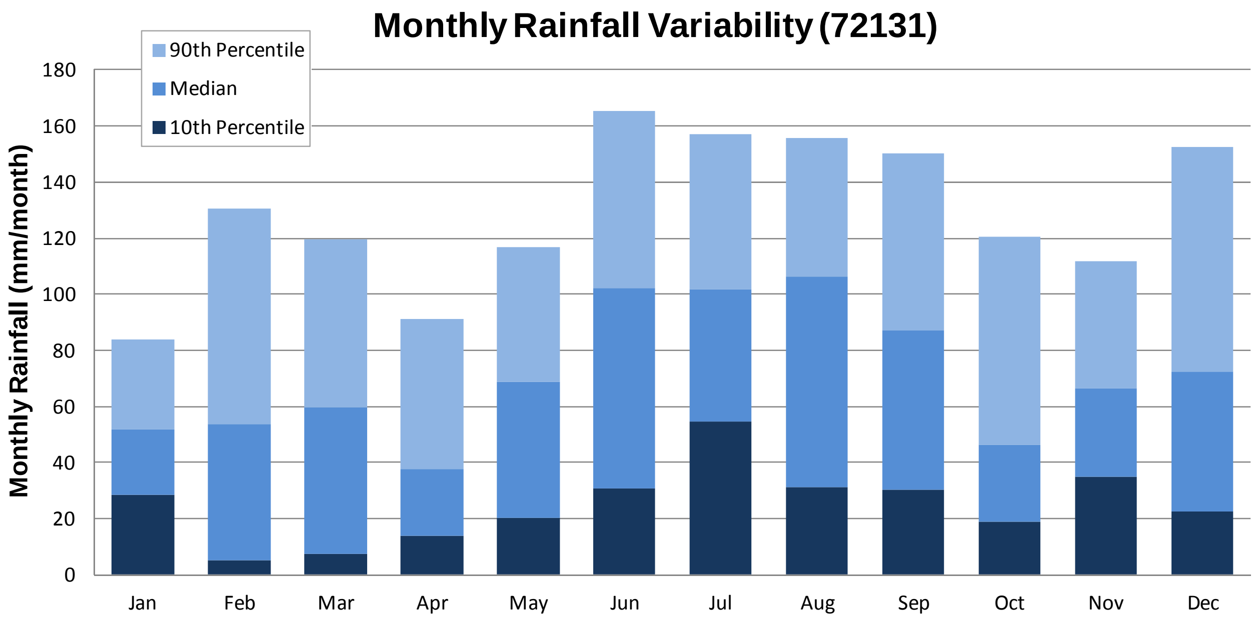


Figure 4.2 Monthly rainfall variability at Talbingo

i Design rainfall information at Lobs Hole

Design rainfall information is used to calculate aspects of the stormwater management system. The following design rainfall information has been established for the Lobs Hole area:

- Table 4.2 provides design rainfall depths for a range of Annual Exceedance Probability (AEP) events of varying duration. This information was sourced from the ARR2016 data portal; and
- Table 4.3 presents rainfall depths for 2, 5, 10 and 20 day rainfall events. This information was calculated from the Talbingo (72131) rainfall record and is used for establishing sedimentation basin volumes.

Table 4.2 Design rainfall depths from Australian Rainfall and Runoff 2016

	Annual Exceedance Probability (AEP) – Rainfall depths (mm)						
	63.2%	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**
15 min	10	11	14	17	20	24	27
30 min	13	14	19	22	26	31	35
1 hour	17	18	24	28	32	38	43
2 hour	21	24	30	35	40	47	52
3 hour	25	27	35	40	46	53	59
6 hour	32	36	46	52	59	69	76
12 hour	42	46	60	69	78	91	101
24 hour	54	59	77	89	101	118	131
48 hour	65	73	95	109	123	144	160
72 hour	72	80	104	120	134	156	173

Notes: *Data sourced from Australian Rainfall Runoff Data Portal.*

Table 4.3 Design rainfall depths for frequent events

	Rainfall Duration			
	2 day	5 day	10 day	20 day
80th Percentile event	7.5 mm	24.2 mm	47.4 mm	86.9 mm
85th Percentile event	11.4 mm	30.6 mm	56.0 mm	99.0 mm
90th Percentile event	18.4 mm	41.6 mm	68.1 mm	116.0 mm
95th Percentile event	30.0 mm	56.8 mm	85.0 mm	138.0 mm

Notes: Rainfall depths have been calculated from the Talbingo (72131) gauge record

4.2.2 Evaporation

Mean annual pan evaporation in the Australian Alps ranges from approximately 1,400 mm/year at an elevation of 400 m AHD to approximately 1,000 mm/year at an elevation of 1,300 m AHD (Brown and Millner 1988). Table 4.4 presents regional monthly mean evaporation and potential evapotranspiration data sourced from evaporation records at Eucumbene (Brown and Millner 1988) and climate maps that are available from BoM's website. This information is considered to be representative of evaporation characteristics at Lobs Hole in areas that receive full sun. Areas that are partially shaded (such as a road cut into steep topography) would be expected to have lower evaporation rates.

Table 4.4 Evaporation and evapotranspiration data

		Mean Class A pan evaporation		Mean areal potential evapotranspiration
Month	**Units**	**Eucumbene Dam[1]**	**BoM[2]**	**BoM[2]**
January	mm/month	205	206	156
February	mm/month	158	169	118
March	mm/month	133	139	102
April	mm/month	87	76	69
May	mm/month	45	42	47
June	mm/month	30	27	37
July	mm/month	31	29	41
August	mm/month	45	46	54
September	mm/month	77	69	73
October	mm/month	117	110	115
November	mm/month	148	148	140
December	mm/month	192	191	140
Annual	mm/year	**1,268**	**1,255**	**1,091**

Notes: 1. Data Source (Brown and Millner, 1988)
2. Data Source BoM website (climate data online)

4.2.3 Recent weather

Figure 4.3 plots the monthly rainfall totals that were recorded at Talbingo from 1997 to present. The deviation of rainfall totals over the previous 12 month period have been calculated and compared to annualised monthly average rainfall to identify and characterise periods of extended dry and wet conditions. The magnitude and extent of wet and dry periods can be inferred by the shape and value of the deviation curve. This analysis indicates that:

- below average rainfall occurred during the 2001 to 2003, 2006 to mid 2007, and mid 2012 to 2014 periods; and
- above average rainfall occurred during the 2000 to 2001, 2010 to 2012, and 2016 periods. Significant flood events occurred in the Yarrangobilly River in October 2010 and March 2012. Further information on these events is provided in Chapter 5.

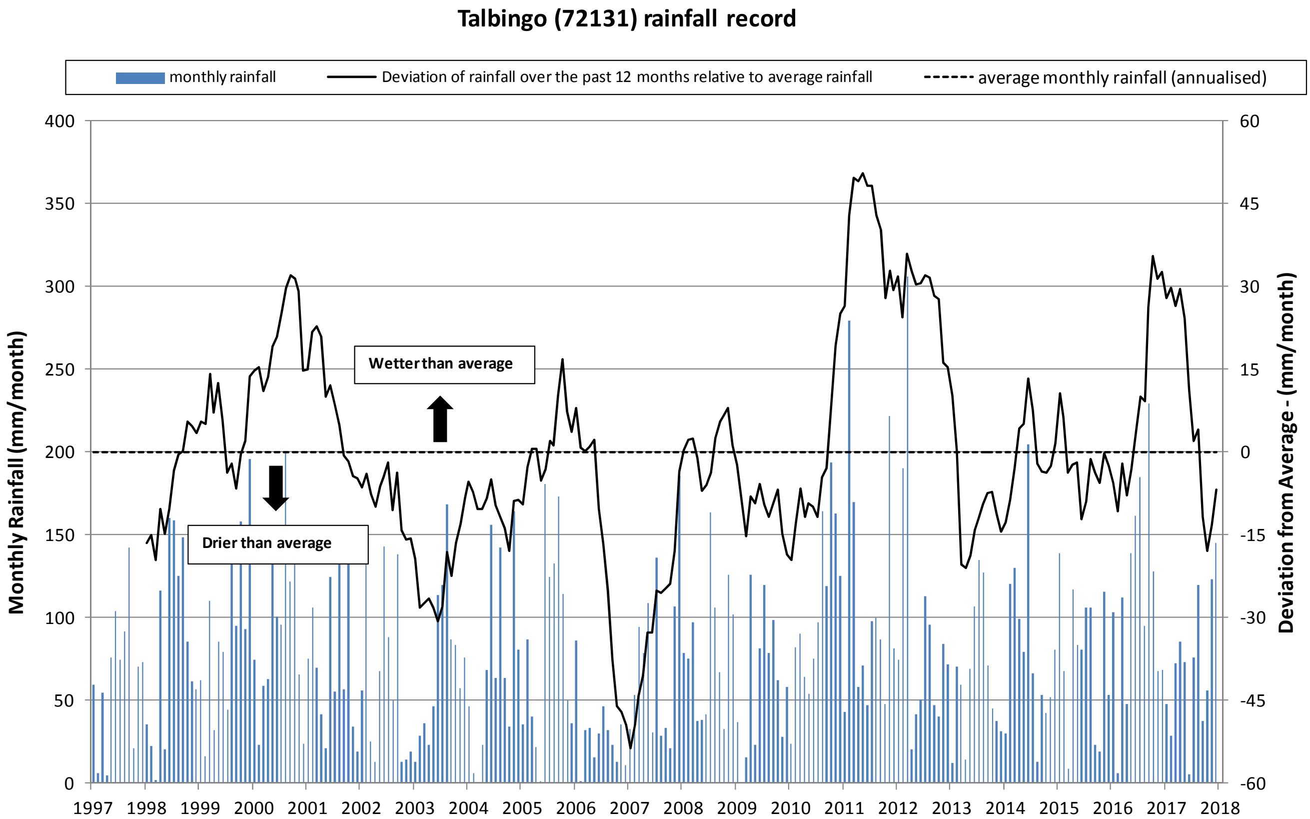


Figure 4.3 Talbingo rainfall over the 1997 to 2017 period

4.3 Soil characteristics

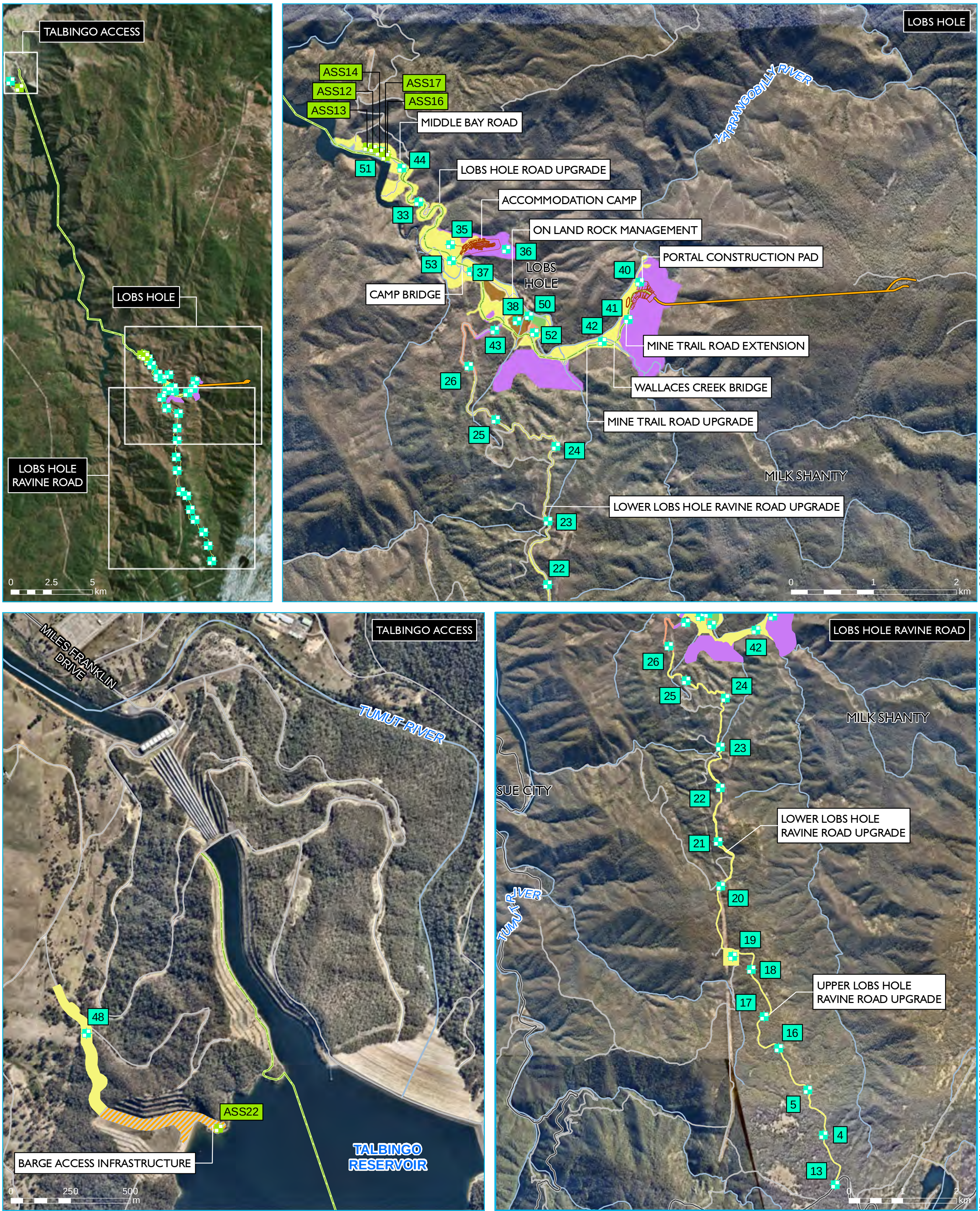
A soil assessment has been undertaken as part of the EIS (EMM 2018a). This assessment identified four predominant soil types in vicinity to the Exploratory Works. The estimated distribution of each soil type is shown in Figure 4.4. Table 4.5 provides a summary of each soil type and includes information on expected hydrologic characteristics and erosion potential. This information is used to inform erosion and sediment control methods that are discussed in Section 6.3.

Table 4.5 Soil characteristics

Soil Type	Description	Hydrologic Characteristics	Erosion potential
Tenosols	The Tenosols generally occur on mid to upper slopes and crests of undulating hills. They can also occur as a result of alluvial processes. Lithic Orthic Tenosols are characterised by a weakly developed B horizon, usually in terms of colour, texture or structure or a combination of these. The B horizon directly overlies hard rock. These soils vary in texture across the project area but typically contain loamy sand to sandy clay loam in the A horizon and silty loam to clay loam in the B horizon. Coarse fragments are common on the soil surface and are of soft, organic condition. The profile has some gravel below the A1 horizon with weak pedality below the A2 horizon (or below the A1 horizon where no A2 is present).	• Low water holding capacity due to their shallowness. • Moderately low inherent soil fertility. • Categorised as Soil Hydrologic Group B due to their medium textures.	• Low to moderate erosion potential. • Moderately dispersive throughout the profile in the eastern portion of the project area.
Kandosols	The Kandosols occur along the gentler mid to upper slopes on Lobs Hole Road (Brown) as well as the lower slopes and flats of Lobs Hole Ravine (Red and Grey) on varying geology. There are two distinct variants of Brown Kandosol, those formed on Basalt surface geology (higher elevations; above Sites 19 and 20) and those formed on Limestone and Shale surface geology (lower elevations; below Sites 19 and 20). Haplic Eutrophic Red Kandosols lack a strong texture contrast and have a well developed, weakly structured B horizon. Sandy clay loams to clay loams occur in the A horizon with clay loams to light clays in the B horizon. The soil surface is without coarse fragments with the exception of those on steeper slopes. The profile has some gravel once below the A1 horizon with weak pedality below the A2 horizon (or below the A1 where no A2 is present).	• Moderate to moderately low water holding capacity due to the high clay content and deep profiles. • Moderately low inherent soil fertility. • Categorised as Soil Hydrologic Group C due to their moderately fine to fine textures and weak structure.	• Low to moderate erosion potential. • Moderately dispersive in the B horizon.
Haplic Epipedal Black Vertosols	Haplic Epipedal Black Vertosols occur in a small area on a floodplain in the south-eastern corner of Lobs Hole. Clay alluvium has been deposited over time by the Yarrangobilly River on the inside of a meander. These soils exhibit strong cracking when dry and at depth have slicken slides and/or lenticular structural aggregates. Gilgai microrelief is not present. A clay texture of 35% or more is present throughout the profile with no thin, crusty surface horizon. The surface horizon is strongly structured and is not self-mulching. The soil surface is without coarse fragments and is of a soft, organic condition. No coarse fragments are evident in the profile. Pedality is strong throughout the profile.	• High water holding capacity due to the very high clay content and deep profiles. • High fertility and are considered some of the most fertile soils in Australia. • Categorised as Soil Hydrologic Group D due to their shrink/swell properties.	• Low erosion potential.

Table 4.5 Soil characteristics

Soil Type	Description	Hydrologic Characteristics	Erosion potential
Dermosols	The Dermosols occurs as a small pocket on mid slopes on Lobs Hole Road and is associated with a reddish pink landscape. They are moderately well developed and do not have a strong texture contrast. These soils have a clay loam A horizon and a light clay B horizon. Some coarse fragments are present on the soil surface. The soil surface is of soft, organic condition. The profile has minimal gravel with moderate pedality in the B horizon.	• Moderately high water holding capacity due to the medium-strong pedality, high clay content and deep profiles. • Moderately high inherent soil fertility. • Categorised as Soil Hydrologic Group C due to their moderately fine textures and moderate structure.	• Low to moderate erosion potential. • Bottom 0.3m of the profile is moderately dispersive.



Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017); LPMA (2011)

GDA 1994 MGA Zone 55

N

KEY

- Soil sample site
- ASS sample site
- Portal construction pad and accommodation camp conceptual layout
- Exploratory tunnel
- Communications cable
- Main road
- Local road or track
- Watercourse

Soils assessment area - Soil type

- Not assessed
- Dermosols
- Kandosols
- Tenosols
- Vertosols
- Water

Soil characteristics

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 4.4

4.4 Yarrangobilly River and tributaries

This section describes the Yarrangobilly River and major tributaries within Lobs Hole. For each watercourse a description of the catchment area, watercourse characteristics and stream flow regimes is provided. Water quality characteristics are discussed separately in Section 4.6.

This section makes frequent reference to Figure 4.5 which shows the key characteristics of the Yarrangobilly River and other local watercourses at Lobs Hole.

4.4.1 Yarrangobilly River

i Catchment overview

The Yarrangobilly River is a major regional watercourse that flows into Talbingo Reservoir, downstream of Lobs Hole. The river's catchment has an area of 271 km^2 that is wholly within the KNP. The catchment is characterised by a range of subalpine grasslands and woodlands and montane dry sclerophyll forests. Elevations range from 550 m AHD at Lobs Hole to more than 1,400 m AHD in the head water catchments. Figure 4.1 (in Section 4.2) shows the Yarrangobilly River catchment and major tributaries.

As discussed in Section 4.2.1, median rainfall within the Yarrangobilly River catchment ranges from 950 mm/year at Lobs Hole to 1350 mm/year in the head water catchments. The spatial variation in median rainfall generally reflects the variation in topography within the catchment.

There are no dams or flow diversions in the Yarrangobilly River catchment upstream of the Talbingo Reservoir.

ii River and floodplain characteristics

The Yarrangobilly River initially flows through Lobs Hole in a southerly direction before turning to the west, towards Talbingo Reservoir. The river's channel ranges in width between 20 and 50 m and has an average longitudinal grade of 2.8%. Channel banks are typically densely vegetated with native and exotic species, including blackberries.

The river's floodplain is typically 2 to 3 m higher than the adjoining channel bed and varies in width between 100 to 350 m and is generally bound by steep topography. There is evidence of remnant river channels at a number of locations within the floodplain. Some areas of floodplain are densely vegetated with native and exotic species, while other areas are characterised by open grasslands.

Former mine workings including shafts and spoil piles are on the Yarrangobilly River floodplain and surrounding areas. These workings are remnant from copper mines that operated intermittently between 1874 and 1919.

Photograph 4.1 to Photograph 4.4 show typical sections of the Yarrangobilly River and its floodplain.

Figure 4.5 shows the following information:

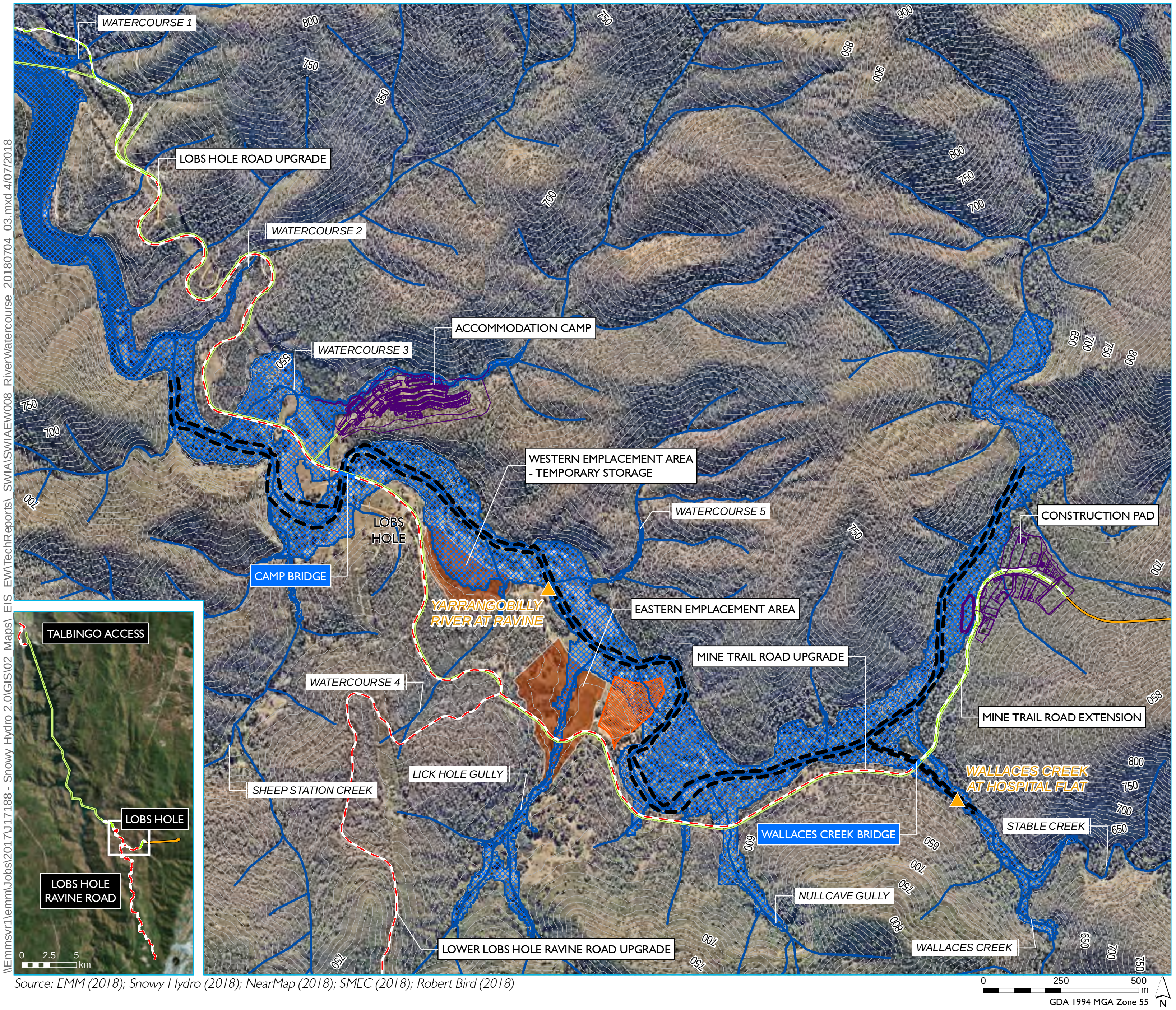
- the alignment of the top of the river bank that has been digitised from LiDAR levels;
- indicative floodplain extents (defined by the 0.2% AEP flood extent); and
- the location of mine workings and spoil piles.

Photograph 4.1 **Shows the Yarrangobilly River floodplain at Lobs Hole, looking north from higher ground**

Photograph 4.2 **Shows the Yarrangobilly River at Lobs Hole (looking upstream to the east). Mine workings are evident on the southern overbank area**

Photograph 4.3 **Shows a typical reach of the Yarrangobilly River at Lobs Hole (looking downstream to the west)**

Photograph 4.4 **Shows a remnant river channel on Yarrangobilly River floodplain in Lobs Hole**



Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018)

River and watercourse characteristics

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 4.5

iii Stream flow regime

Yarrangobilly River stream flows are measured at a Snowy Hydro-operated stream gauge at Lobs Hole (gauge ID: Yarrangobilly River at Ravine: 410574). The gauge location is shown in Figure 4.5. A continuous stream flow record from 1972 to present time (a 46 year period) was provided by Snowy Hydro. Stream gauge data is summarised in the following tables and figures:

- Table 4.6 presents the range in annualised runoff volumes and runoff coefficients that have been calculated by EMM from the gauge record.
- Figure 4.6 plots the minimum 10th, 50th, and 90th percentile monthly stream flows that have been calculated by EMM from the gauge record.
- Figure 4.7 plots the monthly stream flows recorded over the 2000 to 2017 period. The monthly stream flows are compared to median monthly flows.

Table 4.6 Annual stream flow statistics (Yarrangobilly River at Ravine – 410574)

	Annual runoff	Runoff coefficient[1]
Minimum	15 GL/year	10% of rainfall
10th percentile	58 GL/year	22% of rainfall
50th percentile	99 GL/year	32% of rainfall
Average	115 GL/year	34% of rainfall
90th percentile	184 GL/year	47% of rainfall
Maximum	235 GL/year	54% of rainfall

Notes: 1.The runoff coefficient has been calculated using rainfall from the Yarrangobilly Caves (72141) rainfall record
GL - gigalitres

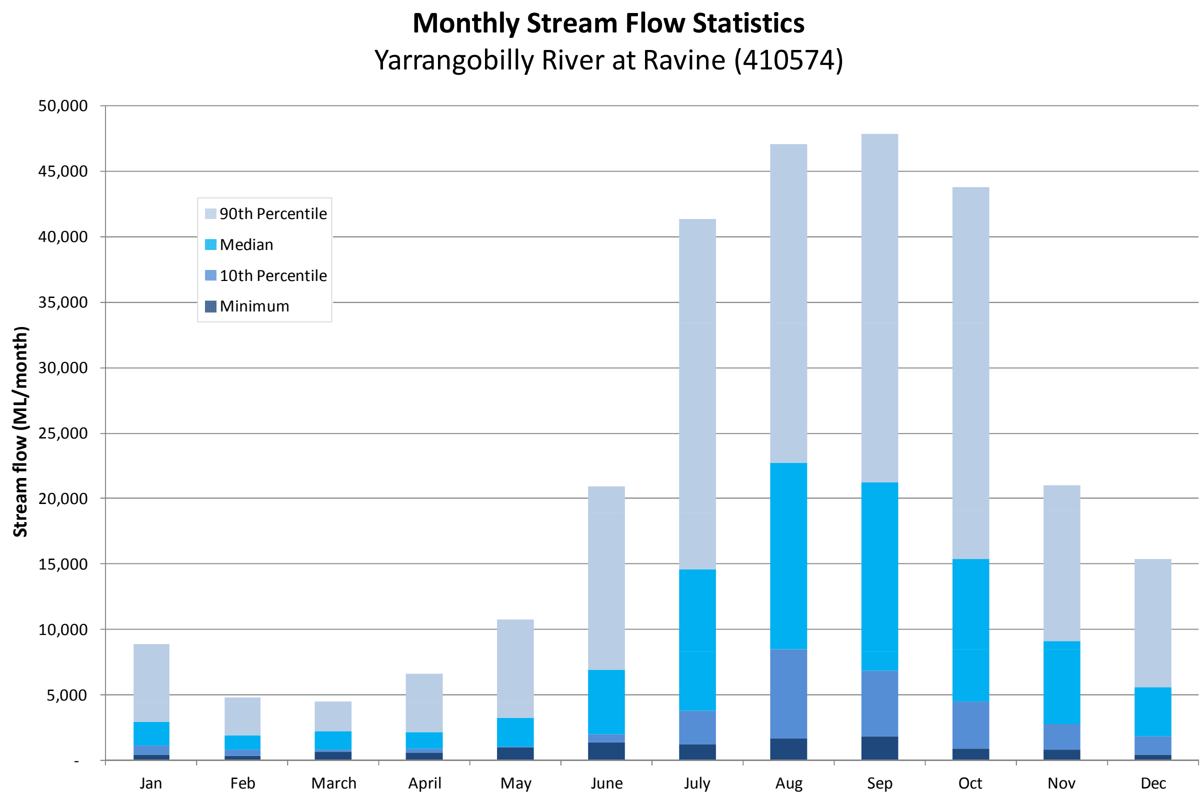


Figure 4.6 Monthly stream flow statistics (Yarrangobilly River at Ravine – 410574)

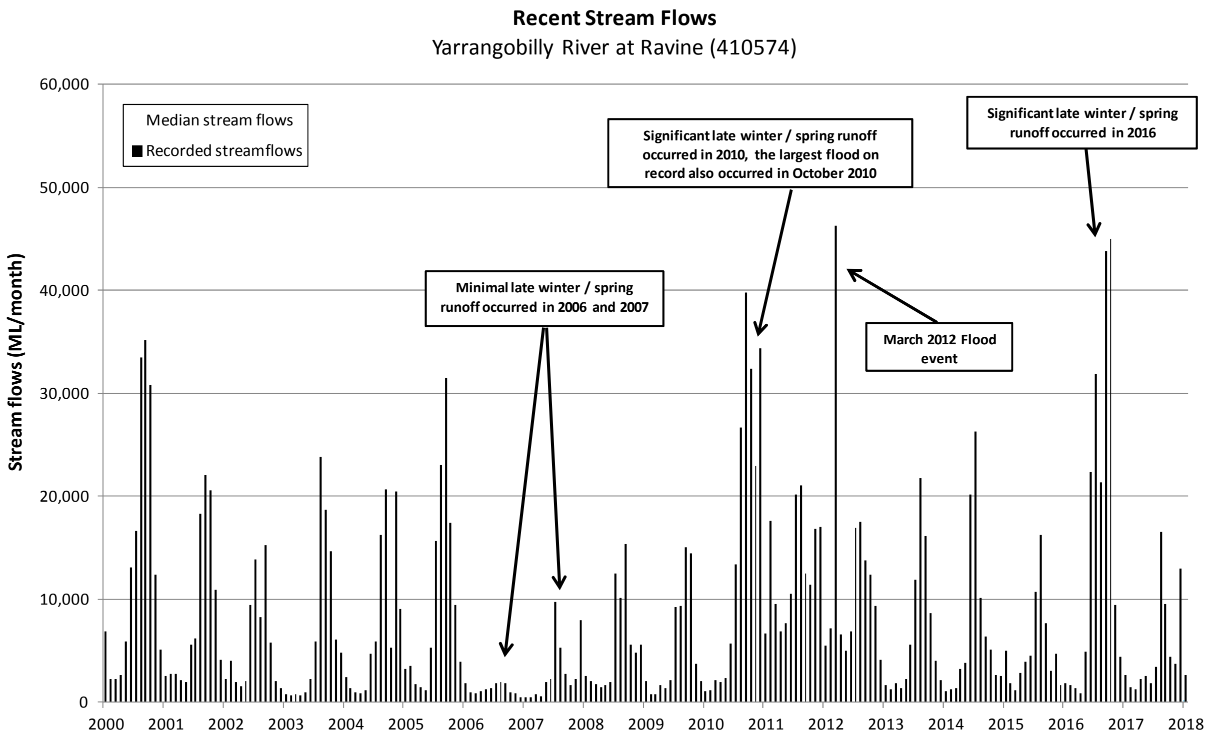


Figure 4.7 Recent stream flows (Yarrangobilly River at Ravine – 410574)

With reference to the data presented in Table 4.6, Figure 4.6, and Figure 4.7, the Yarrangobilly River's stream flow regime is described as follows:

- The average runoff coefficient for the catchment is estimated to be 34% of rainfall, but ranges between 10% of rainfall in dry years to 54% of rainfall in wet years.
- The majority of annual stream flows occur in late winter and early spring. Stream flows progressively reduce over summer and are at their lowest in late summer and generally remain low until the winter months. This is a typical regime for rivers in the Australian Alps.
- Winter and spring runoff volumes were abnormally low in 1982 and 2006, following abnormally dry winter months. The lowest monthly flow on record was 390 ML/month, which occurred in February 1983 following an abnormally dry winter and spring/summer in 1982. This data indicates that permanent base flows are maintained in the river by groundwater discharges during drought conditions.
- The 90th percentile stream flows in summer and early autumn months are not substantially higher than the 10th and 50th percentile flows. This indicates that significant stream flows in summer or early autumn will only occur as a result of flood producing rainfall.

Stream gauge information associated with flooding is discussed separately in Chapter 5.

4.4.2 Wallaces and Stable creeks

Wallaces Creek is a major tributary to the Yarrangobilly River. The creek has a catchment area of 43.4 km^2, which extends to the south and forms the southernmost potion of the Yarrangobilly River Catchment. Stream flows in Wallaces Creek are perennial. Photograph 4.5 shows a typical reach of Wallaces Creek. Stable Creek is a watercourse with a 19.6 km^2 catchment that joins Wallaces Creek approximately 600 m upstream of the confluence of Wallaces Creek and the Yarrangobilly River.

Photograph 4.5 Wallaces Creek (looking upstream)

i Stream flow regime

Wallaces Creek stream flows were measured intermittently at a Snowy Hydro-operated stream gauge (410507) between 1969 and 1998. The gauge is currently not operational. The gauge was 350 m upstream of the Yarrangobilly River and downstream of the confluence with Stable Creek. The gauge location is shown in Figure 4.5.

A continuous stream flow record from 1983 to 1998 (a 16 year period) was provided by Snowy Hydro. This gauged data indicates that Wallaces Creek has a similar flow regime to the Yarrangobilly River. The total gauged flows over the 1983 to 1998 period was equivalent to 15% of the total gauged flows in the Yarrangobilly River (at 410574), which is similar to the relative catchment area ratios.

4.4.3 Other watercourses

There are a number of smaller watercourses in Lobs Hole, which are shown in Figure 4.5. Table 4.7 describes the stream order, catchment area and flow regime of the 2nd order or greater watercourses in proximity to the Exploratory Works. Flow regimes have been established based on site observations and have been categorised as follows:

- Perennial – refers to watercourses where stream flows are continuous all year round during normal rainfall conditions.
- Intermittent – refers to watercourses where stream flows will cease for weeks or months each year. This will typically occur in late summer and early autumn.
- Ephemeral – refers to watercourses where stream flows only occur during and shortly after rainfall.

Table 4.7 Description of smaller watercourses

Name	Stream order[1]	Catchment area	Flow regime[2]
Cave Gully	3rd order watercourse	128 ha	Intermittent
Lick Hole Gully	3rd order watercourse	149 ha	Intermittent
Sheep Station Creek	3rd order watercourse	396 ha	Intermittent
Watercourse 1	3rd order watercourse	44 ha	Intermittent
Watercourse 2	3rd order watercourse	130 ha	Intermittent
Watercourse 3	3rd order watercourse	224 ha	Intermittent
Watercourse 4	2nd order watercourse	33 ha	Ephemeral
Watercourse 5	2nd order watercourse	56 ha	Intermittent

Notes: 1.Stream order has been established using the Strahler system of ordering watercourses using information provided on a 1:25 000 topographic map.

2. Flow regimes have been estimated based on site observations.

3. ha - hectares

4.5 Talbingo Reservoir

Talbingo Reservoir is an existing reservoir that forms part of the Snowy Scheme. The reservoir is approximately 25 km long and has a surface area of approximately 19.4 km^2 (at full supply level). Water is released from the reservoir through the Tumut 3 power station into Jounama Pondage, which releases water into Blowering Reservoir. Blowering Reservoir is operated by Water NSW and releases water into the Tumut River to supply a variety of consumptive users but primarily large irrigation schemes such as that run by Murrumbidgee Irrigation. The Tumut 3 power station also has the ability to pump water from Jounama Pondage back into Talbingo Reservoir.

Table 4.8 provides a summary of key operating levels, storage volumes and Tumut 3 power station discharge and pump capacities.

Table 4.8 Talbingo Reservoir information

Characteristic	Value
Full supply level (FSL)	543.2 m AHD
Minimum operating level (MOL)	534.4 m AHD
Operating range (FSL-MOL)	8.8 m
Spillway crest	544.7 m AHD
Active storage (within operating range)	239 GL
Gross storage	921 GL
Tumut 3 peak discharge	1,100 m^3/s
Tumut 3 pump back rate	300 m^3/s

4.5.1 Operating regime

Talbingo Reservoir is operated as head water pondage for generation of hydro-power from the Tumut 3 power station and head storage for the operation of the Tumut 3 pumped storage project. As noted in Table 4.8, the water level is maintained within an 8.8 m operating range, between the FSL and MOL.

The reservoir receives inflows from:

- the Tumut River (primary from discharges from Tumut 2 power station);
- Yarrangobilly River;
- pumping from Jounama Pondage; and
- minor tributaries.

Water levels can change rapidly due to discharge of water through Tumut 3 power station or from inflows due to rainfall or discharge from Tumut 2 power station. Figure 4.8 shows the reservoir water level between 2010 and 2017.

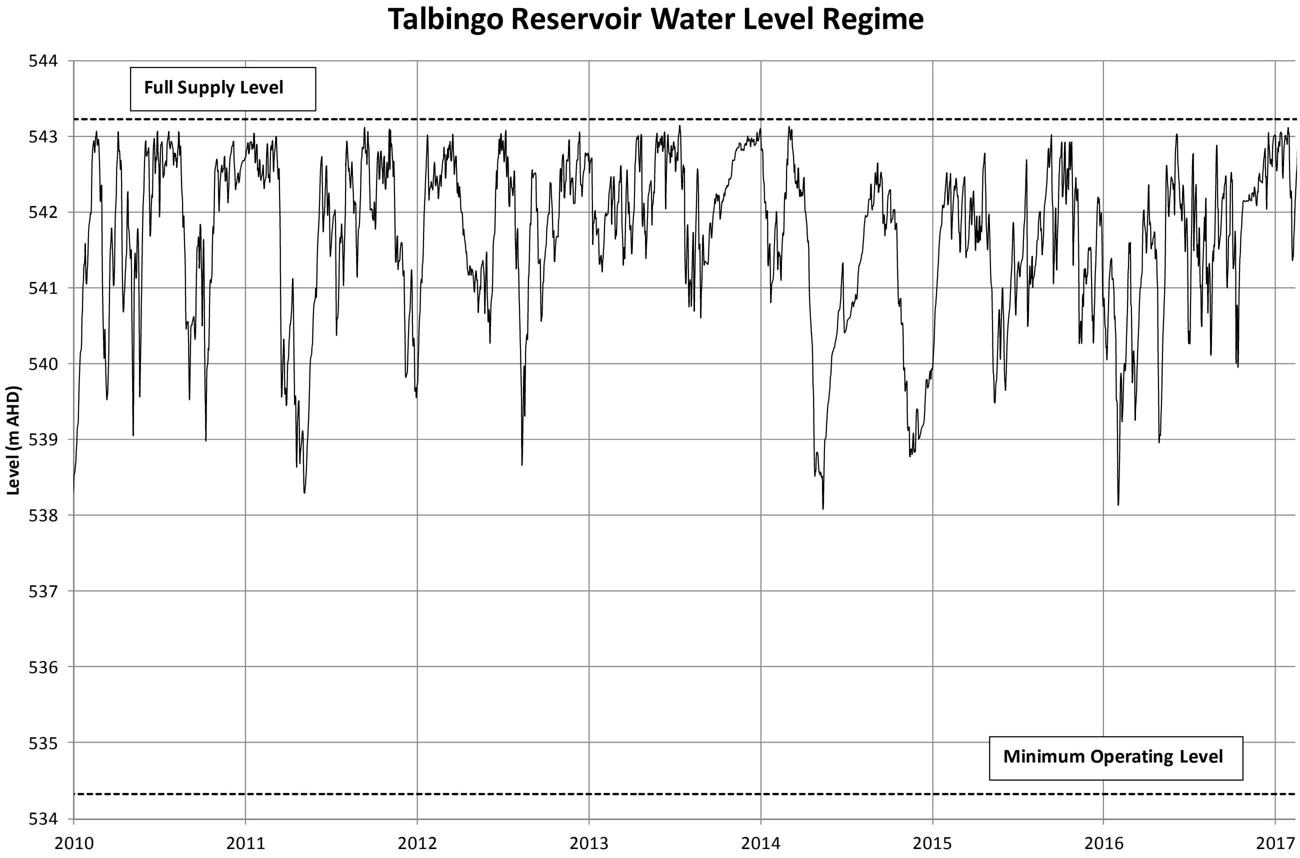


Figure 4.8 Talbingo Reservoir water level regime

Snowy Hydro provided estimates of daily discharge from Tumut 2 and Tumut 3 power stations and Tumut 3 pump-back volumes. Annual average values have been calculated over the 1994 to 2017 period. These values are presented in Table 4.9 along with the gauged Yarrangobilly River stream flows over the period. Table 4.9 also provides estimates of the inflows expressed as a percentage of the net discharge from the reservoir.

Table 4.9 Talbingo Reservoir inflow and discharge statistics

	Average annual flow volume[1] (GL/year)	Percentage of net discharge through Tumut 3 (%) [1 & 2]
Inflows		
- Yarrangobilly River	100[4]	8%
- Tumut 2 discharge	1,043	86%
- Tumut 3 pumping	394	-
- Other (ungagged catchments less evaporation losses)[3]	78	6%
Total inflows	1,615	-
Outflows		
- Tumut 3 discharge	1,615	-
Net discharge[2]	1,221	

Notes: 1.Calculated over the 1994 to 2017 period

2. net discharge refers to Tumut 3 discharge less Tumut 3 pumping

3. value calculated as the difference between inflows and outflows.

4. The average annual flow from the Yarrangobilly River is different to the value provided in Table 4.6. This is due to the values being calculated from different periods.

The average residence time or turnover time of water in the reservoir can be calculated as a function of the gross storage volume (921 GL) divided by the average net discharge volume of 1,221 GL/year. This calculation indicates that water on average will remain in the reservoir for 9 months before discharge.

4.6 Water quality characteristics

This section describes a surface water characterisation program that has commenced for the broader Snowy 2.0 project and available results that are relevant to the Exploratory Works.

4.6.1 Surface water characterisation program

A surface water quality characterisation program commenced for the broader Snowy 2.0 project in February 2018. This program includes water quality sampling from Tantangara and Talbingo reservoirs, all major watercourses that contribute runoff to the reservoirs and watercourses within proximity to potential surface infrastructure. Water quality data from the Yarrangobilly River and its tributaries, Talbingo Reservoir and Tumut River sampling locations are considered to be relevant to Exploratory Works and are presented and discussed in this report.

i Sampling locations

Sampling locations referenced in this report are shown in Figure 4.9 and described in Table 4.10.

Table 4.10 Surface water sampling locations

ID	location	Notes
Yarrangobilly River sampling locations		
PN_SW_001	Yarrangobilly Caves, 20km upstream of Lobs Hole	
LH_SW_004	Upstream of Wallaces Creek confluence	
LH_SW_007	Adjacent to remnant mine workings	
LH_SW_006	Upstream of Talbingo Reservoir	
Wallaces and Stable Creeks sampling locations		
LH_SW_001	Stable Creek, upstream of Wallaces Creek confluence	
LH_SW_002	Wallaces Creek, upstream of Stable Creek confluence	
LH_SW_003	Wallaces Creek, downstream of Stable Creek confluence	
Minor Watercourse sampling locations		
LH_SW_005	Lick Hole Gully	No samples collected[1]
Tumut River sampling locations		
TalS_SW_001	Tumut River, upstream of Talbingo Reservoir	
Talbingo Reservoir sampling locations		
TAL_01	Northern end of the reservoir, adjacent to the dam wall	Samples collected from the surface, mid-depth and bottom of the reservoir
TAL_09	Middle portion of the reservoir	
TAL_15	Long Creek inlet	
TAL_19	Southern end of the reservoir, Tumut River inlet	
TAL_20	Southern end of the reservoir, Yarrangobilly River inlet	

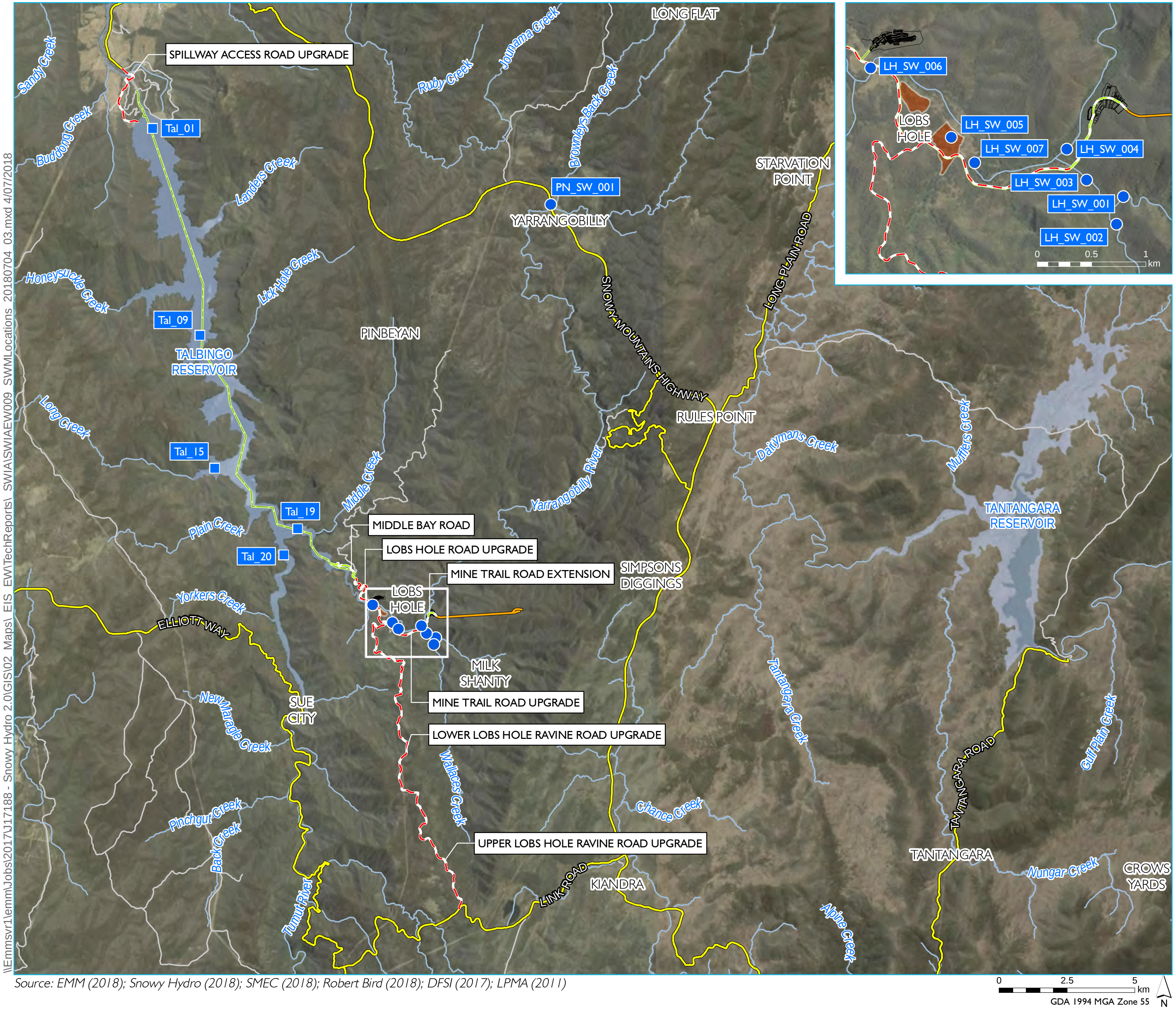
Notes: 1.No samples were collected as the sampling locations were dry during the monitoring period (February to April 2018)

ii Analysis methods

The applied sampling and analysis methods and monitoring analytes are detailed in Table 4.11. It is noted that there was some variation in analysis parameters between the sampling events.

Table 4.11 Analysis methods and parameters

Category	Sampling analytes	Analysis method
Physiochemical properties	pH, electrical conductivity (EC), turbidity, dissolved oxygen, temperature, redox potential	Measured using a portable water quality meter in the field
	total suspended solids, total dissolved solids, total hardness	Analysis undertaken by a NATA certified laboratory
Nutrients	total nitrogen, ammonia, nitrate, nitrite and total kjeldahl nitrogen	Analysis undertaken by a NATA certified laboratory
	total phosphorus and reactive phosphorous	
	total organic carbon, dissolved organic carbon	
Metals (dissolved)	Al, As, Ag, B, Ba, Cr (total), Co, Cu, Fe, Hg, Mg, Mn, Ni, Pb, Se, V and Zn	Analysis undertaken by a NATA certified laboratory



KEY

- Watercourse sampling location
- Reservoir sampling location
- Access road upgrade
- Access road extension
- Exploratory tunnel
- Portal construction pad and accommodation camp conceptual layout
- Communications cable
- Main road
- Local road
- Perennial watercourse
- Scheme storage
- On land rock management

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); DFSI (2017); LPMA (2011)

Surface water monitoring locations

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 4.9

iii Sampling frequency

At the time of writing this report, results from the following sampling events were available:

- Samples collected from river locations in February, March and April 2018. All sampling was undertaken during base flow conditions.
- A single round of samples collected from Talbingo Reservoir in March 2018.

iv Water quality data

Water quality data is presented in the following tables:

- Table 4.12 provides a summary of water quality results in the Yarrangobilly River and Wallaces Creek. All results are provided in Table A1 (Yarrangobilly River) and Table A2 (Wallaces Creek) in Appendix A.
- Table 4.13 provides a summary of water quality results from Talbingo Reservoir. A summary of results from the Yarrangobilly and Tumut rivers is provided for context. All Talbingo Reservoir results are provided in Table A3 in Appendix A.

The results, where relevant, are compared to guideline values that have been established using:

- default trigger values that were sourced from relevant sections of ANZECC (2000) where available; and
- low reliability trigger levels were established for analytes that do not have default trigger values in ANZECC (2000) using the methods recommended in Section 8.3.4.5 of ANZECC (2000).

The results are discussed in Section 4.6.2.

Table 4.12 Water quality results summary: Yarrangobilly River (base flow conditions)

			Yarrangobilly River				Wallaces Creek			
	Unit	Guideline value[2]	# Samples	10th percentile[5]	Median	90th percentile[5]	# Samples	Min	Median	Max
Field Parameters										
Temperature	°C	-	11	14	19	22	5	13	15	16
Dissolved Oxygen (DO)	%	90 – 110[1]	8	**75**	**85**	93	5	**75**	**78**	92
Electrical Conductivity (EC)	µS/cm	30 – 350[1]	11	32	171	185	5	65	178	185
pH		6.5 – 8.5[1]	11	7.5	7.9	8.1	5	7.5	7.6	8.4
Oxidising and Reducing Potential (ORP)		-	11	112	130	143	5	62	133	146
Turbidity	NTU	2 - 25	7	<2	<2	5	3	<2	<2	<2
Analytical Results - General										
Suspended Solids (SS)	mg/l	-	11	<5	<5	<5	5	<5	<5	<5
Total Alkalinity (as $CACO_3$)	mg/l	-	7	15	86	109	3	38	99	104
Total Hardness (as $CACO_3$)	mg/l	-	4	9	89	97	2	87	96	94
Analytical Results - Nutrients										
Ammonia	mg/l	0.013	7	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01
Oxidised Nitrogen (NOx)	mg/l	0.015	7	0.01	**0.03**	**1.9**	2	**0.03**	**0.035**	**0.04**
Total Kjeldahl Nitrogen (TKN)	mg/l	-	7	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1
Total Nitrogen (TN)	mg/l	0.25	7	<0.1	<0.1	**1.9**	2	<0.1	<0.1	<0.1
Reactive Phosphorus	mg/l	0.015	4	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01
Total Phosphorus (TP)	mg/l	0.020	7	0.01	0.01	0.02	2	<0.01	<0.01	<0.01
Total Organic Carbon	mg/l	-	4	1	11	23	2	8	16.5	25
Dissolved Organic Carbon	mg/l	-	4	<1	<1	<1	2	<1	<1	<1
Analytical Results - Inorganics (Dissolved)										
Fluoride	mg/l	0.115[3]	7	0.1	0.1	**0.6**	3	0.1	0.1	0.1
Analytical Results - Metals (Dissolved)										
Aluminium (Al)	mg/l	0.055	4	0.01	0.01	**0.06**	2	<0.01	<0.01	<0.01
Arsenic (As)	mg/l	0.013	4	<0.001	<0.001	<0.001	2	<0.001	<0.001	<0.001

Table 4.12 Water quality results summary: Yarrangobilly River (base flow conditions)

			Yarrangobilly River				Wallaces Creek			
	Unit	**Guideline value[2]**	**# Samples**	**10th percentile[5]**	**Median**	**90th percentile[5]**	**# Samples**	**Min**	**Median**	**Max**
Barium (Ba)	mg/l	0.008[3]	4	**0.011**	**0.0285**	**0.042**	2	**0.088**	**0.097**	**0.106**
Boron (B)	mg/l	0.370	4	<0.05	<0.05	<0.05	2	<0.05	<0.05	<0.05
Cobalt (Co)	mg/l	0.0014[3]	4	<0.001	<0.001	<0.001	2	<0.001	<0.001	<0.001
Total Chromium (Cr)	mg/l	0.001	7	<0.001	<0.001	<0.001	3	<0.001	<0.001	<0.001
Copper (Cu)	mg/l	0.0014	4	<0.001	<0.001	<0.001	2	0.001	0.002[4]	0.003[4]
Manganese (Mn)	mg/l	1.9	4	0.001	0.001	0.002	2	0.001	0.0015	0.002
Nickel (Ni)	mg/l	0.011	7	0.001	0.001	0.002	3	0.001	0.002	0.002
Lead (Pb)	mg/l	0.0034	4	<0.001	<0.001	<0.001	2	<0.001	<0.001	<0.001
Selenium (Se)	mg/l	0.005	4	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01
Silver (Ag)	mg/l	0.0005	4	<0.001	<0.001	<0.001	2	<0.001	<0.001	<0.001
Vanadium (V)	mg/l	0.006[3]	4	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01
Zinc (Zn)	mg/l	0.008	4	<0.005	<0.005	<0.005	3	<0.005	<0.005	<0.005
Mercury (Hg)	mg/l	0.00006	4	<0.0001	<0.0001	<0.0001	2	<0.0001	<0.0001	<0.0001
Iron (Fe)	mg/l	0.3[3]	4	0.05	0.05	0.06	2	<0.05	<0.05	<0.05

Notes: *1. The Guideline Values for field parameters and nutrients refer to the trigger values for physical and chemical stressors in south-east Australia (upland rivers) that are reported in Tables 3.3.2 and 3.3.3 of ANZECC (2000).*

2. Unless otherwise stated, the Guideline Values for dissolved metals refer to the trigger values for slightly-moderately disturbed ecosystems that are reported in Table 3.4.1 of ANZECC (2000). It is noted that no hardness adjustments have been made.

3. The Guideline Value refers to a low reliability trigger value that has been established using the methods recommended in Section 8.3.4.5 of ANZECC (2000).

4. Value is below guideline values once adjustments for hardness are made using the hardness adjustment algorithms provided in Table 3.4.3 of ANZECC (2000).

5. If less than 10 samples are available, the minim value is reported instead of the 10th percentile value and the maximum value is reported instead of the 90th percentile value.

***Bold** denotes Guideline Value or Range is exceeded.*

Table 4.13 Water quality results summary: Talbingo Reservoir (March 2018)

			Talbingo Reservoir (March 2018)				Yarrangobilly River (Feb – April 2018)				Tumut River (Tals_SW_001)	
	Unit	**Guideline value**	**# Samples**	**10th percentile[5]**	**Median**	**90th percentile[5]**	**# Samples**	**Min**	**Median**	**Max**	**March 18**	**April 18**
Field Parameters												
Temperature	°C	-	-	-	-	-	11	13	19	22	22	13
Dissolved Oxygen (DO)	%	90 – 110[1]	-	-	-	-	8	**75**	**85**	93	**82**	**74**
Electrical Conductivity (EC)	µS/cm	30 – 350[1]	15	27	29	32	11	32	171	185	86	115
pH		6.5 – 8.5[1]	15	6.8	7.0	7.2	11	7.5	7.9	8.1	7.8	9.5
Oxidising and Reducing Potential (ORP)		-	-	-	-	-	11	112	130	143	137	183
Turbidity	NTU	2 - 25	-	-	-	-	7	<2	<2	5	<2	-
Analytical Results - General												
Suspended Solids (SS)	mg/l	-	15	<1	2	6	11	<5	<5	<5	<5	<5
Total Alkalinity (as $CACO_3$)	mg/l	-	15	<20	<20	<20	7	15	86	109	46	-
Total Hardness (as $CACO_3$)	mg/l	-	15	6	7	10	4	9	89	97	-	30
Analytical Results - Nutrients												
Ammonia	mg/l	0.013	15	<0.01	<0.01	<0.01	7	<0.01	<0.01	<0.01	-	<0.01
Oxidised Nitrogen (NOx)	mg/l	0.015	15	<0.05	<0.05	**0.07**	7	<0.01	**0.03**	**1.9**	-	**0.03**
Total Kjeldahl Nitrogen (TKN)	mg/l	-	15	<0.2	<0.2	<0.2	7	<0.1	<0.1	<0.1	-	<0.1
Total Nitrogen (TN)	mg/l	0.25	15	<0.2	<0.2	<0.2	7	<0.1	<0.1	**1.9**	-	<0.1
Reactive Phosphorus	mg/l	0.015	15	<0.05	<0.05	<0.05	4	<0.01	<0.01	<0.01	-	<0.01
Total Phosphorus (TP)	mg/l	0.020	15	<0.05	<0.05	<0.05	7	0.01	0.01	0.02	-	<0.01
Total Organic Carbon	mg/l	-	15	<5	<5	<5	4	1	11	23	-	<1
Dissolved Organic Carbon	mg/l	-	15	<5	<5	<5	4	<1	<1	<1	-	<1
Analytical Results - Inorganics (Dissolved)												
Fluoride	mg/l	0.115[3]	15	<0.5	<0.5	<0.5	7	0.1	0.1	**0.6**	0.13	-
Analytical Results - Metals (Dissolved)												
Aluminium (Al)	mg/l	0.055	15	<0.05	<0.05	<0.05	4	0.01	0.01	**0.06**	-	<0.01

Table 4.13 Water quality results summary: Talbingo Reservoir (March 2018)

			Talbingo Reservoir (March 2018)				Yarrangobilly River (Feb – April 2018)				Tumut River (Tals_SW_001)	
	Unit	**Guideline value**	**# Samples**	**10th percentile[5]**	**Median**	**90th percentile[5]**	**# Samples**	**Min**	**Median**	**Max**	**March 18**	**April 18**
Arsenic (As)	mg/l	0.013	15	<0.001	0.001	0.001	4	<0.001	<0.001	<0.001	-	<0.001
Barium (Ba)	mg/l	0.008[3]	15	<0.02	<0.02	<0.02	4	**0.011**	**0.0285**	**0.042**	-	**0.01**
Boron (B)	mg/l	0.370	15	<0.05	<0.05	<0.05	4	<0.05	<0.05	<0.05	-	<0.05
Cobalt (Co)	mg/l	0.0014[3]	15	<0.001	<0.001	<0.001	4	<0.001	<0.001	<0.001	-	<0.001
Total Chromium (Cr)	mg/l	0.001	15	<0.001	<0.001	<0.001	7	<0.001	<0.001	<0.001	<0.002	-
Copper (Cu)	mg/l	0.0014	15	<0.001	**0.032**	**0.069**	4	<0.001	<0.001	<0.001	-	0.001
Manganese (Mn)	mg/l	1.9	15	<0.005	<0.005	0.007	4	0.001	0.001	0.002	-	0.008
Nickel (Ni)	mg/l	0.011	15	0.001	0.003	0.005	7	0.001	0.001	0.002	-	0.001
Lead (Pb)	mg/l	0.0034	15	<0.001	0.002	0.003	4	<0.001	<0.001	<0.001	-	<0.001
Selenium (Se)	mg/l	0.005	15	<0.001	<0.001	<0.001	4	<0.01	<0.01	<0.01	-	<0.01
Silver (Ag)	mg/l	0.0005	15	<0.005	<0.005	<0.005	4	<0.001	<0.001	<0.001	-	<0.001
Vanadium (V)	mg/l	0.006[3]	15	<0.005	<0.005	<0.005	4	<0.01	<0.01	<0.01	-	<0.01
Zinc (Zn)	mg/l	0.008	15	<0.005	**0.024**	**0.065**	4	<0.005	<0.005	<0.005	-	<0.005
Mercury (Hg)	mg/l	0.00006	15	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	<0.0001	-	<0.0001
Iron (Fe)	mg/l	0.3[3]	15	<0.05	<0.05	<0.05	4	0.05	0.05	0.06	-	0.09

Notes: *1. The Guideline Values for field parameters and nutrients refer to the trigger values for physical and chemical stressors in south-east Australia (upland rivers) that are reported in Tables 3.3.2 and 3.3.3 of ANZECC (2000).*
2. Unless otherwise stated, the Guideline Values for dissolved metals refer to the trigger values for slightly-moderately disturbed ecosystems that are reported in Table 3.4.1 of ANZECC (2000). It is noted that no hardness adjustments have been made.
3. The Guideline Value refers to a low reliability trigger value that has been established using the methods recommended in Section 8.3.4.5 of ANZECC (2000).
4. Value is below guideline values once adjustments for hardness are made using the hardness adjustment algorithms provided in Table 3.4.3 of ANZECC (2000).
5. If less than 10 samples are available, the minim value is reported instead of the 10th percentile value and the maximum value is reported instead of the 90th percentile value.
***Bold** denotes Guideline Value or Range is exceeded.*

4.6.2 Surface water quality

This section describes the water quality characteristics of the Yarrangobilly River, Wallaces Creek and Talbingo Reservoir.

i Yarrangobilly and tributaries water quality

Water quality monitoring was undertaken in the Yarrangobilly River and Wallaces Creek on three occasions between February and April 2018. All samples were collected during base flow conditions, which are dominant in the summer months. During base flow conditions, constant stream flows are maintained by groundwater discharges into the river and its tributaries. Accordingly, water quality during base flow conditions reflects the water quality of regional groundwater systems that contribute to base flows and may not be representative of water quality during periods of higher stream flow when surface water runoff is dominant.

With reference to Table 4.12 the water quality of the Yarrangobilly River and Wallaces Creek during base flow conditions can be characterised as:

- Neutral to slightly alkaline, with pH measurements ranging between 7.5 and 8.4, within the guideline range of 6.5 to 8.5.

- High carbonate levels and associated hardness and alkalinity. This is associated with the groundwater origin of base flows. Lower carbonate levels are expected during non base flow conditions.

- Low salinity, with electrical conductivity (an indicator of salinity) ranging between 32 to 185 µS/cm, within the guideline range of 30 to 350 µS/cm. Low salinity levels are expected during non base flow conditions.

- Low levels of suspended solids and turbidity. Suspended solids and turbidity were consistently either below detection limits or within the lower end of the guideline range. This is in line with expectations given the base flow conditions and clear appearance of the water. There is potential for higher levels of suspended solids during non base flow conditions.

- Low levels of nutrients (phosphorus, nitrogen and carbon). Phosphorus and nitrogen concentrations were below guideline values in all samples except for a single sample from the Yarrangobilly River that recorded a Nitrate concentration of 1.9 mg/l. There is potential for higher levels of nutrients during non base flow conditions.

- Low levels of metals. All dissolved metal concentrations were below guideline values following hardness adjustments with the exception of:

  - a single sample of Aluminium was marginally elevated relative to the guideline value;

  - all samples of Barium were elevated relative to the low reliability trigger value; and

  - a single sample of Fluoride was elevated relative to a low reliability trigger value.

These are associated with the groundwater origin of stream base flows.

ii Talbingo Reservoir water quality

The Talbingo Reservoir is operated as part of the Snowy Hydro scheme. As discussed in Section 4.5, the gross volume of the reservoir is equivalent to 75% of the average annual flow through the reservoir and significant inflows are maintained during the summer months due to diversions from the greater Snowy Scheme. As a result, the water quality is expected to be less sensitive to seasonal changes in stream flow regimes than river systems such as the Yarrangobilly River.

With reference to Table 4.13 the water quality of Talbingo Reservoir can be characterised as having a neutral pH, low carbonate (hardness and alkalinity), low salinity, low levels of suspended solids and low nutrient levels.

Metal concentrates were below guideline levels with the exception of copper and zinc. Dissolved copper concentrations ranged from below detection to 0.088 mg/l (the 90^{th} percentile value was 0.069 mg/l) relative to a guideline value of 0.0014 mg/l. 7 of the 15 samples exceeded the guideline value. Dissolved zinc concentrations ranged from below detection to 0.068 mg/l (the 90^{th} percentile value was 0.065 mg/l) relative to a guideline value of 0.008 mg/l. 9 of the 15 samples exceeded the guideline value. With reference to Table A3 (in Appendix A), the elevated copper and zinc occurred at TAL 09 (mid reservoir), TAL 15 (long creek inlet) and TAL 19 (Tumut River inflow arm).

Elevated copper and zinc concentrations were not identified in either the Yarrangobilly or Tumut River inflow locations. Hence, the source of the elevated metal concentrations is unknown. This is not considered relevant to Exploratory Works but will be further investigated as part of the broader Snowy 2.0 project.

5 Flooding

This section documents the flood assessment for Exploratory Works and is structured as follows:

- Section 5.1 describes the assessment methodology;
- Section 5.2 describes existing flood characteristics;
- Section 5.3 describes proposed infrastructure that will be located on flood prone land, associated flood risks and changes to existing flooding regimes;
- Section 5.4 discusses flood emergency response; and
- Section 5.5 provides a summary of this section.

This section makes reference to:

- Appendix B, which provides a detailed assessment method statement; and
- Appendix C, which provides all flood figures.

5.1 Assessment methodology

EMM engaged GRC Hydro to undertake hydrology analysis and flood modelling for Exploratory Works. The analysis and modelling was undertaken in accordance with the methods recommended in ARR2016. This section provides an overview of the assessment methodology and key outcomes. A detailed method statement prepared by GRC Hydro is provided in Appendix B.

5.1.1 Hydrology analysis

The hydrological assessment approach included both Flood Frequency Analysis (FFA) and hydrologic modelling. The FFA was undertaken using the peak annual flows recorded at the Yarrangobilly River at Ravine stream gauge (410574) between 1972 to 2017, a 46 year period. The largest flood on record occurred in 2010 and had a peak flow of 210 m^3/s. This event is estimated to be a 1 in 70 year event.

Hydrologic modelling of the Yarrangobilly River catchment was undertaken using XP-RAFTS software. The model was developed using the methods recommended in ARR2016 and was parameterised to the peak flows derived from the FFA. The calibrated hydrologic model was applied to simulate the 20%, 5%, 1%, 0.2%, 0.05% and Probable Maximum Flood (PMF) events.

Table 5.1 compares the peak flows that were derived from the FFA and hydrologic model. The peak flows estimated from the hydrologic model have been adopted as design flows. Refer to Appendix B for a detailed description of analysis and modelling methodologies, assumptions and results.

Table 5.1 Yarrangobilly River Design flow summary

Event	Peak flows (m^3/s)	
	FFA	Hydrologic model
20% AEP	83	92
5% AEP	142	154
1% AEP	233	244
0.2% AEP	-	408
0.05% AEP	-	714
PMF	-	6,000

5.1.2 Hydraulic Modelling

Hydraulic modelling was undertaken using the TUFLOW two-dimensional numerical modelling package. The model includes the Yarrangobilly River reach between the portal construction pad and Talbingo Reservoir and all tributaries in proximity to the Exploratory Works. Refer to Appendix B for a description of the model set-up.

The model was applied to simulate the 20%, 5%, 1%, 0.2%, 0.05% AEP and PMF events for both existing and Exploratory Works conditions. The model results were used to establish existing flood characteristics, identify potential flood impacts and inform flood risk management measures for the Exploratory Works. The results have and will be used to inform engineering design of the project.

5.2 Existing flooding characteristics

Flood model results for each event are presented in figures that show flood depth and level (as contours) and the peak velocity depth product (VD). The VD results provide an indication of flood hazard and flood conveyance. Results for all events assessed are provided in figures in Appendix C. Table 5.2 provides a figure reference.

Table 5.2 Flood characteristics figure reference

	Flood depth and level	Peak VD
20% AEP	Figure C1	Figure C7
5% AEP	Figure C2	Figure C8
1% AEP	Figure C3	Figure C9
0.2% AEP	Figure C4	Figure C10
0.05% AEP	Figure C5	Figure C11
PMF	Figure C6	Figure C12

The flood model results indicate that:

- for the lower magnitude flood events such as the 20% and 5% AEP events, flooding is predominantly confined to the channel and immediate floodplain areas. Full inundation of the floodplain occurs in the 1% AEP and greater magnitude events; and

- for all events except the PMF, the majority of the flow conveyance occurs within the channel and immediate floodplain areas.

5.3 Potential flood impacts

5.3.1 Proposed infrastructure on flood prone land

The Exploratory Works avoid flood prone land where possible. However, some infrastructure will unavoidably need to be constructed on flood prone land. Table 5.3 lists and describes this infrastructure.

It is noted that:

- The flood extents of minor tributaries are not considered to be flood prone land for the purposes of this assessment. Management of runoff from minor tributaries is addressed in Section 6.2.

- With reference to Figure C6, minor portions of the eastern emplacement area, accommodation camp and portal construction pad are located within the periphery of the PMF flood extent, but below the 0.05% AEP event. As the magnitude of inundation is minor further assessment of flood risks and impacts is not considered to be necessary.

Table 5.3 Proposed infrastructure on flood prone land

Infrastructure	Permanent / temporary	Description of infrastructure
Camp Bridge (Lobs Hole Road crossing over the Yarrangobilly River)	Permanent	Lobs Hole Road will cross the Yarrangobilly River to the south of the accommodation camp. The floodplain width at the bridge location is approximately 120 m. The bridge will be a double span structure with the deck soffit elevated above the 1% AEP flood level. The road embankment leading to the bridge is approximately 1.5 m above floodplain levels and will form a complete blockage of floodplain conveyance on the left (southern) floodplain area.
Wallaces Bridge (Mine Trail Road crossing over Wallaces Creek)	Permanent	Mine Trail Road will cross Wallaces Creek approximately 110 m upstream of the Yarrangobilly River. The floodplain width at the bridge location is approximately 90 m. The bridge will be a single span structure with the deck soffit elevated above the 1% AEP flood level. The bridge abutments will be constructed to levels that are 4 to 5 m above floodplain levels and will form a complete blockage of floodplain conveyance.
Western emplacement area	Temporary, the western emplacement will be removed at the end of the project.	The western emplacement area will be established on the southern portion of the Yarrangobilly River floodplain. The footprint of the emplacement area is indicated in all flood results figures. The floodplain width at the emplacement location ranges between 120 to 190 m. The emplacement is located on a higher portion of the floodplain and avoids areas of elevated flow conveyance that are indicated in the VD results. It is expected that the emplacement will result in a constriction of the floodplain during higher magnitude (1% AEP and greater) flood events.
Portal construction pad water management basin	Temporary, the dam will be removed as part of the portal construction pad rehabilitation.	The water management basin for the portal construction pad will be established on the eastern side of the Yarrangobilly River floodplain. The basin will be constructed on top of the floodplain, rather than via excavation. The footprint of the basin is indicated in all flood results figures. The floodplain width at the basin location is approximately 110 m. The basin is on a higher portion of the floodplain and avoids areas of elevated flow conveyance that are indicated in the VD results. It is expected that the basin embankments will result in a constriction of the floodplain during higher magnitude (5% AEP and greater) flood events.

5.3.2 Changes to flooding regimes

The hydraulic model was applied to assess changes to the existing flooding regime associated with the infrastructure described in Table 5.3. This was done by applying the following modifications to the existing conditions hydraulic model:

- The assumed surface levels (also referred to as the digital elevation model) were updated to include the design levels and footprints of the road and dam embankments and the western emplacement area.
- Bridge structures were included in the model using flow constriction cells. This method accounts for blockage and form losses at bridge structures associated with the bridge piers and deck structures.

Refer to Appendix B for further details on methodologies applied to assess proposed conditions.

The Exploratory Works hydraulic model was simulated for the 20%, 5%, 1%, 0.2%, 0.05% AEP and PMF events. For each event, changes to the existing flooding regime have been quantified by calculating the difference in peak flood levels and velocities between existing and Exploratory Works model results. The resulting changes are shown spatially in:

- flood level difference maps that show the areas and magnitude of flood level change; and
- velocity difference maps that show changes to velocity expressed as a percentage.

Results for all events assessed are provided in figures in Appendix C. Table 5.4 provides a figure reference.

Table 5.4 Flood difference maps figure reference

	Change in flood level	Change in velocity
20% AEP	Figure C13	Figure C19
5% AEP	Figure C14	Figure C20
1% AEP	Figure C15	Figure C21
0.2% AEP	Figure C16	Figure C22
0.05% AEP	Figure C17	Figure C23
PMF	Figure C18	Figure C24

The following sections discuss the changes to flood regimes due to the proposed infrastructure on flood prone land.

i Camp Bridge

Camp Bridge will be a double span bridge structure that crosses the Yarrangobilly River channel. The road embankment leading to the bridge will be constructed to levels that are approximately 1.5m above floodplain levels and will form a complete blockage of floodplain conveyance through the left (southern) floodplain area. The road is elevated to provide flood free access during a 1% AEP event. Model results indicate that:

- For the 20 and 5% AEP events, there will be minimal change to existing flooding regimes. This is because the majority of the flow conveyance occurs in the river channel and flood levels are below the bridge soffit.

- For the 1% AEP event, flood levels upstream of the bridge structure are predicted to increase by up to 200 mm. Velocities are predicted to increase by 10 to 20% in floodplain areas that are adjacent to the bridge abutments.

- For the 0.2% AEP events flood levels upstream of the bridge structure are predicted to increase by up to 900 mm. This is due to the road embankment forming a complete blockage of floodplain conveyance on the left (southern) floodplain area. Velocities are predicted to increase by up to 30% in vicinity of the bridge structure. Similar results are predicted for the 0.05% AEP event.

- For the PMF event, flood waters overtop the road embankment. Hence, the flood level and velocity impacts are lower relative to the 0.2% and 0.05% AEP events.

The predicted changes to flooding regimes is consistent with expectations for a bridge that is designed to AustRoads standards and are unavoidable if the bridge is to be designed to maintain access during a 1% AEP event. It is noted that:

- there is no infrastructure or items of heritage significance in the flood level and velocity impact areas; and

- the former Washington Hotel is downstream of the road embankment. Model results indicate that the road embankment will shield this area, reducing the risk of flood damage to the ruins.

During detailed design, the potential to lower the levels of the road embankment leading into the bridge will be reviewed. This will reduce the magnitude of flood level increases in 0.2% AEP and greater magnitude events. If this is practical, the design will be amended to incorporate lower road embankment levels.

ii Wallaces Bridge

Wallaces Bridge will comprise a single span structure with the deck soffit elevated above the 1% AEP flood level. The bridge abutments will be constructed to levels that are 4 to 5 m above floodplain levels and will form a complete blockage of floodplain conveyance. The road is elevated to provide flood free access during a 1% AEP event. Model results indicate that the bridge structure will result in similar impacts to those described above for the Lobs Hole Road crossing (Camp Bridge) over the Yarrangobilly River. There is no infrastructure or items of heritage significance in the flood level and velocity impact areas.

iii Western emplacement area

The western emplacement area will be used as temporary rock and soil stockpiles and will be established on the southern portion of the Yarrangobilly River floodplain. The stockpile area will be rehabilitated at the end of Exploratory Works. The stockpiles will be on a higher portion of the floodplain and avoid areas of elevated flow conveyance that are indicated in the VD results. Model results indicate that the stockpiles will result in minimal change to existing flood regimes for the 1% AEP and lower magnitude events. For the 0.2% AEP and higher magnitude events, the emplacement will displace flow conveyance area resulting in moderate flood level and velocity increases in the adjoining floodplain areas. There is no infrastructure or items of heritage significance in the flood level and velocity impact areas.

iv Portal construction pad water management basin

The water management basin for the portal construction pad will be established on the eastern side of the Yarrangobilly River floodplain. The basin will be removed at the end of Exploratory Works as part of the construction pad rehabilitation. Model results indicate that the basin will result in minimal change to existing flood regimes for the 1% AEP and lower magnitude events. For the 0.2% AEP and higher magnitude events, the basin will displace flow conveyance area resulting moderate flood level and velocity increases in the adjoining floodplain areas. There is no infrastructure or items of heritage significance in the flood level and velocity impact areas.

5.4 Emergency response

With reference to Figures C6 and C12, the accommodation camp and portal construction pad will be predominantly established above the PMF flood extent and will therefore provide flood refuge for site personal. Snowy Hydro routinely monitor weather conditions and have sufficient expertise, systems and monitoring equipment in place to identify weather systems that have potential to produce flood producing rainfall. Accordingly, it is expected that adequate warning will be provided to enable to safe and orderly evacuation of all site personnel to designated flood refuge locations above the PMF extent.

A flood emergency response plan will be prepared as part of the Exploratory Work's emergency response plans.

5.5 Summary and mitigation

A flood assessment has been undertaken as part of the EIS. The assessment is informed by modelling of flooding in the Yarrangobilly River, Wallaces Creek and minor tributaries in proximity to the Exploratory Works. The modelling has been undertaken in accordance with the methods recommended in ARR2016. The flood model results have been used to establish flood characteristics within Lobs Hole for the 20%, 5%, 1%, 0.2%, 0.05% AEP and PMF events.

The Exploratory Works avoid flood prone land where possible. However, the following infrastructure will unavoidably need to be constructed on flood prone land:

- bridge crossings over the Yarrangobilly River and Wallaces Creek;
- the western emplacement area; and
- the water management basin for the portal construction pad.

The flood model was applied to assess changes to the existing flooding regime associated with the infrastructure. This process concluded that the predicted changes to flood regimes will not impact infrastructure or items of heritage significance.

Table 5.5 provides a summary of the proposed flood risk management controls and commitments to additional design development that are recommended.

Table 5.5 Proposed flood risk management controls and design development recommendations

Control	Description
Proposed controls	
FM 01 – Bridge Design	Camp and Wallaces bridges will be designed in accordance with AustRoads bridge design standards which require the: • bridge deck soffit to be located above the 1% AEP flood level; • bridge structure to be designed to withstand a 0.05% AEP event; and • abutments to be protected by appropriately designed scour protection.
FM 02 – Emplacement area design	The western emplacement will be designed to prevent the risk of emplacement material being entrained in flood waters during a 0.2% AEP event. This may require a flood protection berm or rock armouring along the northern toe of the emplacement.
FM 03 – Flood Emergency Response	A flood emergency response plan will be prepared as part of the project's emergency response plans
Proposed design development	
Lobs Hole Road Embankment Design	During detailed design, the potential to lower the levels of the road embankment leading into the bridge will be reviewed. This will reduce the magnitude of flood level increases in 0.2% AEP and greater magnitude events. If this is practical the design will be amended to incorporate lower road embankment levels.

6 Water Management

6.1 Overview

A water management system will manage both runoff from the Exploratory Works and water produced by and used by Exploratory Works. The water management system for Exploratory Works has been categorised into the following focus areas:

- management of runoff from clean water catchments that traverse the project area;
- water management during construction disturbance;
- management of runoff from unsealed access roads;
- management of stormwater runoff from the accommodation camp;
- management of stormwater runoff from the portal construction pad;
- management of water produced by or used by the Exploratory Works. This water is referred to as process water in this report;
- management of waste water (ie sewage); and
- rock and soil emplacement water management.

This chapter describes the water management risks, water management approach, expected impacts and monitoring and contingency measures proposed for each of the above focus areas. The eight water management focus areas listed above are documented in Sections 6.2 to 6.9 respectively.

Each section includes a number of water management controls. These controls are labelled sequentially as WM 1, WM 2 etc. A summary of all controls proposed is provided in Appendix F.

6.1.1 Terminology

The following terminology is used in this section:

- Receiving water – refers to any watercourse that receives runoff or water discharge from the Exploratory Works.
- Clean water – refers to surface water runoff from catchments that are undisturbed or rehabilitated following disturbance.
- Sediment laden water – refers to surface water runoff from construction disturbance and unsealed access roads. Sediment laden water is likely to contain elevated suspended sediment levels and requires sedimentation treatment prior to release.
- Stormwater – refers to runoff from the accommodation camp and portal compound. Stormwater may contain elevated concentrations of suspended sediment and nutrients.
- Process water – refers to water that will be produced by or used by the proposed construction activities.

- Tunnel affected water – refers to intercepted groundwater and all other water that is dewatered from the exploratory tunnel. It is part of the process water stream.
- Emplacement seepage – refers to water that seeps from the rock and soil emplacements.
- Waste water – refers to waste water generated from the accommodation camp and other onsite amenities.
- Potable water – refers to water that has been treated to a potable water standard.
- Fire water – refers to water that is produced by fire fighting activities.

6.2 Clean water management

6.2.1 Overview

The Exploratory Works will predominately be constructed in steep terrain and will traverse existing drainage lines and watercourses of varying sizes. Management of clean water from upslope areas and transverse drainage lines or watercourses will be an integral aspect of the water management system and civil design for the project.

6.2.2 Potential water management impacts

Identified water management risks include:

- potential for clean water runoff during major flood events to result in damage or failure of road embankments and other infrastructure;
- potential for clean water runoff to enter the water management system. This can increase the volume of water that requires management, reducing the effectiveness of the proposed controls;
- diversion of clean water into adjoining watercourse. This can increase flow rates and erosion risks; and
- potential for erosion upstream and downstream of culvert and bridge structures.

6.2.3 Proposed mitigation and management

The management of clean water interfaces with the Exploratory Works can be achieved through appropriate design and construction of clean water diversion systems. The most appropriate design for each diversion system needs to be established on a case by case basis. Table 6.1 describes proposed controls (or design principles) that will be applied to the design of all clean water diversions.

Table 6.1 Clean water management controls

Control	Description
WM_1.1	Where possible, all clean water will be diverted around or through water management areas. Runoff from clean water areas than cannot be diverted must be accounted for in the design of water management systems.
WM_1.2	All clean water drainage will be designed and constructed to convey the 1% AEP peak flow and will have adequate scour protection.
WM_1.3	Where possible, diversions will seek to avoid materially increasing flow rates in adjoining watercourses.
WM_1.4	Where possible, the diversion of drainage lines or watercourses using contour drains[1] will be avoided.

Notes: 1.Contour drains refer to diversion drains that are constructed along the contour. Contour drains for larger watercourses can require substantial earthworks and are prone to failure on the fill batter side if uncontrolled overflows occur due to the drain capacity being exceeded or a blockage (such as a tree falling into the drain).

6.2.4 Residual impacts

It is expected that clean water interfaces with the Exploratory Works can be adequately managed through the appropriate design and construction of clean water diversion systems.

6.2.5 Monitoring and contingency measures

All clean water diversions will be inspected and maintained as required. No water quality monitoring from clean water diversions is proposed.

6.3 Water management during construction

6.3.1 Overview

As described in Section 2.9 the construction of surface infrastructure including the access roads, construction pad, accommodation camp, services infrastructure and barge access infrastructure will be undertaken within the initial phase of Exploratory Works. Table 6.2 provides an overview of the construction activities, disturbance areas, disturbance periods and receiving waters for the various construction works. The predominant soil type in each construction zone is also noted.

Disturbance associated with the rock and soil emplacement areas is discussed separately in Section 6.9.

Table 6.2 Summary of construction disturbance areas

Infrastructure	Construction activities	Disturbance area[1]	Disturbance period	Predominant soil type(s)[2]	Receiving waters
Access roads					
Upper Lobs Hole Ravine Road upgrade	Minor upgrades to 7.5 km section of existing road. Only single lane access will be provided. No cut and fill earthworks or vegetation clearing will be undertaken.	3.0 ha	6 months	Kandosols	Yarrangobilly River tributaries • Wallaces Creek Tumut River tributaries • Prospectors Creek
Lower Lobs Hole Ravine Road upgrade	Upgrades to 6 km section of existing road involving cut and fill earthworks in some sections. Only single lane access will be provided.	10.5 ha	6 months	Kandosols Tenosols Dermosols	Yarrangobilly River tributaries • Wallaces Creek • Cave Gully • Lick Hole Gully Tumut River tributaries • O'Hares Creek
Lobs Hole Road upgrade	Upgrade to 7.3 km section of existing road providing two-way access.	16.8 ha	6 months	Kandosols	Yarrangobilly River
Mine Trail Road upgrade	Upgrade to 2.2 km section of existing track to two-way access.	8.3 ha	6 months	Kandosols	Yarrangobilly River
Mine Trail Road extension	Establishment of a new two-way road providing access to the exploratory tunnel portal.	3.8 ha	6 months	Kandosols	Yarrangobilly River
Middle Bay Road	Establishment of a new two-way road to the proposed Middle Bay barge ramp.	12.0 ha	6 months	Kandosols	Talbingo Reservoir
Spillway Road	Upgrade of a 3 km section of existing road to provide two-way access to the proposed spillway barge ramp.	13.7 ha	6 months	Kandosols	Jounama Pondage and Talbingo Reservoir
Access Roads (total)		**68.1 ha**			
Portal construction pad	Vegetation clearing, substantial earthworks and establishment of all proposed infrastructure.	9.9 ha	6 months	Tenosols	Yarrangobilly River
Accommodation camp	Vegetation clearing, earthworks and construction of roads and buildings.	7.6 ha	6 months	Tenosols	Watercourse 2 and Yarrangobilly River
Services infrastructure	Services will be installed within service corridors that will form part of the access roads	minimal	6 months	Kandosols	Yarrangobilly River
Total (all works)		**85.6 ha**			

Notes: 1.Distrubance area refers to the area subject to clearing and ground disturbance.

2. Figure 4.4 shows the distribution of soil types relative to the Exploratory Works.

6.3.2 Potential water management impacts

The construction of surface infrastructure will unavoidably require the removal of vegetation and disturbance of soils. Hence, key water management risks include:

- sedimentation in receiving waters due to runoff from construction areas laden with coarse sediment; and
- discharge of runoff laden with fine and/or dispersive sediments that will not readily settle under gravity in receiving waters.

6.3.3 Proposed mitigation and management

The risk of sediment laden water discharge from construction areas can be managed through minimising disturbance areas and durations and establishing appropriately designed erosion and sediment controls for areas that are disturbed. The proposed erosion and sediment control approach is described as follows.

i Soil characteristics

The effectiveness of erosion and sediment control strategies is a function of the characteristics of the soils that will be disturbed. With reference to Table 6.2 the majority of construction activities will occur in Kandosols and Tenosols soils (refer to Section 4.3 for a description of soil characteristics).

It is expected that runoff from disturbed areas in both the Kandosols and Tenosols soil types will be laden with coarse and fine sediments, with some potential for dispersive material.

ii Terrain constraints

Sediment and erosion control options are limited for construction areas that will occur in steep terrain. In particular, the construction of sedimentation basins is not considered possible in steep terrain. Hence, sediment and erosion control strategies have been established for construction areas that are constrained by terrain and are not constrained by terrain.

Table 6.3 provides a break-down of the portion of each construction area this is and isn't constrained by terrain.

Table 6.3 Construction area disturbance: terrain constraints

	Construction disturbance area (ha)		
	Constrained by terrain	**Not constrained by terrain**	**Total**
Access roads			
Upper Lobs Hole Ravine Road upgrade	Nil	3.0	3.0 ha
Lower Lobs Hole Ravine Road upgrade	10.5 ha	Nil	10.5 ha
Lobs Hole Road upgrade	Nil	16.8 ha	16.8 ha
Mine Trail Road upgrade	5.0 ha	3.3 ha	8.3 ha
Mine Trail Road extension	Nil	3.8 ha	3.8 ha
Middle Bay Road	6.0 ha	6.0 ha	12.0 ha
Spillway Road	Nil	13.7 ha	13.7 ha

Table 6.3 Construction area disturbance: terrain constraints

	Construction disturbance area (ha)		
	Constrained by terrain	Not constrained by terrain	Total
Access roads (combined)	**21.5 ha**	**46.6 ha**	**68.1 ha**
Portal construction pad	Nil	9.9 ha	9.9 ha
Accommodation camp	Nil	7.6 ha	7.6 ha
Total (all works)	**21.5 ha**	**64.1 ha**	**85.6 ha**

iii Proposed controls

Erosion and Sediment Control Plans (ESCPs) will be established for each construction area as part of the detailed design of the project. Table 6.4 describes proposed controls (or design principles) that will be applied to the design of all ESCPs.

Table 6.4 Erosion and sediment controls: Construction areas

Control	Description
Controls for all construction areas	
WM_2.1	An ESCP will be prepared for each construction area. The plan will consider local soil characteristics, clean water management and the proposed construction methods.
WM_2.2	The clean water management controls WM_1.1 to 1.4 apply to all ESCPs.
WM_2.3	Source controls such as mulching, matting and sediment fences will be utilised where appropriate.
WM_2.4	Stockpiles will also be located where they are not exposed to overland or flood flow. Monitoring for dispersion and erosion of soil stockpiles will be undertaken, particularly on moderately dispersive soils. Addition of ameliorants, such as gypsum and organic matter for dispersive soils will be undertaken as needed.
WM_2.5	Soils will be lightly scarified on the contour to encourage rainfall infiltration and minimise run-off. As soon as practicable after respreading, a sterile cover crop should be established to limit erosion and soil loss. This will also provide good mulch for native plant establishment.
WM_2.6	Sediment traps or filters will be maintained at all discharge locations. The filters will only use biodegradable materials. The sediment traps and filters will target the removal of coarse sediments.
Additional controls for construction areas that are not constrained by terrain	
WM_2.7	Where appropriate, sedimentation dam will be constructed in accordance with the methods recommended in Managing Urban Stormwater: Soils and Construction: Volume 1 (Landcom, 2004) and Volume 2D (DECC, 2008). Sedimentation dam sizing methodologies are provided in Appendix E. Sedimentation dams will reduce the frequency and volume of discharge and will provide sedimentation treatment during overflow.
WM_2.8	Water captured in sedimentation basins will be used for dust suppression.

6.3.4 Residual impacts

The construction of surface infrastructure will unavoidably require the removal of vegetation and disturbance of soils. The disturbance is expected to occur for a period of up to 9 months during the initial phase of the project. Erosion and sediment controls are proposed to manage sediment laden runoff from construction areas.

For construction areas that are constrained by terrain (25% of the total construction area), it is expected that erosion and sediment controls will effectively remove coarse sediment in runoff. However, entrained fine dispersive sediments are unlikely to be removed. As no sedimentation dams can be constructed in terrain constrained areas, runoff from these construction areas will not be retained. Hence, potentially sediment laden runoff will occur to receiving waters following any material rainfall (10 mm/day or more).

For construction areas that are not constrained by terrain (75% of the total construction area), sedimentation basins will be established to capture and treat runoff. The basins will be sized to capture the 5 day 85th percentile rainfall depth of 30.6 mm and will be de-watered after rainfall (for use as dust suppression). The basins are expected to:

- prevent the discharge of sediment laden water during minor to moderate rainfall (ie less than 30.6mm over five days); and
- during overflow conditions, provide sedimentation treatment, reducing the concentration of fine sediments entering receiving waters.

The following residual impacts to receiving water quality are expected:

- Erosion and sediment controls for all construction areas are expected to effectively remove coarse sediment. Hence, no sedimentation impacts in receiving waters are expected.
- Runoff from construction areas entrained with fine and potentially dispersive sediments is expected to enter receiving waters during and shortly after rainfall. It is expected that any sediment laden water that enters the Yarrangobilly River will be significantly diluted by river flows and will rapidly dissipate. Hence, no material change to the Yarrangobilly River water quality is expected.

It is noted that these impacts will only occur during the initial phase of Exploratory Works.

6.3.5 Monitoring and contingency measures

i Proposed monitoring

The following inspections and water quality monitoring will be undertaken during construction disturbance:

- Erosion and sediment controls will be inspected daily to ensure they are maintained in good working order.
- Monitoring of turbidity and visual inspections will be undertaken on a daily basis when runoff from construction areas to the receiving waters occurs.
- Comprehensive monitoring of runoff from construction areas to the receiving waters will be undertaken four times per year, during wet weather conditions.

A comprehensive receiving water monitoring program will also be undertaken for the duration of the Exploratory Works project. Refer to Chapter 8 for further details on the proposed surface water monitoring plan.

ii Contingency measures

The following additional measures could be implemented if monitoring identifies unacceptable impacts:

- Flocculants or coagulants could be added to sedimentation basins to enhance the removal of fine and dispersive sediments prior to discharge. If this is implemented, specialist advice would be required to ensure that appropriate agents, mixing techniques and monitoring measures are in place.

- Runoff from construction areas with terrain constraints could be collected in sumps and dewatered via pumping to a storage and treatment facility to be sited nearby. This would add significant cost to the project and would have limited effectiveness during intense rainfall conditions when a pump dewatering system would be overwhelmed with the runoff volumes.

6.4 Access road water management

6.4.1 Overview

The project will require the use of access roads that have a collective trafficable area of 12.6 ha. It is noted that trafficable area is less than the construction disturbance area that includes all areas subject to land clearing and ground disturbance during construction.

The access roads will be constructed in the initial six months of the project schedule and will generally comprise upgrades to existing unsealed public roads. Sections of existing public dirt tracks at Lobs Hole that will no longer be required following construction of the new access roads will be removed and rehabilitated.

The access roads will be designed and constructed as permanent roads, will be unsealed and will be used by both light and heavy vehicle traffic.

This section discusses the management of runoff from access roads during Exploratory Works (ie following site establishment and completion of roads). Water management during construction is addressed in Section 6.3.

6.4.2 Potential water management impacts

The access roads will be unsealed and heavily used by both light and heavy vehicle traffic. Accordingly, the key water management risks include:

- sedimentation in receiving waters due to runoff from access roads laden with coarse sediment;

- discharge of runoff laden with fine or dispersive sediments that will not readily settle under gravity in receiving waters; and

- erosion due to failure of the road drainage.

6.4.3 Proposed mitigation and management

The effective management of runoff from unsealed access roads requires appropriate design and ongoing maintenance of the road and drainage systems. Table 6.5 describes proposed controls (or design principles) that will be applied to the design and management of access roads.

Table 6.5 Water management controls: access roads

Control	Description
WM_3.1	Existing dirt tracks that will no longer be required following the construction of the new access roads will be removed and rehabilitated. This will reduce associated sediment loads.
WM_3.2	All cut and fill batters will be stabilised by vegetation.
WM_3.3	The clean water management controls WM_1.1 to 1.4 will apply to the design of all access roads.
WM_3.4	Access road surfaces will be maintained with appropriate aggregate material to reduce sediment loads.
WM_3.5	Access roads will be single cross fall and will grade to a tables drain located against the toe of the cut batters. The drains will be stabilised by rock armouring as required. The table drains will drain into either sedimentation basins or clean water transverse drainage structures.
WM_3.6	Sediment traps or filters will be maintained at all discharge locations. The filters will only use biodegradable materials. The sediment traps and filters will target the removal of coarse sediments.
WM_3.7	Where appropriate, the sedimentation dams established to manage runoff during construction of the access roads will be maintained to provide ongoing treatment of runoff from access roads.

6.4.4 Residual impacts

Access roads will have a single cross fall that will grade to table drains located against the toe of the cut batters. The table drains will drain into either sedimentation basins or clean water transverse drainage structures.

Runoff from access roads has potential to be sediment laden water. The roads will be designed and constructed with appropriate aggregate materials and adequately sized drainage. This will reduce potential sediment loads from the road areas. Sediment and erosion controls will also be established and maintained. These controls are expected to capture coarse sediment and will prevent sedimentation impacts in receiving waters.

There is potential for some runoff from access roads to be laden with fine and potentially dispersive sediments, especially if the roads are used during wet weather. The sediment and erosion controls are expected to provide limited removal of fine and dispersive sediments. Hence, some sediment laden runoff from access roads may drain into receiving waters. It is expected that this water would be rapidly mixed with clean water before flowing into the Yarrangobilly River where it will be significantly diluted by river flows and will rapidly dissipate. Hence, no material change to the Yarrangobilly River water quality is expected.

It is noted that sediment laden runoff is already likely to occur from the numerous existing unsealed roads and tracks in the Lobs Hole area as well as from the exposed mine workings areas. Accordingly, the Yarrangobilly River and other receiving watercourses would have received sediment laden runoff from local catchment runoff for a number of decades.

6.4.5 Proposed monitoring and contingency measures

i Proposed monitoring

Monitoring of runoff from access roads at four random locations will be undertaken four times per year, during wet weather conditions as part of the comprehensive wet weather monitoring program. Refer to Chapter 8 for further details on the proposed surface water monitoring plan.

ii Contingency measures

The following additional measures could be implemented if monitoring identifies unacceptable impacts:

- restrictions could be applied to the use of access roads during intense rainfall; and
- poorly performing sections of road could be sealed.

6.5 Stormwater management: Accommodation camp

6.5.1 Overview

i Proposed facility

The accommodation camp will provide accommodation and supporting services for workers in close proximity to the exploratory tunnel. The camp layout is shown on Figure 2.6 and includes ensuite rooms surrounding central facilities including a kitchen, tavern, gym, admin office, laundry, maintenance building, sewage and water treatment plants and parking. An access road will connect to the north side of Lobs Hole Road.

ii Setting

The accommodation camp will be located to the south of Watercourse 3 (refer to Figure 4.5) on steep topography that falls to the north at approximately 1V to 4H. All runoff from the camp area drains into Watercourse 3, which is described in Table 4.7 as being a 3^{rd} order watercourse that has an intermittent flow regime. Watercourse 3 has a catchment area of 224 ha and flows into the Yarrangobilly River approximately 500 m downstream of the camp and 400 m upstream of Talbingo Reservoir.

The camp will be established in Tenosols soils that are described in Table 4.5 as being shallow soils that typically overlie hard rock. The soils have a low water holding capacity (due to their shallowness) and are categorised as Soil Hydrologic Group B, implying a low to medium runoff potential. Due to the shallow nature of the soils and steep terrain, infiltration based stormwater systems are not considered to be suitable.

A conceptual design has been prepared to inform the camp layout (Figure 2.6). Given the steep terrain, the design seeks to establish accommodation units on terraced landforms. Stormwater runoff from each terrace will drain to a swale drain that will be located along the back (ie along the toe of the next lift) of the terrace. These drains are likely to be founded within hard rock and may need to be concrete lined. Larger buildings and services such as water tanks will be constructed on flat pads that will be established by earthworks.

6.5.2 Potential water management impacts

The accommodation camp will provide accommodation and supporting services for workers. No construction activities that could potentially contaminate stormwater runoff will occur within the accommodation camp. Hence, identified water management risks include:

- stormwater flooding issues and/or erosion of the landform due to inadequate drainage system design;
- changes to runoff regimes due to the introduction of impervious areas; and

- increased concentrations and loads of suspended solids and nutrients in runoff from roof areas and road pavements.

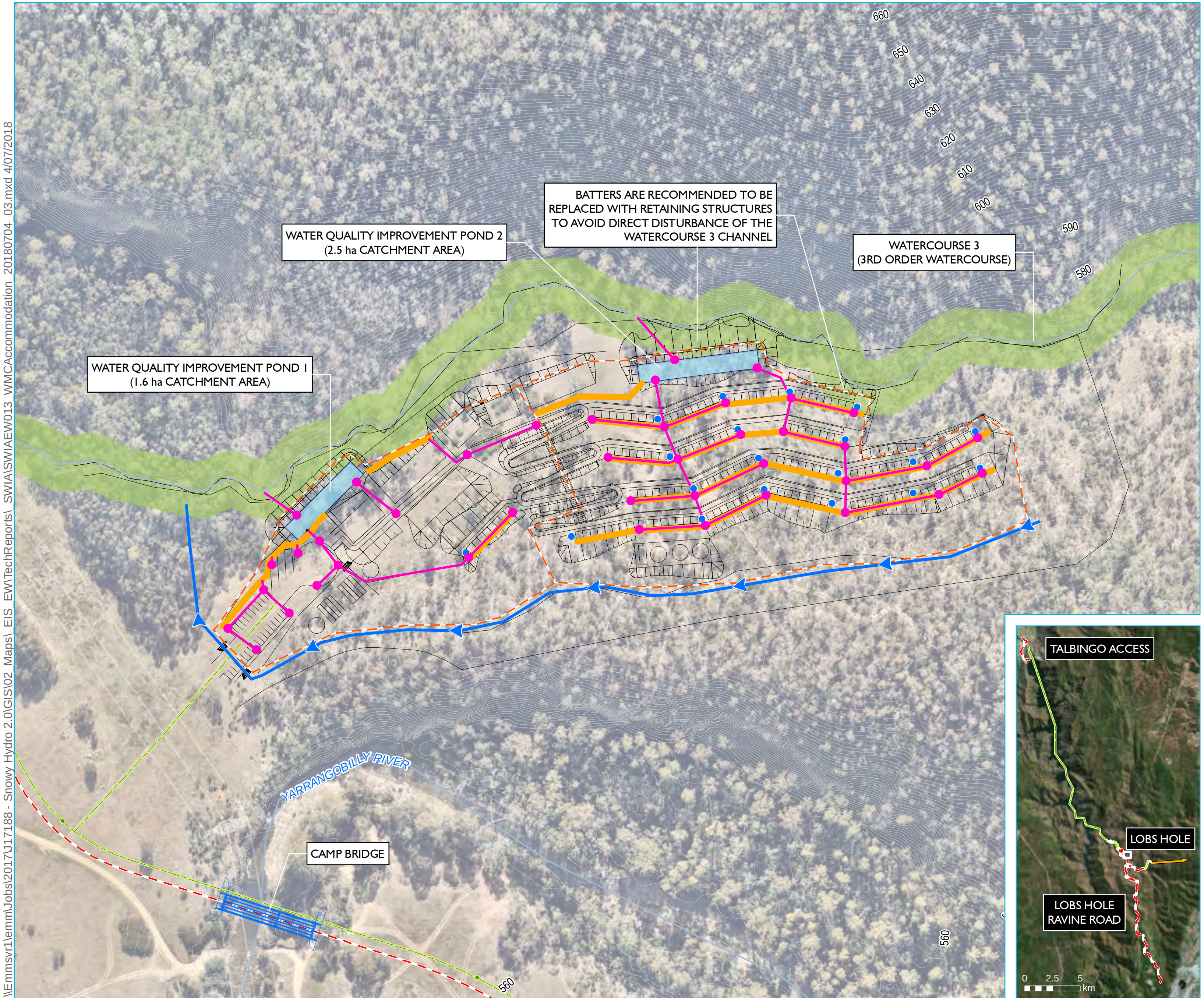
Waste water management is discussed separately in Section 6.8.

6.5.3 Proposed mitigation and management

The effective management of stormwater from the accommodation camp requires a stormwater system design that can be integrated with the proposed civil design and is suitable for the steep topography and shallow soils. The proposed approach will seek to:

- maximise the use of source controls, such native endemic landscaping, permeable paving and rain gardens;
- avoid infiltration based systems (due to the shallow soils);
- provide a piped drainage system to convey stormwater through the camp area to downstream controls; and
- provide water quality improvement ponds to treat runoff from the accommodation camp and attenuate peak runoff flows.

Table 6.6 provides a summary of the proposed controls (or design principles). These controls have been applied to stormwater concept, which is shown in Figure 6.1. As noted in Figure 6.1, the stormwater management area is 4.1 ha.



Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018)

KEY

- Accommodation camp conceptual layout
- Exploratory tunnel
- Permanent bridge
- Access road upgrade
- Communications cable
- Watercourse
- Contour (1m LiDAR)
- Rainwater tank
- Clean water diversion
- Piped drainage
- Surface drain
- Water quality improvement pond
- 15m vegetated riparian zone (inner zone)
- Catchment area boundary

Accommodation camp: stormwater management concept

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 6.1

snowy 2.0 EMM

Table 6.6 Water management controls: accommodation camp

Control	Description
WM_4.1	A stormwater management plan will be prepared as part of the detailed design of the project. The plan will consider geotechnical constraints including shallow soils.
WM_4.2	Clean water from upslope areas will be diverted around the accommodation camp.
WM_4.3	A piped drainage system will be established to capture stormwater and convey it to the proposed water quality improvement ponds. The drainage system will have a 20% AEP capacity. Overland flow paths will be provided as required.
WM_4.4	All pervious areas including batters will be vegetated with endemic native vegetation.
WM_4.5	Runoff from roof areas will be collected in rainwater tanks where possible. Captured water will be used for non potable uses, reducing runoff volumes.
WM_4.6	Source controls including permeable pavers and rain gardens will be used where possible.
WM_4.7	All runoff from the accommodation camp will be treated in one of two water quality improvement ponds. The ponds will be designed as constructed wetlands and will provide a water quality improvement function and attenuate peak runoff rates from the accommodation camp.
WM_4.8	Collectively, the stormwater controls will be sized and configured to achieve the following pollution load reductions (as calculated using the MUSIC water quality model): • 85% reduction in post development mean annual load of total suspended solids; • 60% reduction in the post development mean annual load of total phosphorous; and • 45% reduction in the post development mean annual load of total nitrogen.
WM_4.9	The water quality improvement pond batters will be established using retaining structures to avoid disturbance of the Watercourse 3 channel.

6.5.4 Residual impacts

It is expected that the proposed stormwater controls will mitigate potential water management risks. Hence, no material impacts to receiving waters are expected.

6.5.5 Proposed monitoring and contingency measures

i Monitoring

Monitoring of runoff from the two water quality improvement ponds will be undertaken four times per year during wet weather conditions as part of the comprehensive wet weather monitoring program. Refer to Chapter 8 for further details on the proposed surface water monitoring plan.

ii Contingency measures

The following additional measure could be implemented if monitoring identifies unacceptable impacts:

- Stormwater from the water quality improvement ponds could be dewatered to Talbingo Reservoir using the pipeline that will convey treated waste water and controlled discharge of process water. This arrangement is discussed in Section 6.7.

6.6 Stormwater management: portal construction pad

6.6.1 Overview

i Proposed facility

A portal construction pad for the exploratory tunnel will provide a secure area for construction activities. Proposed infrastructure at the pad will primarily support tunnelling activities and include a concrete batching plant and associated stockpiles, site offices, maintenance workshops, refuelling facilities, construction support infrastructure, car parking and equipment laydown areas.

Stockpile areas will allow for around two to three months supply of concrete aggregate and sand for the concrete batching plant to ensure that the construction schedule for the proposed access road works do not interfere with the exploratory tunnel excavation schedule. A temporary excavated rock stockpile area is also required to stockpile material excavated during tunnel construction prior to its transfer to the larger excavated material emplacement areas.

The proposed layout of the portal construction pad is shown in Figure 2.4.

ii Setting

The portal construction pad will be established in steep topography that falls to the west towards the Yarrangobilly River floodplain at approximately 1V to 5H. There are a number steep ephemeral drainage lines that traverse the pad area. These drainage lines receive runoff from the steep terrain located to the east of the proposed construction pad and have catchment areas of up to 6 ha.

Soils within the construction pad and upslope area are identified as Tenosols soils that are described in Table 4.5 as being shallow soils that typically overlie hard rock.

The construction pad will comprise a terraced landform that will provide near level lay down areas that are suitable for the proposed activities. The landform will be primarily established by cutting into the underlying hard rock material. However, the lower lay down area will be partially established by filling. Stabilised rock batters or retaining walls will be established between terraces and the existing landform.

The lay down areas will comprise either concrete hardstand or compacted road base and will be integrated with an access road that will be aligned centrally through the facility. Stormwater runoff will be collected in a piped drainage system that will discharge to a water management basin located on the Yarrangobilly River floodplain.

iii Water management overview

Water within the construction pad will be managed by the following water management systems:

- The risk of contamination of stormwater from construction activities will be minimised through the use of covering and bunding high risk areas.
- A stormwater system will manage runoff from the pad and upslope clean water areas. The stormwater management system is described in this section.
- A process water system will manage water produced by or used by the construction activities. The process water management system is described in Section 6.7.

- Waste water (ie sewage) will be transported (via tanker) to a waste water treatment plant near the accommodation camp. The waste water management system is described in Section 6.8.

6.6.2 Potential water management impacts

The portal construction pad will provide a secure area for construction activities. Some construction activities and material stored within in the pad area have potential to contaminate stormwater. Identified water management risks include:

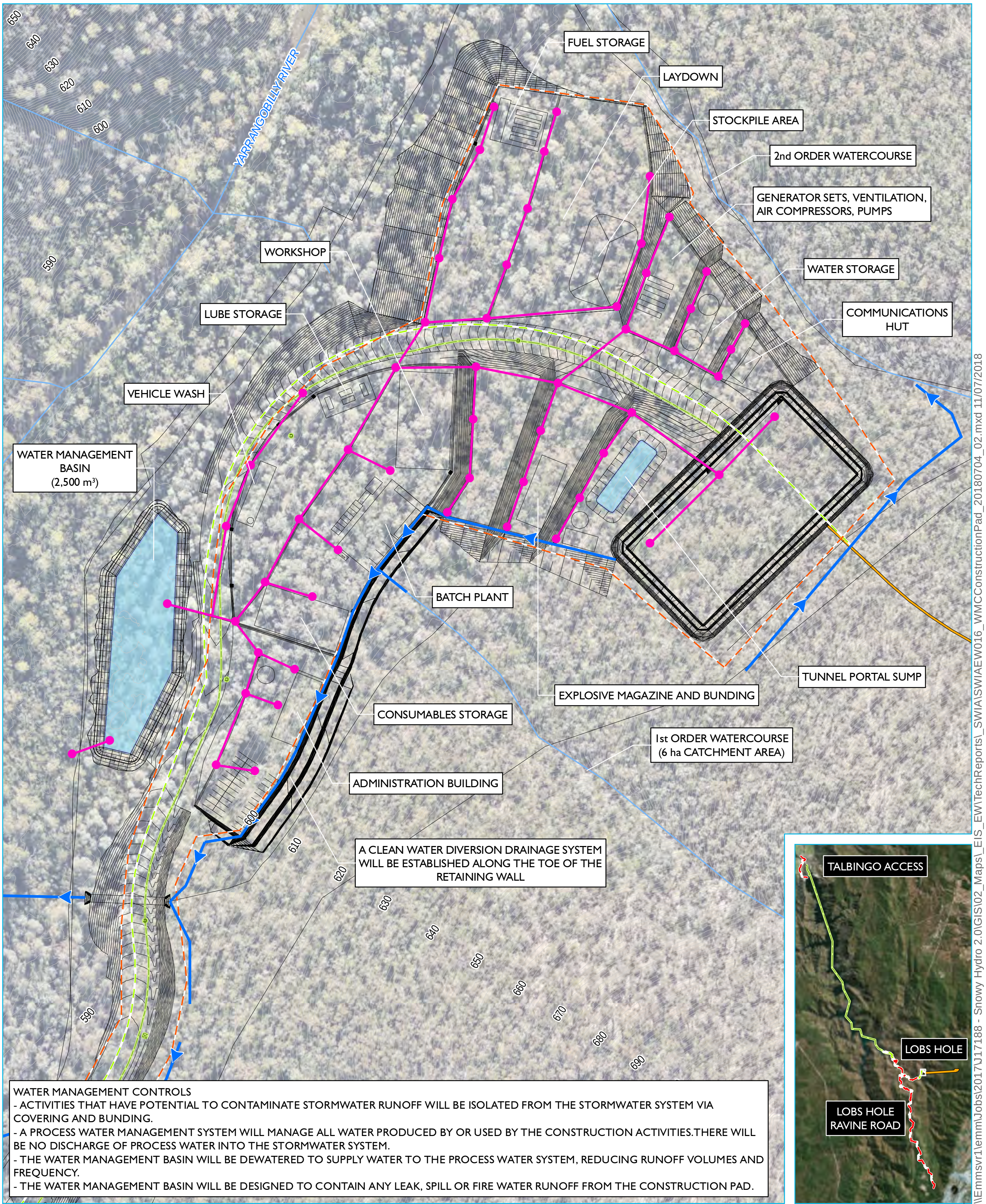
- contamination of stormwater runoff due to construction activities;
- stormwater flooding issues and/or erosion of the landform due to inadequate drainage system design;
- increased concentrations and loads of suspended solids and nutrients in runoff from the construction pad; and
- potential for contamination of receiving waters due to accidental leaks or spills or runoff of water used for fire fighting purposes (referred to as fire fighting water).

6.6.3 Proposed water management and mitigation

The effective management of stormwater from the portal construction pad requires controls to:

- minimise the risk of contamination of stormwater from construction activities;
- manage stormwater runoff from the construction pad and upslope clean water areas; and
- contain accidental leaks or spills and fire water runoff.

Figure 6.2 describes a stormwater management concept for the portal construction pad. Additional information on the proposed controls is provided below the figure.



Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017)

KEY

- Exploratory tunnel
- Access road extension
- Communications cable
- Portal construction pad conceptual layout
- Watercourse
- Contour (1m LiDAR)
- Clean water drainage
- Piped drainage
- Water management area

Portal construction pad: water management concept

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 6.2

i. Management of areas with elevated water quality risks

Some activities that will occur on the portal construction pad have the potential to contaminate stormwater runoff. These areas are to be isolated from the stormwater system through the use of covering (ie by a building or roof) and/or bunding. Water produced within the covered and bunded areas will be either:

- managed by the process water system that is described in Section 6.7; or
- disposed as liquid waste to an appropriate facility.

Table 6.7 describes activities that will be undertaken in covered and or bunded areas.

Table 6.7 Activities that will be undertaken in covered and bunded areas

Activity	Water quality risks	Proposed controls
Concrete batching	Runoff from cementitious areas can contain elevated pH, suspended sediments and metals.	All cementitious areas will be covered and bunded, with all water managed in the process water system.
Equipment wash down bays	Construction equipment will be washed using process water in designated wash bays. Wash down water is likely to contain elevated suspended solids and potential for oils and greases. The use of washing agents may also impact water quality and will be avoided where possible.	• Equipment wash down bays will be bunded to prevent stormwater ingress. • Runoff from the wash bays will be collected and transferred to the process water system.
Consumables storage	Some consumables are likely to be hazardous materials.	Consumables will be stored in a building. Any hazardous materials will be stored in bunded areas.
Workshop	Water produced from work shop area may contain oils and greases and numerous other pollutants.	All workshop activities will be undertaken within a building. Any waste will be disposed offsite to an appropriate waste management facility.
Fuel storage and refuelling area	Hydrocarbons in stormwater runoff and the risk of major leaks or spills of hydrocarbons.	Fuel storage and refuelling areas will be covered and bunded to prevent stormwater ingress and capture any leaks or spills.
Generator and air compressor pumps	Risk of major leaks and spills of hydrocarbons or compressor fluids.	The generator and air compressor pumps will be bunded to contain any leak or spill.

ii. Management of stormwater runoff

A stormwater management system will be required to mange runoff from:

- the portal construction pad and adjoining access road area, which has a collective area of 5.6 ha; and
- clean water catchments that have areas of up to 6 ha.

The following management approach is proposed:

- Clean water runoff from upslope catchments (that have areas of up to 6 ha) will be diverted through the portal construction pad in a designated clean water drainage system. This will avoid the use of contour drains to divert clean water around the pad.

- Runoff from the pad area will be collected in a piped stormwater drainage system that will convey runoff to a water management basin that will be located on the Yarrangobilly River floodplain, immediately to the west of the pad. The piped drainage system will have a 1% AEP capacity.

- All aggregate storage and stockpile areas will be bunded to prevent stormwater ingress. Runoff from these areas will be treated in sediment wedge pits to remove all coarse material. Sediment wedge pits will overflow into the piped drainage system.

- All runoff from the portal construction pad and adjoining access road will be conveyed to a water management basin that will have a volume of at least 2,500 m^3, providing more than 400 m^3 of treatment volume per hectare of catchment. The basin will be designed as a constructed wetland and will provide a water quality improvement function. Water captured in the basin will be extracted to supply the process water system. Water balance modelling that is described in Section 6.7 estimates that extraction will reduce overflow volumes from the basin into the Yarrangobilly River by 69% (reference Table 6.11) over the 26 month tunnel construction period.

i Containment leaks or spills and fire water runoff

A major leak, spill or firewater runoff could occur from any portion of the portal construction pad area. Where possible and safe, leaks and spills will be contained near the source and remediated. However, as these incidents are generally associated with some sort of accident or emergency containment at source may not be possible.

The water management basin will be designed to provide a freeboard between its overflow pipe and spillway. The freeboard volume will be calculated to contain all conceivable leak, spill and firewater runoff volumes. The overflow pipe will have a manual shutoff valve that will enable site management to shut off the overflow pipe to enable the basin to contain any leak, spill or fire water runoff.

ii Summary of proposed controls

Table 6.8 provides a summary of the proposed controls (or design principles).

Table 6.8 Water management controls: portal construction pad

Control	Description
WM_5.1	A stormwater management plan will be prepared as part of the detailed design of the project. The plan will be integrated with the process water system.
WM_5.2	Where practical, all activities that will occur on the portal construction pad with potential to contaminate stormwater runoff will be isolated from the stormwater system through the use of covering (ie by a building or roof) and bunding. Water produced within the covered and bunded areas will be either: • managed by the process water system; or • disposed as liquid waste to an appropriate facility.
WM_5.3	Clean water from upslope areas will be diverted through the portal construction pad in a designated clean water drainage system.
WM_5.4	A piped drainage system will be established to capture stormwater and convey it to the water management basin. The drainage system will have a 1% AEP capacity. Overland flow paths will be provided as required.
WM_5.5	All aggregate storage and stockpile areas will be bunded to prevent stormwater ingress. Runoff from these areas will be treated in sediment wedge pits to remove all coarse material. Sediment wedge pits will overflow into the piped drainage system.

Table 6.8 Water management controls: portal construction pad

Control	Description
WM_5.6	All runoff from the portal construction pad and adjoining access road will be conveyed to a water management basin that will have a volume of at least 2,500 m^3. The basin will be designed as a constructed wetland and will provide a water quality improvement function. Water captured in the basin will be extracted to supply the process water system.
WM_5.7	The water management basin will be designed to provide a freeboard between its overflow pipe and spillway. The freeboard volume will be calculated to contain all conceivable leaks, spills and firewater runoff volumes. The overflow pipe will have a manual shutoff valve that will enable site management to shut off the overflow pipe to enable the basin to contain any leak, spill or fire water runoff.

6.6.4 Residual impacts

It is expected that the proposed stormwater controls will mitigate potential water management risks. Hence, no material impacts to receiving waters are expected.

6.6.5 Proposed monitoring and contingency measures

i Monitoring

Monitoring of water in water management basin will be undertaken four times per year during wet weather conditions as part of the comprehensive wet weather monitoring program. Refer to Chapter 8 for further details on the proposed surface water monitoring plan.

ii Contingency measures

The following additional measure could be implemented if monitoring identifies unacceptable impacts:

- Stormwater from the water management basin could be dewatered to Talbingo Reservoir using the pipeline that will convey the controlled discharge of process water (discussed in Section 6.7).

6.7 Process water management

6.7.1 Overview

As discussed in Section 6.6, construction activities that may produce contaminated water streams will be isolated from the stormwater system to avoid the contamination of stormwater runoff. A process water system is required to manage this water. In particular, the system will be configured to manage tunnel affected water that will be dewatered from the exploratory tunnel.

Groundwater modelling undertaken for the Exploratory Works predicts that groundwater inflows into the tunnel will increase from zero at tunnel commencement to 0.45 ML/day (161 ML/yr) near completion (EMM 2018b). Hence, the volume of water that requires management will progressively increase over the tunnel construction period. Figure 6.3 shows the predicted and maximum plausible inflow rates over the 26 month tunnel construction period (EMM 2018b).

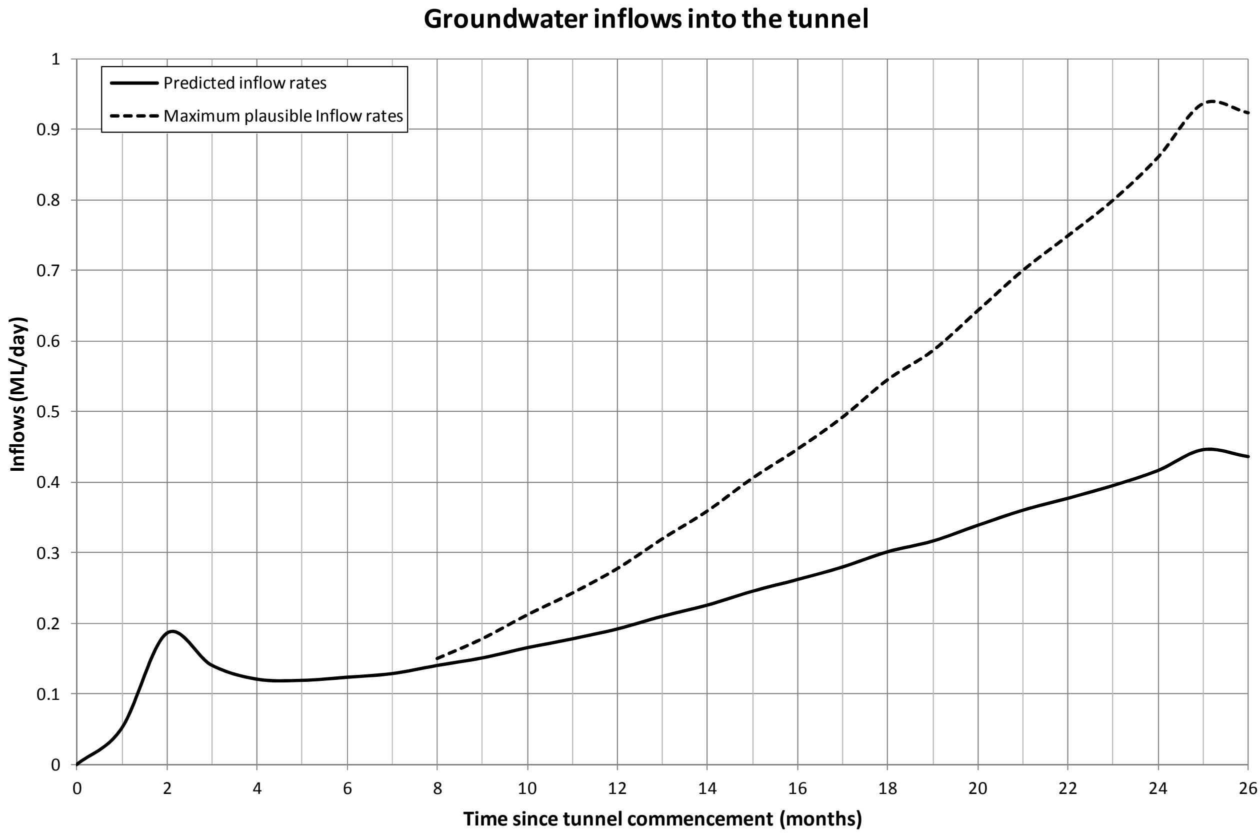


Figure 6.3 predicted groundwater inflow rates (EMM, 2018b)

Water balance modelling has been undertaken to assess and describe the functionality of the process water system over the tunnel construction period, under a range of weather conditions. Modelling methods, assumption and results are explained in a method statement provided in Appendix D.

This section describes the process water management system and presents key water balance results.

6.7.2 Potential water management impacts

Untreated process water has the potential to be contaminated due to its use in / interaction with construction activities. Potential management risks include:

- the uncontrolled discharge of process water into the stormwater system due to inadequate system design or stormwater ingress into the process water system;
- operational health and safety risks due to the re-use of process water; and
- receiving water impacts due to the:
  - controlled discharge of process water with inadequate treatment; or
  - extraction of water.

6.7.3 Process water management system

The process water management system will be designed to:

- manage potentially contaminated water produced from construction activities; and
- supply water for use in construction activities.

The system will be designed to prevent (where possible) the ingress of stormwater into the process water system. This will be achieved by covering and bunding process water areas. Captured process water will be treated in a water treatment plant. Treated process water will be used for:

- tunnel construction;
- concrete production;
- equipment wash down; and
- access road dust suppression.

The process water management system will source additional water from the portal construction pad's water management basin and Talbingo Reservoir as required to meet demand. Any surplus treated process water will be discharged to Talbingo Reservoir. This arrangement will avoid either discharge to or extraction from the Yarrangobilly River.

Figure 6.4 describes the process water management system. Additional information on the sources and uses of process water and water treatment plant specifications is provided in Table 6.9.

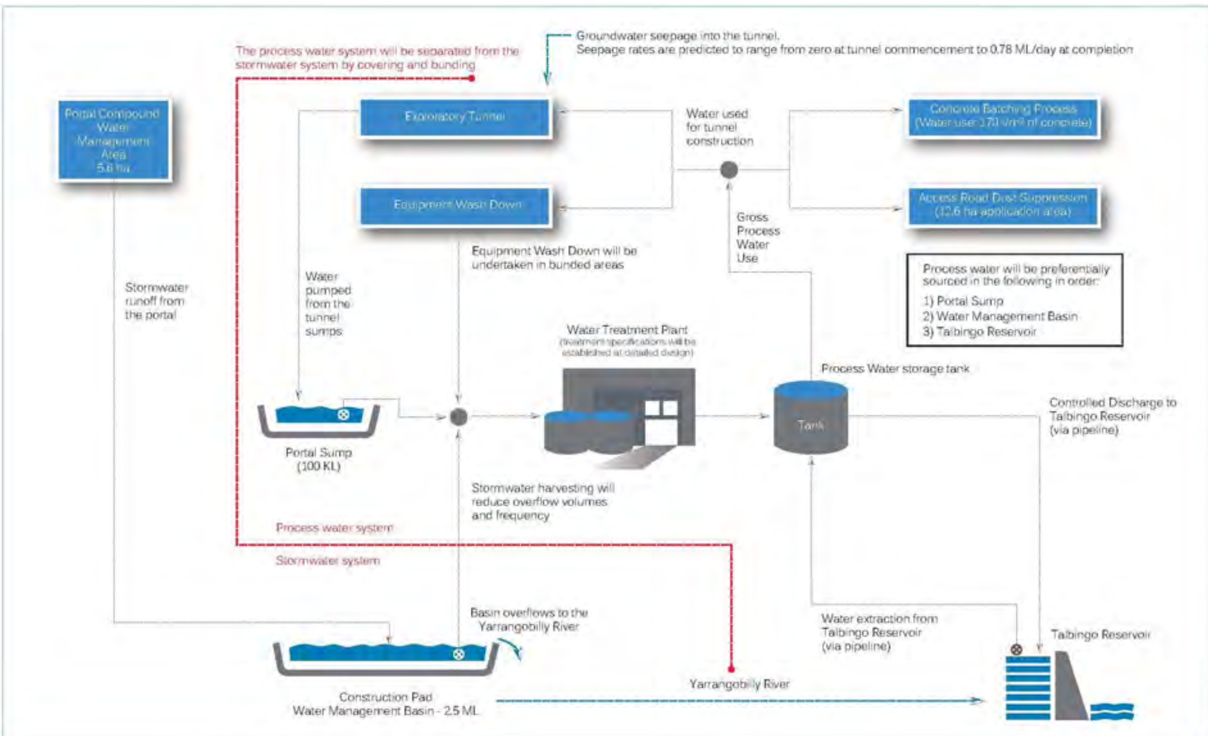


Figure 6.4 Process water management system

i Process water sources and uses

Table 6.9 provides information on expected process water sources and uses.

Table 6.9 Process water sources and uses

	Description
Sources	
Tunnel affected water	Tunnel affected water refers to all water that will be dewatered from sumps within the exploratory tunnel. The majority of the water will originate from groundwater inflows which are expected to progressively increase from zero to 0.45 ML/day over the estimated 26 month exploratory tunnel construction period. Some additional water will originate from water used in the construction activities. Groundwater inflows into the tunnel are not expected to have poor water quality based on groundwater sampling results (EMM 2018b). Hence, the potential for contamination of the tunnel affected water is due to the use and interaction with construction activities that include drilling, blasting, shotcreting and washing down of equipment. The water quality characteristics of tunnel affected water are likely to be variable and cannot be reliably established. However, the water may contain elevated suspended solids, nitrate (due to use of explosives) and metals.
Uses	
Equipment wash facilities	Construction equipment will be washed using process water in designated wash bays. Runoff from the wash bays will be collected and transferred to the process water system. As the washing will be undertaken with process water, the net use of water will be minimal. Wash down water is likely to contain elevated suspended solids and potential for oils and greases. The use of washing agents may also impact water quality and will be avoided where possible.
Shotcrete production	The production of shotcrete will require 170 litres of water per m^3 of concrete. Average water use for shotcrete is estimated to be 12 KL/day.
Tunnel construction water use	Process water will be used in the tunnel construction process. The average water use is estimated to be 10 KL/day.
Access road dust suppression	Water application to access roads is a proposed air quality management control (Jacobs 2018). It is estimated that water application to 12.6 ha of access roads will be required for the duration of Exploratory Works. Daily water use for dust suppression will range from zero during wet weather to over 1 ML/day on a dry summers day.

ii Water treatment

A water treatment plant will treat all process water using the following treatment processes:

- pH adjustment (as required);
- treatment of suspended solids; and
- disinfection (as required).

Additional treatment may be required subject to process water quality monitoring and verification of the need for controlled discharge to the Talbingo Reservoir.

6.7.4 Water balance

A water balance of the process water system has been prepared using GoldSim water balance software. The objectives of the model are to:

- demonstrate the functionality of the process water system over the estimated 26 month exploratory construction period;
- estimate the probable range in water transfer volumes over the above period, having regard to variable weather conditions; and
- assist in the determination of water licensing requirements.

Modelling methods, assumptions and results are explained in a method statement provided in Appendix D.

i Model results

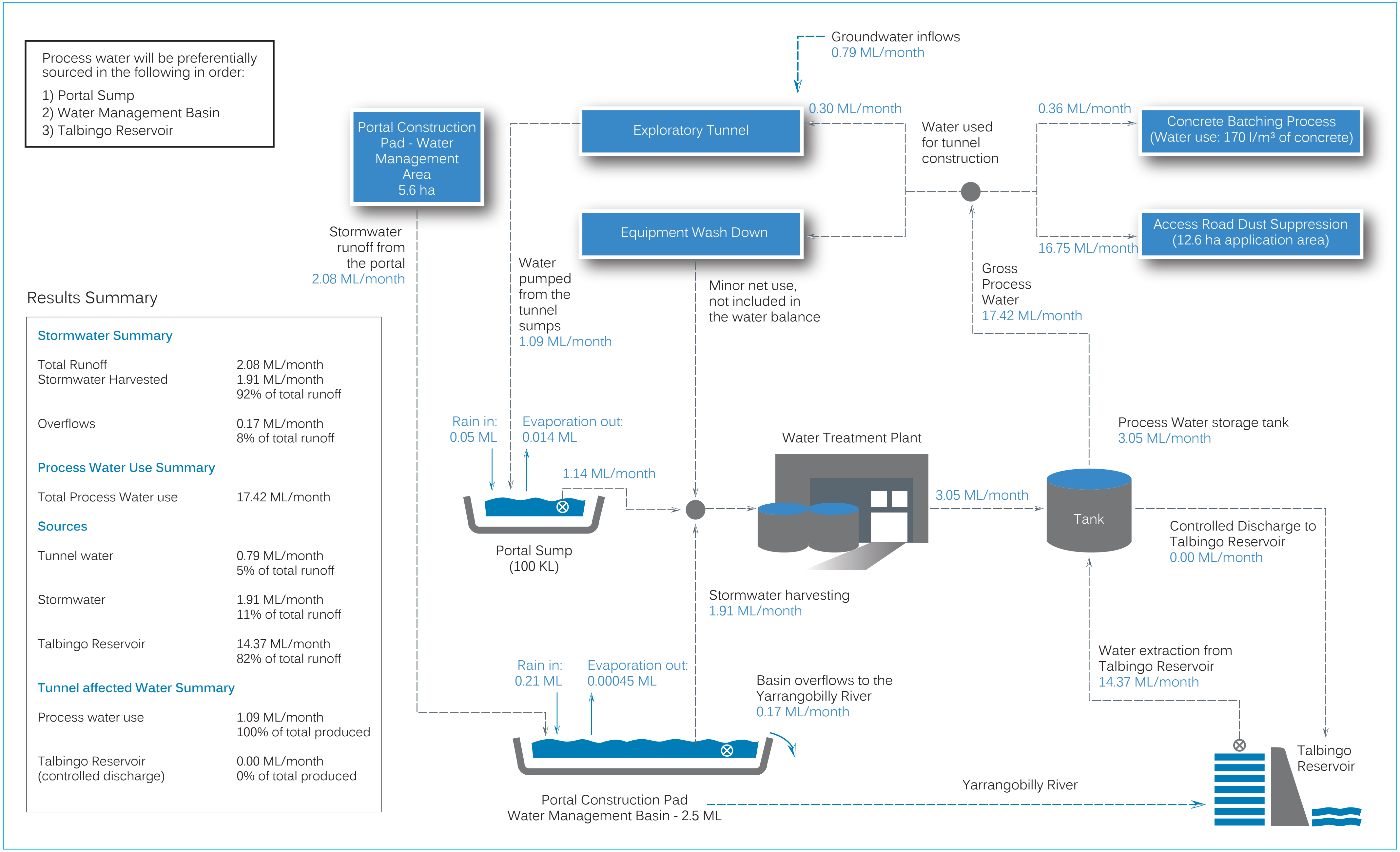
Model results are presented in flow chart and table formats.

a. Flow chart results

The flow charts have been prepared to describe the typical functionality of the process water management system during dry, median and wet rainfall conditions. The flow charts present monthly values that have been calculated from annualised results (ie monthly value = annual value divided by 12). This was done to avoid any seasonal variation in the results. Flow charts have been prepared for months 1, 12 and 26 of the tunnel construction period. Results from median conditions are provided in this section while other flow charts are provided in Appendix D. Table 6.10 provides a reference to all figures.

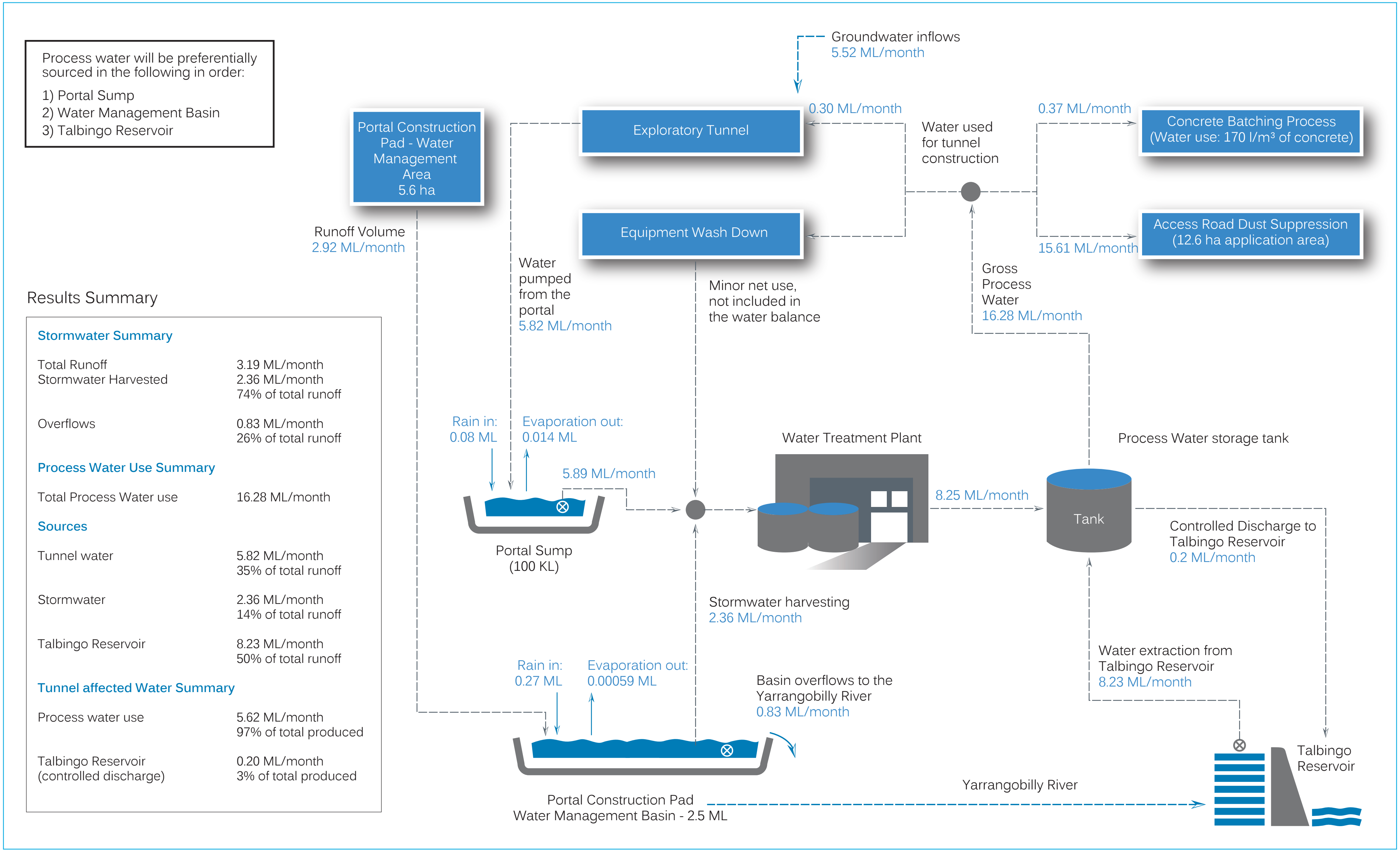
Table 6.10 Water Balance figure reference

	Dry conditions	Median conditions	Wet conditions
Month 1	Figure D3	Figure 6.5	Figure D5
Month 12	Figure D6	Figure 6.6	Figure D8
Month 26	Figure D9	Figure 6.7	Figure D11

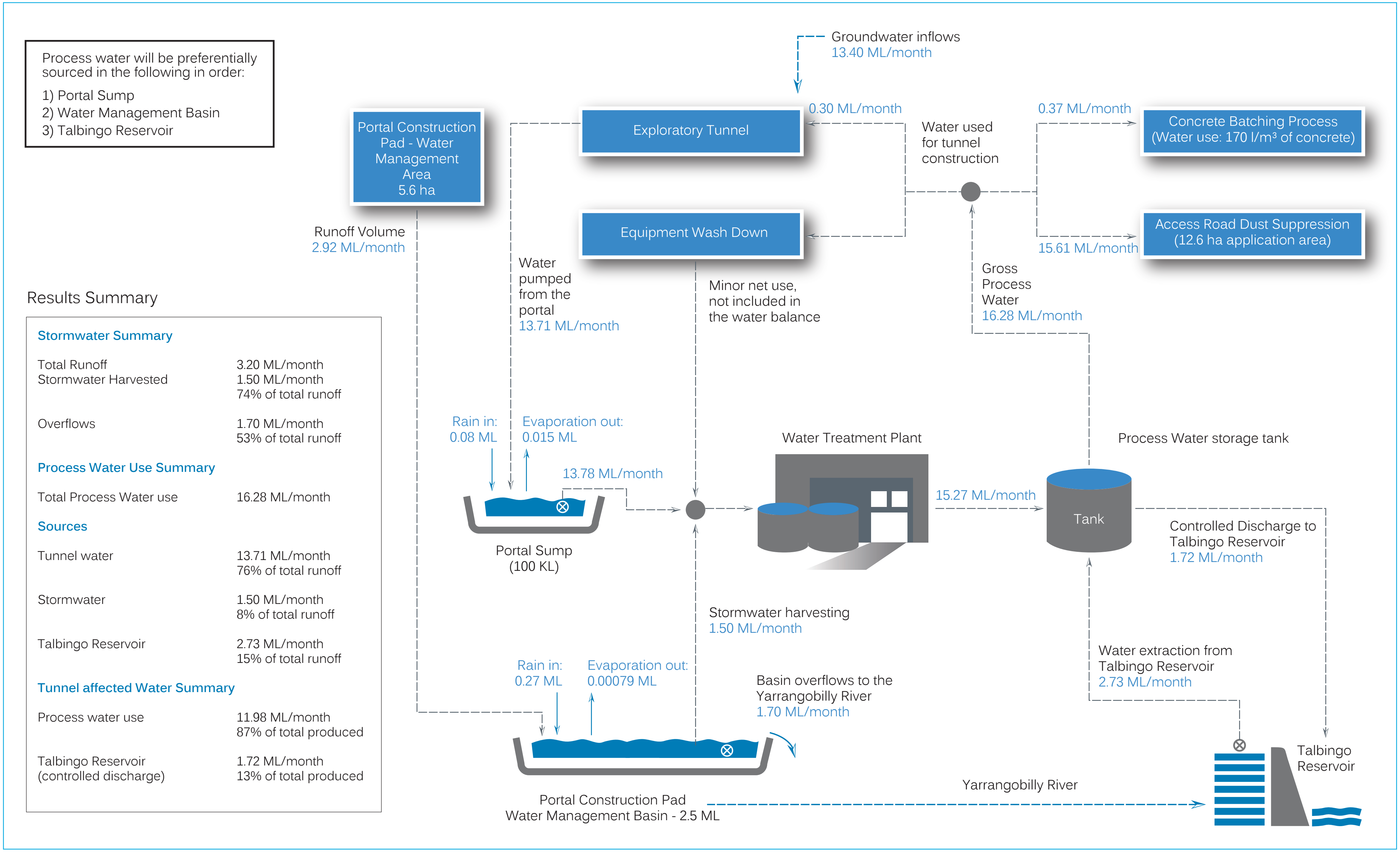


Water balance results: Tunnel Month 1 – median rainfall year

Snowy 2.0
Environmental Impact Statement
Exploratory Works
Figure 6.5



Water balance results: Tunnel Month 12 – median rainfall year



Water balance results: Tunnel Month 26 – median rainfall year

Snowy 2.0
Environmental Impact Statement
Exploratory Works
Figure 6.7

b. Tabulated results

The following results are provided in table format:

- Table 6.11 provides a summary of key results that have been calculated over the estimated 26 month exploratory tunnel construction period; and
- Table 6.12 provides monthly and annual statistics for transfers between the process water system and Talbingo Reservoir. The statistics are provided for months 1, 12 and 26 of the tunnel construction period.

Table 6.11 Water balance model results summary

Results	Average values[1]
Stormwater summary	
Stormwater harvested	69% of total runoff
Stormwater overflows	31% of total runoff
Process water use summary	
Sourced from tunnel affected water	41% of total use
Sourced from stormwater	10% of total use
Sourced from Talbingo Reservoir	49% of total use
Tunnel affected water management	
Used process water sources	95% of the total tunnel affected water
Discharge to Talbingo Reservoir (controlled discharge)	5% of the total tunnel affected water

Notes: 1.average values have been over the 26 month tunnel construction period using the probalistic modelling methods that are discussed in Appendix D.

Table 6.12 Talbingo Reservoir water transfers

	Water transfer volumes		
Conditions	**Month 1**	**Month 12**	**Month 26**
Monthly statistics (ML/month)			
Controlled discharge to Talbingo Reservoir			
Minimum value	0	0	0
10th percentile value	0	0	0.1
50th percentile value	0	0	1.0
90th percentile value	0	0.4	3.1
Maximum value	0	1.1	4.9
Extraction from Talbingo Reservoir			
Minimum value	2.8	0	0
10th percentile value	7.9	3.3	0
50th percentile value	16.9	10.7	2.8
90th percentile value	23.1	18.2	9.4
Maximum value	26.2	21.8	12.5
Annualised statistics (ML/year)			
Controlled discharge to Talbingo Reservoir			
Minimum value	0	0	6

Table 6.12 Talbingo Reservoir water transfers

	Water transfer volumes		
Conditions	**Month 1**	**Month 12**	**Month 26**
10th percentile value	0	0	12
50th percentile value	0	1	16
90th percentile value	0	2	20
Maximum value	0	4	22
Extraction from Talbingo Reservoir			
Minimum value	146	94	26
10th percentile value	149	100	38
50th percentile value	172	118	44
90th percentile value	186	133	55
Maximum value	209	152	64

c. Results discussion

The water balance model results indicated that:

- The majority of tunnel affected water produced over the estimated 26 month exploratory tunnel construction period can be used as process water. However, discharge of treated process water to Talbingo Reservoir will be required at times. This is most likely to occur during winter months or extended periods of wet weather when access road dust suppression water use requirements are low. The frequency and magnitude of discharge will increase over the exploratory tunnel construction period, in line with the expected increase in groundwater inflows.

- Extraction of water from Talbingo Reservoir will be required in most months to meet process water demand. Extraction will be required more frequently in the summer most when access road dust suppression demands are higher and during the initial construction period when groundwater inflows are lower.

- Extraction from the portal construction pad's water management basin will reduce overflow volumes from the basin into the Yarrangobilly River by 69% (reference Table 6.11) over the estimated 26 month exploratory tunnel construction period.

ii Model sensitivity

The water balance model has been applied to assess the functionality of the process water management system based on predicted groundwater inflows and estimates of process water use rates. As indicated in Figure 6.3 and described in the groundwater assessment (EMM 2018b), the maximum plausible groundwater inflow rate is approximately double the predicted rate near the end of the tunnel construction period.

Table 6.13 describes the expected changes to model results due to variation in the following key water balance assumptions.

- assumed groundwater inflow rate; and

- assumed water use for access road dust suppression.

Table 6.13 Model sensitivity

Changes to assumptions	Resulting changes to model results
• Groundwater inflows lower than predicted; and/ or • Access road dust suppression water use higher than predicted	• Decrease in the frequency and magnitude of controlled discharge to Talbingo Reservoir. • Increase in the frequency and magnitude of extraction from to Talbingo Reservoir. • Greater opportunities for stormwater harvesting.
• Groundwater inflows higher than predicted; and/ or • Access road dust suppression water use lower than predicted	• Increase in the frequency and magnitude of controlled discharge to Talbingo Reservoir. • Decrease in the frequency and magnitude of extraction from to Talbingo Reservoir. • Reduced opportunities for stormwater harvesting.

6.7.5 Proposed mitigation and management

Table 6.14 provides a summary of the process water management system controls.

Table 6.14 Water management controls: process water management system

Control	Description
WM_6.1	A process water management system will be established to manage any potentially contaminated water that may be produced by the construction activities.
WM_6.2	The process water management system will be separated from the stormwater system to avoid uncontrolled overflows associated with stormwater ingress.
WM_6.3	The process water management system will incorporate a water treatment plant that will treat water to a suitable quality for its use in construction activities or discharge to Talbingo Reservoir (if required).
WM_6.4	The process water management system will have the ability to extract water from the portal construction pad's water management basin. This will be done to top-up supply.
WM_6.5	A reticulation system will be established to enable the process water system to: • extract water from Talbingo Reservoir (as required); and • discharge treated process water into Talbingo Reservoir (as required).

6.7.6 Residual impacts

The process water management system will be operated in a controlled manner and will be regularly monitored and adjusted as required. The system configuration will avoid any discharge to or extraction from the Yarrangobilly River. Hence, no impacts to the Yarrangobilly River are expected.

Water balance modelling indicates that:

- occasional discharge of treated process water into Talbingo Reservoir will be required; and
- extraction of up to 26 ML/month of water from Talbingo Reservoir.

It is expected that the extraction of water from Talbingo Reservoir will not result in any environmental impacts. Potential impacts associated with controlled discharge to Talbingo Reservoir can be managed through the appropriate treatment of process water prior to discharge. Accordingly, no material receiving water impacts are expected.

6.7.7 Proposed monitoring and contingency measures

i Proposed monitoring

The process water management system will be progressively monitored to ensure adjustments to the system configuration and operation can be made if required. The following monitoring will be undertaken:

- Continuous measurement of all key water transfers including water pumped from the tunnel, all process water use, stormwater harvesting and transfers to and from Talbingo Reservoir.

- Monthly comprehensive monitoring of the quality of tunnel affected water and treated process water.

A comprehensive receiving water monitoring program will also be undertaken for the duration of the Exploratory Works. This program will include monitoring of water quality in Talbingo Reservoir, upstream and downstream of the process water controlled discharge location. Refer to Chapter 8 for further details on the proposed surface water monitoring plan.

ii Contingency measures

If the controlled discharge of water to Talbingo Reservoir is of an unacceptable quality, tunnel affected water can be temporarily stored in the tunnel (or an alternative storage) until appropriate adjustments to the water treatment plant are made.

6.8 Waste water management

6.8.1 Overview

As described in Section 2.9.4, it is currently expected that the workforce for the Exploratory Works will be approximately 200 people at peak construction. These workers will be accommodated within the accommodation camp. Waste water will be produced from amenities (showers, toilets, laundry, cooking etc) within the accommodation camp and construction pad.

Waste water loads have been estimated using a hydraulic load of 240 L/person/day, which includes a 20% contingency above typical values. Applying this load to the peak workforce of around 200 people, a total project waste water load of 48 KL/day has been estimated.

This section describes the waste water management approach and expected impacts.

6.8.2 Potential water management impacts

Potential management risks include:

- changes to the ambient water quality in Talbingo Reservoir due to the disposal of treated waste water; and

- potential for the discharge of untreated waste water into the Yarrangobilly River due to equipment failure.

6.8.3 Proposed mitigation and management

Effective management of waste water requires controls to:

- manage the volumes and quality of waste water produced;
- provide emergency storage to minimise the risk of overflows of untreated waste water to the receiving environment; and
- provide treatment of waste water prior to discharge to the receiving environment.

These controls are described in the following sections.

i Source controls

The following source controls will be implemented to manage the volumes and quality of waste water produced:

- Waste water from the accommodation camp will be reticulated to the waste water treatment plant via a sewer system. The sewer system will be designed to restrict stormwater ingress into the waste water system.
- Water efficient appliances will be used throughout the accommodation camp to minimise waste water volumes.
- Low phosphorus products will be used for washing activities controlled by site management (ie laundry services and mess hall) and encouraged (via education) for general use.

ii Emergency storage

The waste water treatment plant will provide emergency storage to minimise the risk of overflows of untreated waste water due to power outages or equipment failure. The storage volume will be calculated at detailed design based on analysis of response times from regional waste management contractors to provide emergency trucking and offsite disposal options.

iii Waste water treatment

A waste water treatment plant will treat all waste water produced by the Exploratory Works. Table 6.15 provides the proposed waste water quality specifications for the treatment plant. These specifications are based on a high performance treatment plant that will be remotely monitored and requires some local input. Treated waste water will be disposed to Talbingo Reservoir via the controlled discharge pipeline described in Section 6.7. Solids and gross pollutants will be removed by a licensed contractor as required.

Table 6.15 Treated waste water quality

Parameter	Units	Treated waste water quality
5 day Biological Oxygen Demand (BOD)	mg/l	< 10
Suspended solids	mg/l	< 5
Total Nitrogen	mg/l	< 15
Ammonia	mg/l	< 2
Total Phosphorus	mg/l	< 5
Oil and grease	mg/l	< 5
E-coli	cfu/100ml	<100

iv Summary of proposed controls

Table 6.16 provides a summary of the proposed waste water management controls.

Table 6.16 Water management controls: waste water management system

Control	Description
WM_7.1	Waste water from the accommodation camp will be reticulated to a waste water treatment plant via a sewer system. The sewer system will be designed to restrict stormwater ingress into the waste water system.
WM_7.2	Water efficient fittings will be used to minimise waste water loads.
WM_7.3	Low phosphorus products are to be used for washing activities controlled by site management (ie laundry services and mess hall) and encouraged (via education) for general use.
WM_7.4	The waste water storage system will include emergency storage of untreated waste water. The storage volume will be calculated at detailed design based on analysis of response times from regional waste management contractors to provide emergency trucking and offsite disposal options.
WM_7.5	A waste water treatment plant will treat all waste water produced by the Exploratory Works. The plant will treat waste water to the water quality specifications provided in Table 6.15 or as specified by an EPL.
WM_7.6	Treated waste water will be disposed to Talbingo Reservoir via the controlled discharge pipeline.

6.8.4 Residual impacts

Treated waste water will be discharged into the Yarrangobilly arm of Talbingo Reservoir over the duration of the Exploratory Works. The discharge will occur from the bottom of the reservoir via a diffuser arrangement. As discussed in Section 4.6, the ambient water quality in Talbingo Reservoir is characterised as having low nutrient levels, with all of the 15 samples collected in March 2018 returning total nitrogen and phosphorus concentrations below the applied laboratory detection limits of 0.2 mg/l for total nitrogen and 0.05 mg/l for total phosphorus.

The potential for discharge of treated waste water to change the ambient water quality in Talbingo Reservoir is a function of the increase in nitrogen and phosphorus loads, relative to the flushing from reservoir inflows. Reservoir inflows near the discharge location will primarily occur from inflows from the Yarrangobilly River, but are expected to be assisted by the frequent level change in the reservoir due to its hydropower operation function.

Table 6.17 calculates the increase in average nitrogen and phosphorus concentrations based on Yarrangobilly River flows during drought and typical summer conditions and average total inflows into the reservoir.

Table 6.17 Treated waste water dilution

		Talbingo Reservoir (Yarrangobilly River arm)		Talbingo Reservoir
	Units	**Drought flow[1]**	**Median summer flow[2]**	**Average flow**
Treated waste water discharge	KL/day	48	48	48
Reservoir Inflows	KL/day	12,581	51,613	3,345,000
Dilution factor	-	262	1,075	69,688
Average increase in nitrogen[3]	mg/l	0.06	0.014	<0.001
Average increase in phosphorus[3]	mg/l	0.02	0.005	<0.001

Notes: 1. Calculation based on the lowest monthly stream flow on record of 390 ML/month.

2. Calculation based on a typical median monthly stream flow in summer months of 1,600 ML/month.

3. Calculation based on the water quality specifications provided in Table 6.15

With reference to Table 6.17, the discharge of treated waste water into the Yarrangobilly River arm of Talbingo Reservoir has potential to increase average nitrogen and phosphorus concentrations by 0.06 and 0.02 mg/l respectively during drought conditions. This increase in phosphorus concentration is equal to the trigger value for physical and chemical stressors provided in Table 3.3.2 of ANZECC 2000. Hence, if ambient levels are greater than zero, this trigger level may be exceeded (near the discharge location) for a number of months (if drought conditions occur).

During median summer flow conditions, the potential increase in nitrogen and phosphorus concentrations reduces to 0.014 and 0.005 mg/l respectively. It is unlikely that this concentration increase will result in nitrogen or phosphorus concentrations exceeding trigger values for physical and chemical stressors that are provided in Table 3.3.2 of ANZECC 2000.

With reference to Table 6.17, no material change to water quality in the greater reservoir is expected due to high inflows associated with the existing operation of the Snowy Scheme.

6.8.5 Proposed monitoring and contingency measures

The waste water system will be progressively monitored to ensure adjustments to the system configuration and operation can be made if required. The following monitoring will be undertaken:

- continuous measurement of the volumes of treated waste water discharge; and
- monthly comprehensive monitoring of treated waste water.

A comprehensive receiving water monitoring program will also be undertaken for the duration of the Exploratory Works. This program will include monitoring of water quality in Talbingo Reservoir, upstream and downstream of the treated waste water discharge location. Refer to Chapter 8 for further details on the proposed surface water monitoring plan.

i Contingency measures

The following additional measures could be implemented if monitoring identifies unacceptable impacts:

- waste water can be temporarily removed from Lobs Hole via waste management contractors; or
- the waste water treatment plant can be modified to improve treatment performance.

6.9 Rock and soil emplacement water management

6.9.1 Overview

i Management concept

It is estimated that up to 750,000m^3 of bulked rock and soil will be excavated from the following sources:

- Exploratory Works rock (the rock) — 156,000 bulk m^3 from the portal construction pad and 350,000 bulk m^3 from the exploratory tunnel;
- Middle Bay reservoir bed sediment (the sediment) — 36,000 bulk m^3;
- Lobs Hole Ravine Road cuttings (the cuttings) — 45,000 bulk m^3; and
- Soil from the eastern emplacement footprint — 36,100 bulk m^3.

These materials will be placed in one of two emplacement areas at Lobs Hole, which are referred to as the eastern and western emplacement areas. As discussed in Section 2.4, some material will also be subaqueously placed in Talbingo Reservoir.

The eastern emplacement area has a proposed capacity of 500,000 m^3 and will be established in a gully known as Lick Hole Gully. Consultation with NPWS throughout the EIS process has identified an opportunity for the proposed eastern emplacement area to form a permanent landform.

The western emplacement area will be used to store cuttings and other material that has a low geochemical risk. Material stored in the western emplacement area will be suitable for use within the construction of Exploratory Works or for re-use by Snowy Hydro or NPWS in KNP maintenance activities. Any remaining material placed in this emplacement area will be removed following the completion of Exploratory Works.

The emplacement areas are shown in Figure 2.5.

ii Setting

a Eastern emplacement

The eastern emplacement will be established within Lick Hole Gully. Lick Hole Gully is a third order watercourse that is described in Table 4.7 as having a 149 ha catchment area that extends to the south of the emplacement location to Round Top Mountain.

There is no known information on the stream flow characteristics of Lick Hole Gully. Site observations indicate that the watercourse has an intermittent flow regime, which means that:

- constant base flows are likely to occur during winter and spring; and
- base flows are expected to cease for weeks or months in late summer and early autumn.

Surface water runoff is expected to occur during and shortly after any material rainfall event.

With reference to the flood maps provided in Appendix C, the eastern emplacement will be above the Yarrangobilly River's 0.05% AEP flood extent, but within the periphery of the PMF extent.

b Western emplacement

The western emplacement will be established on the southern periphery of the Yarrangobilly River floodplain. The flood risk management aspects of the emplacement design are discussed in Chapter 5. There are no watercourses within the emplacement footprint.

6.9.2 Design concept

The primary design objectives are to establish:

- physical stable landforms with low risk of uncontrolled movement either from erosion or flooding; and
- chemical stable landform with salinity, acidity, alkalinity and dissolved metal flux rates at levels that do not result in degradation of environmental values in the receiving environment.

This section provides an overview of the design concepts for both the eastern and western emplacements. The design concepts are described in further detail in the Excavated Rock Emplacement Areas Assessment (SGM environmental 2018).

i Eastern rock emplacement

The eastern emplacement will be designed as a permanent landform. This section describes the landform design and water and geochemistry risk management approaches.

a. Landform design

The eastern emplacement will be constructed within Lick Hole Gully. The landform will have a large 'flat top' at a level of 595 m AHD. The stockpile will interface with existing topography at the 595 m AHD contour along the western, southern and some portions of the eastern boundary. Benching is proposed along the northern and some portions of the eastern boundary. The benching will comprise 2 m lifts separated by 4 m benches. The benches will be top soiled and revegetated and will grade back towards the emplacement so any runoff from direct rainfall onto the benches and upslope lift will temporarily pond against the toe of the above lift prior to infiltration.

It is envisaged that the flat top area will be used as a lay down area for the Snowy 2.0 project, should it proceed. At completion of the Snowy 2.0 project the flat top area will be revegetated and rehabilitated in consultation with NPWS.

Figure 6.8 shows a design concept for the eastern emplacement.

b. Water management approach

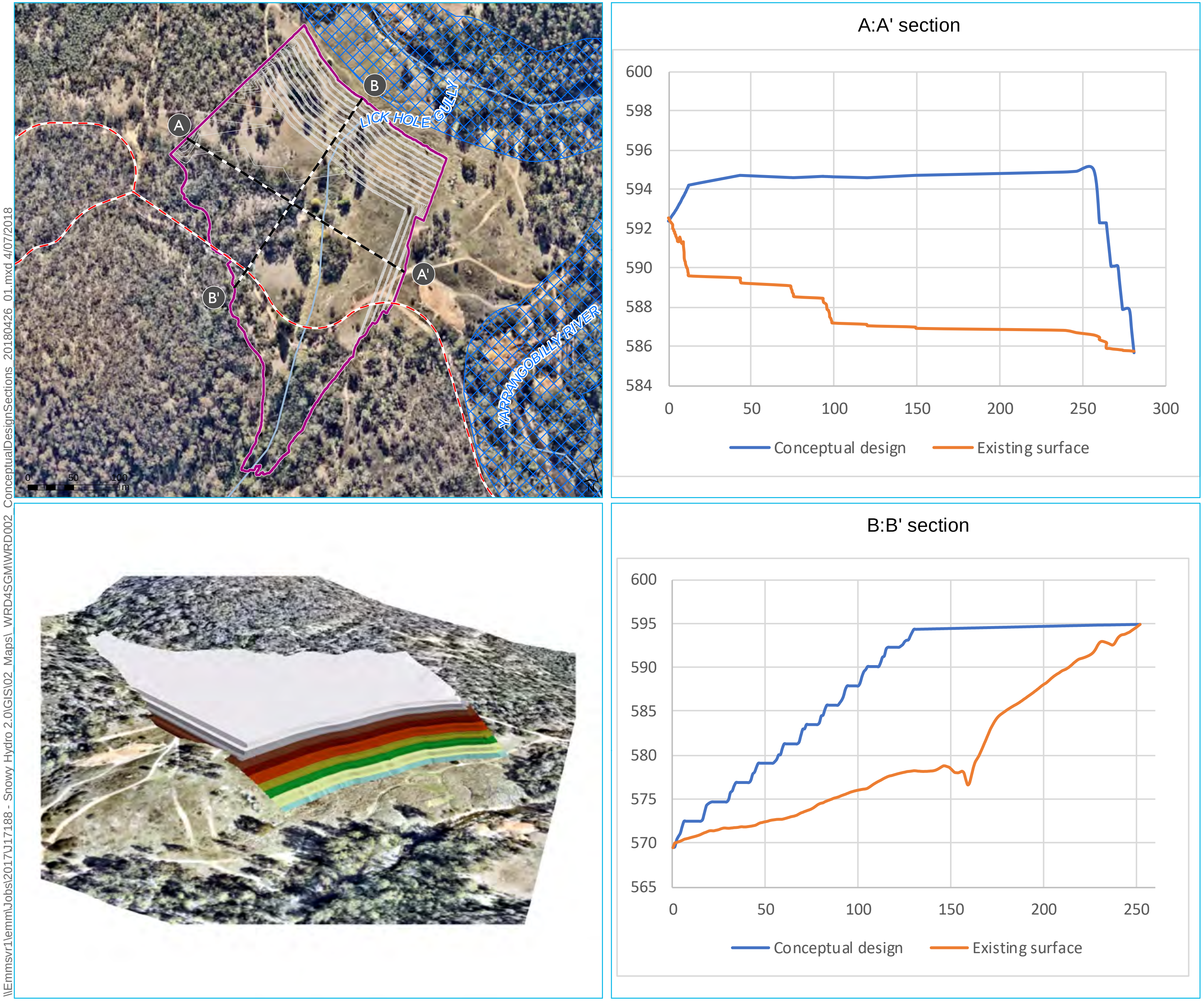
Water management is discussed in Section 6.9.4.

c. Geochemistry risks

Limited geochemistry analysis of rock samples from a drill hole near the Exploratory Tunnel and sediment samples from Middle Bay have been undertaken. The results from this analysis are summarised as follows:

- Some rock samples identified that some material may be potentially acid forming (PAF), while other rock samples had excess acid neutralising capacity (ANC) and therefore have acid consuming (AC) potential (SGM environmental 2018).
- The Middle Bay sediment geochemistry indicated high concentrations of total aluminium and iron, that could be released if exposed to acidity (SGM environmental 2018).

Completed geochemistry analysis cannot determine conclusively that the eastern rock emplacement without treatment will attenuate the potential for acid rock drainage (ARD) from PAF rock, therefore the eastern rock emplacement design considers construction and treatment strategies to manage the potential for ARD (SGM environmental 2018).



KEY

- Cross-section
- Access road upgrade
- Watercourse
- Conceptual WRD design contour
- Yarrangobilly exclusion area
- Conceptual WRD design footprint

Eastern emplacement design concept

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 6.8

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); NearMap (2018)

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d. Construction methods

The emplacement will be constructed using a bottom-up technique described below.

Prior to placing rock and sediment, Lick Hole Gully will be lined with a nominally 1m deep layer of limestone (the limestone pad). The purpose of the limestone pad is to separate the rock and sediment from seepage that will occur along the base of the emplacement. The majority of the flow will originate from Lick Hole Gully. The limestone will maintain an alkaline environment which will maintain low solubility for most metals.

After the construction of the limestone pad, rock and sediment will be placed in 1m layers, with each layer compacted through a combination of truck traffic, dozer pushing and compaction by a drum roller (or similar). Two layers will be placed to create a lift and each lift will be separated by a 4m wide bench. The potential for ARD will be treated by placing and compacting layers of limestone on top of each rock and sediment layer as required. The limestone layer will also be compacted and the volume of limestone in each layer will be determined stoichiometrically so that the maximum potential acidity from the overlying layer of rock and sediment is treated.

ii Western emplacement

The western emplacement will be used to store cuttings and other material that has a low geochemical risk and is able to be reused. The landform will be built in a manner that limits compaction and will be top soiled and vegetated to stabilise the landform.

As discussed in Chapter 5, the western emplacement will be designed to prevent the risk of emplacement material being entrained in flood waters during a 0.2% AEP event. This may require a flood protection berm or rock armouring along the northern toe of the emplacement.

6.9.3 Potential water management impacts

i Eastern emplacement

The design will seek to promote infiltration of runoff from Lick Hole Gully and direct rainfall onto the eastern emplacement. Identified water management risks include:

- the potential for ARD to occur from some portions of the emplacement material;
- the potential for the emplacement water quality from Lick Hole Gully to be degraded as it percolates through the base of the emplacement; and
- the potential for the landform to be eroded.

ii Western emplacement

The eastern emplacement will only be used to store cuttings and other material that has a low geochemical risk. Hence, identified water management risks are limited to the potential erosion of the landform.

6.9.4 Proposed mitigation and management

i Eastern emplacement

The eastern emplacement design requires controls to:

- manage runoff from Lick Hole Gully;
- manage runoff from direct rainfall onto the emplacement; and
- manage ARD risks.

The proposed water management approach seeks to:

- manage surface water by promoting infiltration into the emplacement; and
- manage ARD risks through the limestone pad at the base of the emplacement and construction techniques.

This approach provides some significant surface water management benefits through reducing the frequency and magnitude of surface water overflows from the emplacement that will occur as a result of runoff from the emplacement flat top and benches and Lick Hole Gully. This approach reduces the size of and risk of failure of the downstream drainage works, relative to a design that seeks to minimise infiltration.

The proposed water management concept is described in Table 6.18. The concept is shown in Figure 6.9.

Table 6.18 Water management approach – Eastern emplacement

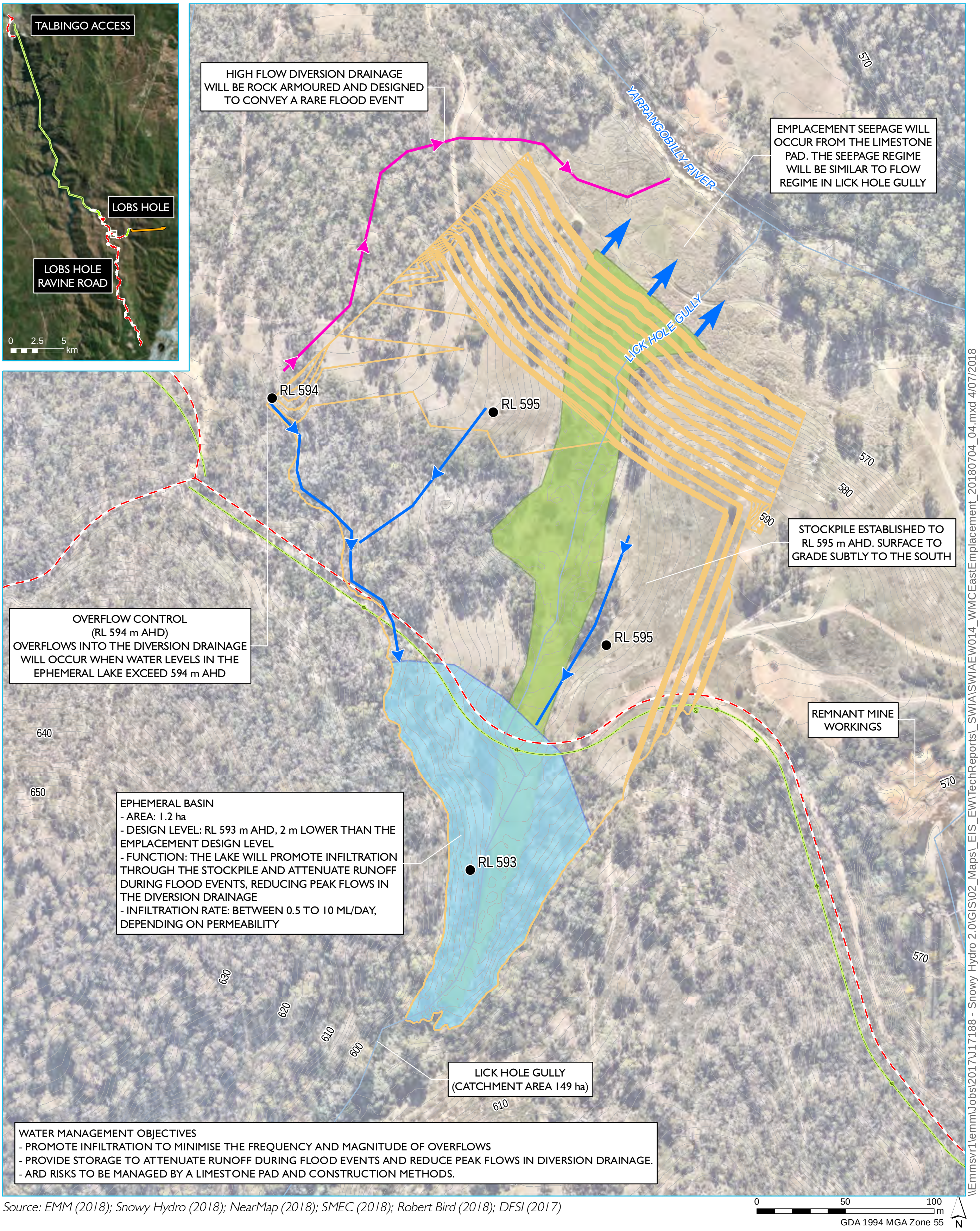
Design aspect	Design approach
Management of runoff from Lick Hole Gully	Runoff from Lick Hole Gully will pond in an ephemeral basin that will be established within the southern extent of the emplacement (as indicated in Figure 6.9). The basin will be established approximately 2m below the emplacement 'flat top' level (595m AHD) and will be a discrete feature in the landform. The floor of the basin will be emplacement material. During normal stream flow conditions, all runoff will infiltrate into the emplacement. Calculating the rate of infiltration is complex, however it is expected to be within the 0.5 to 10 ML/day range. The large variance in range is due to uncertainties around permeability and seepage rates through the emplacement. During significant flood events and periods of extended wet weather, the ephemeral basin will fill as inflow rates will exceed the infiltration rate. When the basin level reaches 594m AHD (1 m deep), it will overflow to the west into a diversion drain (indicated in Figure 6.9). During major flood events, storage above 594m AHD will attenuate peak flows arriving from Lick Hole Gully, reducing overflow rates (by more than 50%) into the diversion drain.
High flow diversion drainage	Overflows from the ephemeral basin will occur during significant flood events and periods of extended wet weather. Diversion drainage will be required to convey overflows into the Yarrangobilly River to the north. The proposed drain alignment is indicated Figure 6.9. The diversion drain will need to be adequately designed to convey peak flows from flood events. This will require rock armouring for drain sections in gullies and excavated drains for sections along the contour. As discussed above, the storage provided by the ephemeral basin will significantly reduce the peak flow rates (by more than 50%), resulting in smaller drains and reduced failure risks.

Table 6.18 Water management approach – Eastern emplacement

Design aspect	Design approach
Management of runoff from the emplacement 'flat top'	The emplacement is expected to have medium to high permeability rates. Accordingly, surface runoff from the 'flat top' will only occur during intense bursts of rainfall. Surface runoff will be directed to the south in subtle drainage (indicated in Figure 6.9) and will drain into the ephemeral basin. Runoff volumes from the 'flat top' area are expected to be insignificant when compared to runoff volumes from Lick Hole Gully.
Management of runoff from the emplacement benches	All runoff from the emplacement 'flat top' will be directed to the south, away from the benches. The benches will be graded back towards the emplacement and any runoff from direct rainfall onto the benches and upslope lift will pond against the toe of the above lift and will form plant available water. As a result, no surface runoff from the benches is expected to occur.
Management of ARD risks	ARD risks will be managed through: • the limestone pad that will form the base of the emplacement within Lick Hole Gully; and • emplacement construction techniques. Refer to Excavated Rock Emplacement Areas Assessment (SGM environmental 2018) for further information on construction techniques.

ii Western emplacement

The western emplacement will be used to store cuttings and other material that has a low geochemical risk and is able to be reused. The landform will be built in a manner that limits compaction and will be top soiled and vegetated to stabilise the landform. Sedimentation basins will be established to manage runoff from the emplacement area during establishment.



Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017)

KEY

- Design level
- Exploratory tunnel and portal
- Access road upgrade
- Communications cable
- Eastern emplacement design contours
- Watercourse
- Contour (1m LiDAR)
- Emplacement drainage
- Diversion drainage
- Ephemeral lake
- Limestone pad

Eastern emplacement: water management concept

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 6.9

6.9.5 Residual impacts

i Eastern emplacement

As described in Section 6.9.4 discharges from the eastern emplacement are expected to occur via seepage from the limestone pad and occasional surface flows in the diversion drainage system. The expected flow regimes and water quality of these discharge mechanisms is described in Table 6.19.

Table 6.19 Eastern Emplacement: Expected receiving water impacts

Type	Flow Regime	Expected water quality
Emplacement seepage	It is expected that the emplacement seepage regime will be similar to the stream flow regime in Lick Hole Gully.	Emplacement seepage is likely to be neutral to alkaline in pH and have low levels of salinity, suspended sediments, nutrients and metals[1].
High flow diversion drainage	Flows into the diversion drainage system are expected to occur occasionally during flood events and extended periods of wet weather.	The water quality of diverted flows is expected to be similar to the water quality of Lick Hole Gully.

Notes: 1. Refer to the Excavated Rock Emplacement Areas Assessment (SGM environmental 2018) for further information on the expected water quality of emplacement seepage.

The water quality of emplacement seepage and diverted flows that is described in Table 6.19 is not expected to degrade the water quality of the Yarrangobilly River. These expected impacts will require verification. The verification approach is described in Section 6.9.6.

ii Western emplacement

No residual impacts are expected from the western emplacement area as:

- the emplacement will only be used to store cuttings and other material that has a low geochemical risk and is able to be reused; and
- the emplacement will be soiled and vegetated to stabilise the landform.

6.9.6 Proposed monitoring, design verification and contingency measures

i Monitoring measures

Water inflows and outflows from the eastern emplacement will be progressively monitored to identify any change in water quality due to the emplacement. The following monitoring will be undertaken:

- stream flows in Lick Hole Gully upstream of the emplacement will be continuously monitored when in flow;
- emplacement seepage rates will be continuously monitored;
- the pH and electrical conductivity of emplacement seepage and stream flows in Lick Hole Gully upstream and downstream of the emplacement will be continuously monitored when in flow; and
- comprehensive water quality monitoring of emplacement seepage and stream flows in Lick Hole Gully upstream and downstream of the emplacement will be undertaken 12 times per year.

A comprehensive receiving water monitoring program will also be undertaken for the duration of the Exploratory Works. This program will include comprehensive monitoring of water quality in the Yarrangobilly River. Refer to Chapter 8 for further details on the proposed surface water monitoring plan.

ii Design verification

It is proposed to design and construct the eastern emplacement as a permanent landform. Once constructed, the emplacement area is proposed to be used as a lay-down area for Snowy 2.0, should it proceed. During this period monitoring will continue. Once sufficient data is available to reliably verify the design outcomes have been achieved, a design verification report will be prepared. It is expected that the design verification outcome will require endorsement from NPWS and government prior to the eastern emplacement being approved as a final landform.

iii Contingency measures

If water quality monitoring identifies that the eastern emplacement is posing an unacceptable risk to the receiving environment, the following contingency measures will be implemented:

- impacts during construction and period of use of the emplacement for Snowy 2.0, should it proceed, can be managed by collecting and treating emplacement seepage; and
- long term impacts can be managed by removing the emplacement and rehabilitating Lick Hole Gully.

7 Summary of impacts and mitigations

This section provides a summary of the identified potential and residual impacts of Exploratory Works on the surface water environment. A summary of mitigations is also provided.

7.1 Impacts to the Yarrangobilly River and Wallaces Creek

7.1.1 Impacts to stream flow regimes

i Surface water impacts

Impacts to stream flow regimes in the Yarrangobilly River and Wallaces Creek can occur due to extraction of water from the watercourses or the capture of water in water management dams. It is not proposed to extract water from the Yarrangobilly River or Wallaces Creek and the volumes of water captured in water management dams will be insignificant when compared to river flows. Hence, no surface water impacts to the stream flow regimes are expected.

ii Groundwater impacts

The Snowy 2.0 Exploratory Works Groundwater Assessment (EMM, 2018) assesses the reduction in baseflows in the Yarrangobilly River associated with groundwater seepage into the Exploratory Tunnel. This assessment concluded that the reduction in baseflows will be minor relative to the simulated baseflows in the Yarrangobilly River. Accordingly, the predicted reductions in baseflows are not expected to change the stream flow regimes in either the Yarrangobilly River or Wallaces Creek during normal and drought conditions.

7.1.2 Impacts to water quality

Impacts to the water quality of the Yarrangobilly River and Wallaces Creek could potentially occur due to:

- runoff from construction areas during the initial phase of Exploratory Works;
- runoff from unsealed access roads;
- stormwater runoff from the accommodation camp;
- stormwater runoff from the portal construction pad; and
- seepage and runoff from the emplacement areas.

i Impacts due to construction disturbance

Section 6.3.4 concluded that the following impacts to receiving water quality are expected due to construction disturbance:

- Erosion and sediment controls for all construction areas are expected to effectively remove coarse sediment. Hence, no sedimentation impacts in receiving waters are expected.

- Runoff from construction areas entrained with fine and potentially dispersive sediments is expected to enter receiving waters during and shortly after rainfall. It is expected that any sediment laden water that enters the Yarrangobilly River will be significantly diluted by river flows and rapidly dissipate. Hence, no material change to the Yarrangobilly River water quality is expected.

It is noted that these impacts will only occur during the initial phase of the Exploratory Works.

ii Impacts due to access roads

Section 6.4.4 concluded that the following impacts to receiving water quality are expected due to the operation of unsealed access roads:

- Road design and maintenance and erosion and sediment controls are expected to effectively remove coarse sediment. Hence, no sedimentation impacts in receiving waters are expected.

- There is potential for some runoff from access roads to be laden with fine and potentially dispersive sediments, especially if the roads are used during wet weather. The sediment and erosion controls are expected to provide limited removal of fine and dispersive sediments. Hence, some sediment laden runoff from access roads may drain into receiving waters. It is expected that this water would be rapidly mixed with clean water before flowing into the Yarrangobilly River where it will be significantly diluted by river flows and rapidly dissipate. Hence, no material change to the Yarrangobilly River water quality is expected.

It is noted that sediment laden runoff is already occurring from the numerous existing unsealed roads in the Lobs Hole area as well as from the nearby exposed mine workings areas. Accordingly, the Yarrangobilly River and other receiving watercourses have received sediment laden runoff from local catchment runoff for a number of decades.

iii Impacts due to the accommodation camp

Section 6.5.4 concluded that the stormwater controls will mitigate potential water management risks associated with stormwater runoff from the accommodation camp. Hence, no material impacts to receiving waters are expected.

iv Impacts due to the portal construction pad

Section 6.6.4 concluded that the proposed stormwater controls will mitigate potential water management risks associated with stormwater runoff from the portal construction pad. Hence, no material impacts to receiving waters are expected.

v Impacts due to the stockpiles

Section 6.9 concluded that the water quality of emplacement seepage and diverted flows around emplacement areas is not expected to degrade the water quality of the Yarrangobilly River. However, it is acknowledged that this outcome will require verification.

7.2 Impacts to local watercourses

Impacts to local watercourses could occur from direct disturbance and changes to water quality and flow regimes. These potential impacts are discussed below.

i Impacts due to direct disturbance

Direct disturbance to the following local watercourses is expected:

- The lower 450 m reach of Lick Hole Gully will be impacted by the eastern emplacement.
- The accommodation camp will disturb some sections of Watercourse 3. The disturbance will be limited to the vegetated riparian zone, no direct impacts to the watercourse channel are expected.
- Numerous watercourses will be disturbed by road (bridge and culvert) crossings.

ii Impacts to water quality

Potential impacts to the water quality in local watercourses will be similar to the Yarrangobilly River and Wallaces Creek impacts described in Section 7.1.2.

iii Impacts to stream flow regimes

No material impacts to the stream flow regimes of local watercourses are expected, with the exception of the lower portion of Lick Hole Gully that will be disturbed by the eastern emplacement area.

7.3 Impacts to Talbingo Reservoir

Impacts to the water quality of Talbingo Reservoir could potentially occur due to the discharge of treated process water and treated waste water into the Yarrangobilly River arm of the reservoir. These potential impacts are summarised below.

i Impacts due to the discharge of treated process water

Section 6.7.6 concluded that the impacts associated with the controlled discharge of process water to Talbingo Reservoir can be managed through the appropriate treatment of process water prior to discharge. Hence, no material impacts to the water quality of Talbingo Reservoir are expected.

ii Impacts due to the discharge of treated waste water

With reference to Table 6.17, the discharge of treated waste water into the Yarrangobilly River arm of Talbingo Reservoir has potential to increase average nitrogen and phosphorus concentrations by 0.06 and 0.02 mg/l respectively during drought conditions. This increase in phosphorus concentration is equal to the trigger value for physical and chemical stressors provided in Table 3.3.2 of ANZECC 2000. Hence, if ambient levels are greater than zero, this trigger level may be exceeded (near the discharge location) for a number of months (if drought conditions occur).

During median summer flow conditions, the potential increase in nitrogen and phosphorus concentrations reduces to 0.014 and 0.005 mg/l respectively. It is unlikely that this concentration increase will result in nitrogen or phosphorus concentrations exceeding trigger values for physical and chemical stressors that are provided in Table 3.3.2 of ANZECC 2000.

With reference to Table 6.17, no material change to water quality in the greater reservoir is expected due to high inflows associated with the existing operation of the Snowy Scheme.

7.4 Flood impacts

The Exploratory Works avoid flood prone land where possible. However, the following infrastructure will unavoidably need to be constructed on flood prone land:

- bridge crossings over the Yarrangobilly River and Wallaces Creek;
- the western emplacement area; and
- the water management basin for the portal construction pad.

The flood model was applied to assess changes to the existing flooding regime associated with the infrastructure. This process concluded that the predicted changes to flood regimes will not impact infrastructure or items of heritage significance.

7.5 Summary of mitigations

A detailed list of all mitigations is provided in Appendix F. Table 7.1 distils these measures and provides a summary for Chapter 6 of the Exploratory Works EIS.

Table 7.1 Summary of water related mitigation measures (Source Chapter 6 of the Exploratory Works EIS)

Impact	Ref #	Environmental management measures
Stormwater management and erosion and sediment control from construction areas	WAT01	Erosion and Sediment Control Plans will be prepared for all construction sites. The plans will consider local soil characteristics, clean water management and the proposed construction methods.
	WAT02	The following controls will be applied to the design of the clean water management system: • Where possible, all clean water will be diverted around or through water management areas. Runoff from clean water areas that cannot be diverted must be accounted for in the design of water management systems. • All clean water drainage will be designed and constructed to convey the 1% AEP peak flow and will have adequate scour protection. • Where possible, diversions will seek to avoid materially increasing flow rates in adjoining watercourses. • Where possible, the diversion of drainage lines or watercourses using contour drains will be avoided.
	WAT03	Where construction areas are not constrained by terrain, sedimentation dams will be constructed in accordance with the methods recommended in Managing Urban Stormwater: Soils and Construction: Volume 1 (Landcom, 2004) and Volume 2D (DECC, 2008). Construction of sedimentation dams in steep terrain will be avoided.
	WAT04	A stormwater management plan for the accommodation camp will be prepared as part of the detailed design and will consider the design measures identified in Section 6.5. Collectively, the stormwater controls will be sized and configured to achieve the following pollution load reductions (as calculated using the MUSIC water quality model): • 85% reduction in post development mean annual load of total suspended solids; • 60% reduction in the post development mean annual load of total phosphorous; and • 45% reduction in the post development mean annual load of total nitrogen.
	WAT05	A stormwater management plan for portal construction pad will be prepared as part of the detailed design and will consider the design measures identified in Section 6.6. Key controls include: • Activities that have the potential to contaminate stormwater runoff will be isolated from the stormwater system through the use of covering (ie by a building or roof) and bunding. • A stormwater management system will manage runoff from the portal construction pad. The system will include a 2,500 m3 water management basin. Captured water in the basin will be harvested for use in construction activities. • The stormwater management system will be designed to contain any leak, spill or fire water runoff from the portal construction pad.

Table 7.1 Summary of water related mitigation measures (Source Chapter 6 of the Exploratory Works EIS)

Impact	Ref #	Environmental management measures
Process water management	WAT06	A process water system will be designed and implemented to manage any potentially contaminated water that may be produced by construction activities. The process water system will: • be separated from the stormwater system to avoid uncontrolled overflows associated with stormwater ingress; • incorporate a water treatment plant that will treat water to a suitable quality for its proposed use in construction activities or discharge to Talbingo Reservoir (if required); and • have the ability to extract water from the portal construction pad's water management basin.
	WAT07	A waste water treatment plant will be designed and implemented to treat all waste water produced by the Exploratory Works. The plant will treat waste water to the water quality specifications provided in Table 6.15 or as specified by an EPL.
Flood risks	WAT08	Camp and Wallaces Bridges will be designed in accordance with AustRoads bridge design standards which require the: • bridge deck soffit to be located above the 1% AEP flood level; • bridge structure to be designed to withstand a 0.05% AEP event; and • abutments to be protected by appropriately designed scour protection.
	WAT9	The western emplacement will be designed to prevent the risk of emplacement material being entrained in flood waters during a 0.2% AEP event.
	WAT10	Flood emergency procedures will be prepared and implemented as part of the Emergency Response Plan.
Spills of hydrocarbons leaching/running into groundwater/ creeks	WAT11	• Procedures to address spills, leaks and tunnel washing will be developed and implemented as part of the CEMP. • The portal construction pad's stormwater management system will be designed to contain any leak, spill or fire water runoff from the portal construction pad.
Impacts on surface and groundwater	WAT12[1]	A Surface and Groundwater Monitoring Program will be developed and implemented to monitor the effectiveness of water quality controls and compliance with licence conditions. The program will: • establish monitoring locations to provide suitable baseline and detection monitoring of surface and groundwater parameters; • monitor groundwater inflows in the tunnel and groundwater levels as well as groundwater quality during construction; and • set out annual monitoring requirements for Yarrangobilly Caves and PCTs potentially reliant on groundwater.
	WAT13[1]	Areas of groundwater inflow will be shotcreted to prevent further ingress

Notes: 1. Refer to the Exploratory Works - groundwater assessment (EMM, 2018b)

8 Monitoring plan

8.1 Overview

This section describes a surface water monitoring program that will be implemented over the duration of the Exploratory Works. The primary objectives of the monitoring program are to collect sufficient data to:

- continue to monitor baseline conditions;
- enable the effectiveness of water quality controls to be assessed;
- identify and quantify water quality impacts; and
- enable compliance with relevant consent and licence conditions to be assessed.

The monitoring program includes requirements to monitor weather, stream flows, process water quantity and quality, stormwater quality and receiving water quality. Table 8.1 provides a break-down of each aspect of the program and describes the monitoring objectives, locations and methods.

Further information on monitoring locations is provided in Section 1.1. Section 8.3 describes the monitoring regime, sampling analytes and analysis methods.

Table 8.1 Surface water monitoring program framework

Aspect	Objectives	Monitoring locations	Monitoring methods
Weather monitoring	• Record rainfall and other meteorological conditions at Lobs Hole.	• Lobs Hole	• Install and operate a weather station within the Lobs Hole area.
Stream gauge monitoring (Monitoring ID[1] = SG)	• Measure stream flows in the Yarrangobilly River and Lick Hole Gully and overflows from the portal construction pad's water management basin.	• Yarrangobilly River • Lick Hole Gully (upstream and downstream of the eastern emplacement). • Portal construction pad water management basin spillway.	• Continue to operate stream gauge 410574 on the Yarrangobilly River, downstream of the eastern emplacement. • Install stream gauges on Lick Hole Gully, upstream and downstream of the eastern emplacement. • Install a water level meter in the portal construction pad's water management basin.
Process water quantity monitoring	• Measure all process water uses, sources and controlled discharge volumes.	• All process water use points including dust suppression and the concrete batching plant • Tunnel dewatering location • Stormwater harvesting from the construction pad's water management dam • Water extraction from Talbingo Reservoir • Controlled discharge to Talbingo Reservoir	• Cumulative flow meters will be installed at all monitoring locations. • Meter readings will be recorded weekly.
Receiving water quality monitoring (Monitoring ID[1] = RW)	Monitor receiving water quality to: • establish baseline conditions; and • identify impacts to water quality.	• Yarrangobilly River (4 locations) • Wallaces Creek (1 location) • Talbingo Reservoir (2 locations)	• A minimum of 12 samples per year will be collected from each monitoring location. Sampling will be undertaken during base flow, wet weather and after wet weather conditions. All samples will be analysed for a comprehensive suite of parameters[2].
Process water quality monitoring (Monitoring ID[1] = PW)	• Monitor the quality of water within the process water management system.	• Exploratory tunnel portal sump. • Process water tank (post treatment)	• Sampling will be undertaken on a monthly basis. All samples will be analysed for a comprehensive suite of parameters[2].

Table 8.1 Surface water monitoring program framework

Aspect	Objectives	Monitoring locations	Monitoring methods
Stormwater quality monitoring (Monitoring ID[1] = SW)	• Monitor the quality of water within stormwater management basins.	• Portal construction pad water management basin • Accommodation camp ponds (2 locations)	• A minimum of 12 samples per year will be collected from each monitoring location. Sampling will be undertaken during base flow, wet weather and after wet weather conditions. All samples will be analysed for a comprehensive suite of parameters[2].
Treated effluent monitoring (Monitoring ID[1] = TE)	• Monitor the quality of treated effluent that will be discharged to Talbingo Reservoir.	• Waste water treatment plant.	• Sampling will be undertaken on a monthly basis. All samples will be analysed for a comprehensive suite of parameters[2].
Emplacement water quality monitoring (Monitoring ID[1] = EM)	• Monitor the quality of seepage and runoff from the eastern and western emplacements.	• Lick Hole Gully (upstream of the eastern emplacement) • Downstream of the eastern emplacement • Downstream of the western emplacement	• Continuous measurement of pH and electrical conductivity. Measurement devices will be incorporated into the stream gauges. • A minimum of 12 samples per year will be collected from each monitoring location. Sampling will be undertaken during base flow, wet weather and after wet weather conditions. All samples will be analysed for a comprehensive suite of parameters[2].
Access road runoff monitoring (Monitoring ID[1] = AR)	• Monitor the quality of runoff from access roads	• Monitoring will be undertaken at four random discharge locations each monitoring round.	• Event based sampling[2] and inspection of sediment and erosion controls will be undertaken following material wet weather events[3]. • A minimum of 4 samples per year will be collected from each monitoring location during wet weather conditions. All samples will be analysed for a comprehensive suite of parameters[2].
Construction disturbance area monitoring (Monitoring ID[1] = CD)	• Monitor the quality of runoff from areas disturbed by construction.	• Monitoring locations will be established as part of the detailed sediment and erosion control plans that will be prepared for each construction zone.	• Event sampling[2] and inspection of sediment and erosion controls will be undertaken following material wet weather events[3]. • A minimum of 4 samples per year will be collected from each monitoring location during wet weather conditions. All samples will be analysed for a comprehensive suite of parameters[2].

Notes: *1. Monitoring ID is used to describe monitoring locations. This is explained further in Section 1.1.*

2. Refer to Section 8.3 for detailed information on the monitoring regime, sampling analytes and analysis methods.

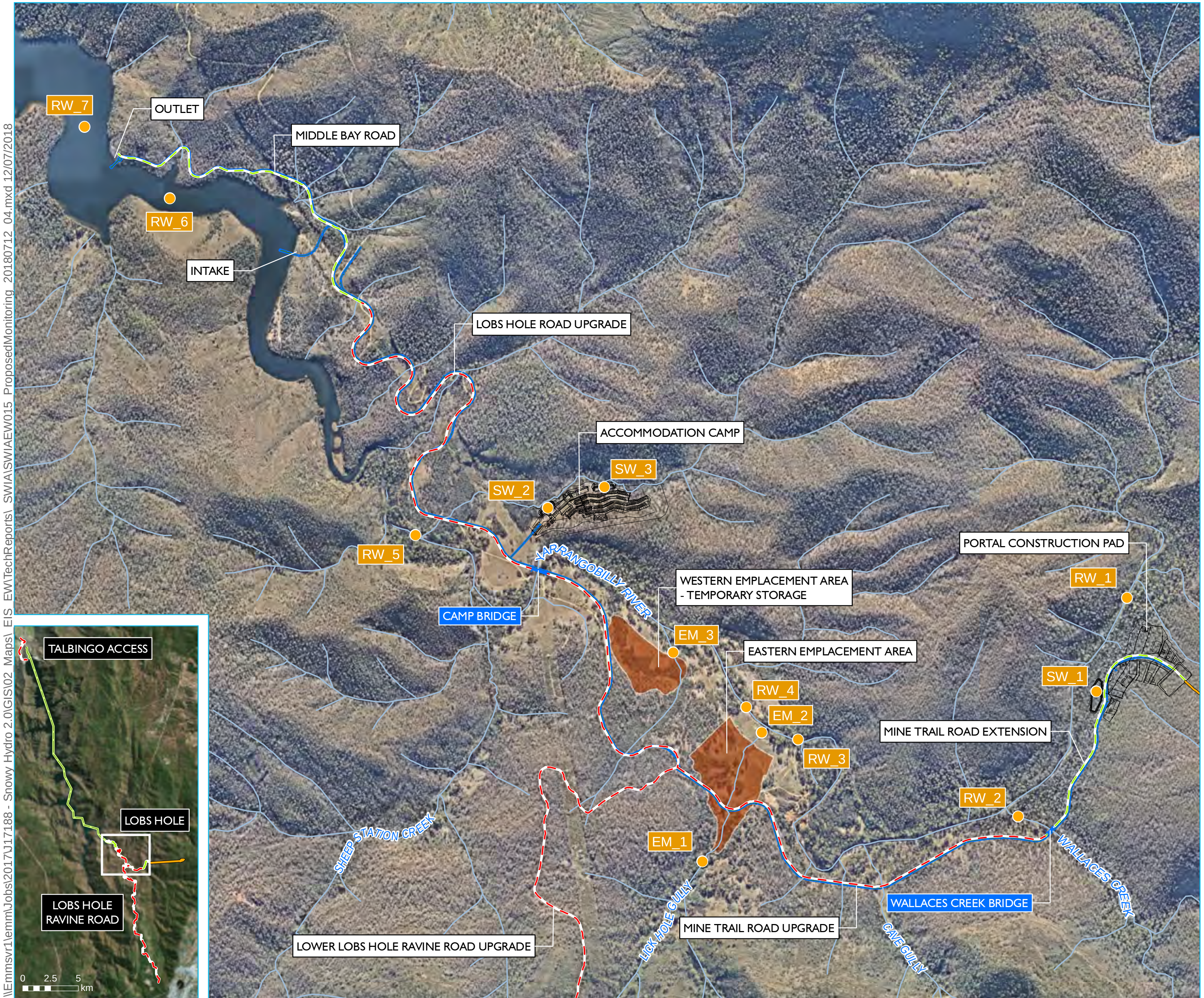
3. a material wet weather event refers to any rainfall event that results in the discharge of surface water from the project's water management dams. This will typically require 30 to 50mm of rainfall over a 2 to 3 day period.

8.2 Monitoring locations

Table 8.2 provides additional information on the monitoring locations described in Table 8.1. The stream gauge, receiving water, stormwater and emplacement monitoring locations are indicated in Figure 8.1.

Table 8.2 Water monitoring locations

ID	Location	Comment
Stream gauge monitoring locations		
SG_1	Yarrangobilly River	Refers to the existing stream gauge (410574) located on the Yarrangobilly River, downstream of the eastern emplacement
SG_2	Lick Hole Gully	A stream gauge will be installed in Lick Hole Gully, upstream of the eastern emplacement
SG_3	Lick Hole Gully	A stream gauge will be installed on Lick Hole Gully, downstream of the eastern emplacement
SG_4	Portal Water Management Dam	A water level meter will be installed in the portal compound's water management dam to record dam overflow volumes and rates
Receiving water monitoring locations		
RW_ 1	Yarrangobilly River	Upstream of the exploratory tunnel and construction pad
RW_ 2	Wallaces Creek	Upstream of the confluence with the Yarrangobilly River
RW_ 3	Yarrangobilly River	Downstream of remnant mine workings, upstream of the eastern emplacement.
RW_ 4	Yarrangobilly River	Downstream of the eastern emplacement
RW_ 5	Yarrangobilly River	Downstream of the accommodation camp, upstream of Talbingo Reservoir
RW_ 6	Talbingo Reservoir	Upstream of the controlled discharge location
RW_ 7	Talbingo Reservoir	Downstream of the controlled discharge location
Process water monitoring locations		
PW_1	Tunnel portal sump	The tunnel portal sump will receive water dewatered from the tunnel
PW_2	Treated process water (from the process water tank)	This water will be used for dust suppression, concrete batching and may be discharge to Talbingo Reservoir via controlled discharge
Treated effluent monitoring locations		
TE_1	Treated effluent	Treated effluent from the waste water treatment plant will be discharged to Talbingo Reservoir
Stormwater monitoring locations		
SW_1	Construction pad basin	Receives runoff from the portal construction pad water management area
SW_2	Accommodation camp pond 1	Receives runoff from the southern portion of the accommodation camp
SW_3	Accommodation camp pond 2	Receives runoff from the northern portion of the accommodation camp
Emplacement monitoring locations		
EM_1	Lick Hole Gully	Upstream of the eastern emplacement
EM_2	Lick Hole Gully	Downstream of the eastern emplacement
EM_3	Western Emplacement	Downstream of the western emplacement
Access road monitoring locations		
AR_1 to AR_4	Four random access road discharge locations will be selected each sampling event.	Access road discharge locations refer to any location where runoff from access road drainage enters a clean water drainage system. This may be overflow from a sedimentation basin or from a sediment trap.
Construction disturbance area monitoring		
Monitoring locations will be established as part of the detailed sediment and erosion control plans that will be prepared for each construction zone.		



KEY

- Proposed monitoring location
- Exploratory tunnel
- Portal construction pad and accommodation camp conceptual layout
- Permanent bridge
- Access road upgrade
- Access road extension
- Water services pipeline
- Watercourse
- On land rock management

Proposed monitoring locations

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 8.1

Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SGM (2018); SMEC (2018); Robert Bird (2018)

8.3 Monitoring regime and methods

8.3.1 Terminology

The following terminology is used to describe the proposed monitoring regime:

- Continuous – refers to the use of continuous monitoring methods.
- Monthly – refers to routine monitoring that will be undertaken monthly, regardless of weather.
- Baseflow (Quarterly) – refers to monitoring that will be undertaken on a quarterly basis to assess base flow conditions.
- Wet Weather (Quarterly) – refers to monitoring that will be undertaken on a quarterly basis during wet weather conditions. Wet weather events are defined as any rainfall event that results in the discharge of surface water from the project's water management dams. This will typically require 30 to 50 mm of rainfall over a 2 to 3 day period.
- After Wet Weather (Quarterly) - refers to monitoring that will be undertaken on a quarterly basis, approximately 1 week after each of the wet weather samples.
- Wet Weather (Event-based) – refers to monitoring that will be undertaken daily during wet weather conditions. Wet weather events are defined as any rainfall event that results in the discharge of surface water from the Exploratory Work's water management dams.

8.3.2 Monitoring regime and methods

Table 8.3 details the proposed monitoring regime for each monitoring category and Table 8.4 details the proposed sampling analytes and analysis methods.

Table 8.3 Monitoring regime

	Continuous	Monthly	Baseflow	Wet weather (comprehensive)	After wet weather	wet weather (Basic)
Frequency	Continuous	Monthly	Quarterly	Quarterly	Quarterly	Event Based
Method	Stream gauge	Comprehensive	Comprehensive	Comprehensive	Comprehensive	Basic
Stream gauge (SG)	✓					
Receiving water (RW)			✓	✓	✓	
Process water (PW)		✓				
Treated effluent (TE)		✓				
Stormwater (SW)				✓	✓	✓
Emplacement (EM)	✓		✓	✓	✓	
Access road (AR)				✓		✓
Construction area (CA)				✓		✓

Table 8.4 Monitoring methods

Category	Proposed sampling analytes	Analysis method
	Basic monitoring	
Physiochemical Properties	pH, electrical conductivity (EC), turbidity, dissolved oxygen, temperature, redox potential	To be measured using a portable water quality meter in the field
Inspection		Inspection of erosion and sediment controls and downstream drainage
	Comprehensive monitoring	
Physiochemical Properties	pH, electrical conductivity (EC), turbidity, dissolved oxygen, temperature, redox potential	To be measured using a portable water quality meter in the field
	major cations (Na, K, Mg, Ca) and major anions (Cl, SO_4, HCO_3 and CO_3)	Analysis to be undertaken by a NATA certified laboratory
	total suspended solids, total dissolved solids, total hardness, Total Recoverable Hydrocarbons	Analysis to be undertaken by a NATA certified laboratory
Nutrients	total nitrogen, ammonia, nitrate, nitrite and total kjeldahl nitrogen	Analysis to be undertaken by a NATA certified laboratory
	total phosphorus and reactive phosphorous	
	total organic carbon, dissolved organic carbon	
Metals (dissolved)	Al, As, Ag, B, Ba, Cr (total), Co, Cd, Cu, Fe, Hg, Mn, Ni, Pb, Se, V and Zn	Analysis to be undertaken by a NATA certified laboratory
	Comprehensive monitoring (TE_1, RW_6 and RW_7 only)	
Oxygen Demand	Chemical oxygen demand, Biological oxygen demand	Analysis to be undertaken by a NATA certified laboratory
Biological	Total plate count, E Coli, Faecal Coli form	Analysis to be undertaken by a NATA certified laboratory

9 Water licensing

This section discusses the surface water licensing requirements for the Exploratory Works.

9.1 Expected surface water take

Surface water extraction from Talbingo Reservoir will be required to provide potable water for the project and to top-up the process water system, which will supply water for use in construction activities. Table 9.1 provides a summary of the expected maximum surface water take.

Table 9.1 Expected maximum surface water take

Water take	Volume
Extraction from the Yarrangobilly River	
No extraction of surface water from the Yarrangobilly River is proposed	nil
Extraction from Talbingo Reservoir	
Extraction for potable water	18 ML/year[1]
Extraction for use in construction activities	209 ML/year[2]
Total	227 ML/year

Notes: 1. Calculated using the estimated daily waste water load of 48 KL/day.
2. The maximum annual total from Table 6.12 has been adopted.

Snowy Hydro will consult with DoI Water to establish licensing requirements for the maximum surface water take from Talbingo Reservoir that is established in Table 9.1.

9.2 Water management dams

Water management dams are proposed to manage runoff from construction disturbance areas, access roads, the construction pad and the accommodation camp. The capture of surface water runoff in the water management dams is considered to be excluded works under *Water Management (General) Regulation 2011, Schedule 1, item 3 (dams solely for the capture, containment or recirculation of drainag*e). Accordingly, no WALs or WUAs are required from DoI Water for the capture of surface water in management dams.

10 Conclusion

This surface water assessment forms part of the EIS for the Exploratory Works. This assessment has been informed by the reference design prepared for the Exploratory Works. The following aspects of the project have been addressed in this assessment:

- Flood risk management associated with the following works that are proposed on flood prone land:
  - Camp and Wallaces bridges;
  - the western rock and soil emplacement area; and
  - the water management basin for the construction pad.
- Water management during construction of access roads, the accommodation camp, portal construction pad and other infrastructure.
- Water management during operation including:
  - stormwater runoff from the access roads, accommodation camp and portal construction pad;
  - water produced by and used by the construction activities; and
  - waste water (ie sewage).
- Water management for rock and soil emplacement areas.

This assessment recommends controls to mitigate potential impacts. These controls are summarised in Appendix F and will be considered in the detailed design of the Exploratory Works.

Residual surface water impacts include:

- **Sediment laden runoff** - runoff from the construction areas (initial phase of the project only) and unsealed access roads will be laden with sediment. Sediment and erosion controls are expected to effectively remove coarse sediment but may provide limited removal of fine and dispersive sediments. Hence, some runoff containing fine and dispersive sediments may drain into receiving waters. It is expected that any runoff laden with fine and dispersive sediments that enters the Yarrangobilly River will be significantly diluted by river flows and will rapidly dissipate. Hence, no material change to the Yarrangobilly River water quality is expected.
- **Treated water discharge** – treated waste water will be discharged into the Yarrangobilly River arm of Talbingo Reservoir. During drought conditions, this discharge may result in the near-field concentration of phosphorus exceeding the trigger value for physical and chemical stressors that is provided in ANZECC 2000. No measurable near-field impacts are expected during non-drought conditions due to higher river inflows. Impacts to the greater reservoir are also not expected due to the high inflows associated with the existing operation of the Snowy Scheme.
- **Impacts to local watercourses** - some local watercourses will unavoidably be disturbed by the establishment of rock emplacement areas, bridge crossings and the accommodation camp.

11 References

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Jacobs (2018), 'Snowy 2.0 Exploratory Works – Air quality assessment'

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SGM environmental (2018), 'Excavated Rock Emplacement Areas Assessment'

Glossary

Term	Meaning
Access road upgrade	Upgrade works (realignment, widening or no widening) of existing access roads
Access road extension	A new access road that is an extension of an existing access road
Accommodation camp	Area used for temporary housing and facilities for construction personnel
Avoidance footprint	Areas excluded from clearing and ground disturbance due to sensitive environmental constraints
Barge access infrastructure	A ramp and associated facilities to allow the loading and unloading of barge(s) on Talbingo Reservoir
Camp bridge	The permanent bridge structure across Yarrangobilly River
Communications cable	Fibre optic communications cable in Talbingo Reservoir
Clean water	surface water runoff from catchments that are undisturbed or rehabilitated following disturbance
Disturbance footprint	The area subject to clearing and ground disturbance
Emplacement seepage	Water that seeps from the rock and soil emplacements
Exploratory tunnel	A 3.1 km tunnel to the cavern of the proposed Machine Hall for the purposes of understanding geotechnical and underground conditions
Exploratory Works	A program of exploratory works for Snowy 2.0, subject of this EIS and as described in Section 2.
Fire water	Water that is produced by fire fighting activities
Lobs Hole	A former settlement location within Kosciuszko National Park, and primary location of Exploratory Works
Lobs Hole Mine	The site of a former copper mine circa 1908, located at Lobs Hole
Lobs Hole Ravine Road	The main access road to Lobs Hole
Lower Lobs Hole Ravine Road	The section of Lobs Hole Ravine Road from Link Road to where it crosses the transmission easement
Middle Bay barge ramp	Location of barge access infrastructure at the southern end of Talbingo Reservoir
Middle Bay Road	The access road from the accommodation camp to the Middle Bay barge ramp. An extension to Middle Bay Road is proposed as part of Exploratory Works.
Miles Franklin Drive	Existing road leading to Spillway Road, for access to the Talbingo barge ramp
Mine Trail Road	The access road from the intersection with Lower Lobs Hole Ravine Road and the portal construction pad. An extension to Mine Trail Road is proposed as part of Exploratory Works.
On land rock emplacement area	The locations for rock emplacement at Lobs Hole being the western emplacement area and the eastern emplacement area
Permanent bridge	The permanent bridge crossings comprising Wallace Creek bridge and Camp bridge
Portal	Location of surface connection with the exploratory tunnel
Portal construction pad	Area used for construction for the exploratory tunnel and portal, including ancillary facilities, laydown and storage, and environmental controls
Potable water	Water that has been treated to a potable water standard
Project area	The area required to access and build project infrastructure, including surface and tunnel components of the project
Process water	Water that will be produced by or used by the proposed construction activities.
Receiving water	Any watercourse that receives runoff or water discharge from the Exploratory Works

Glossary

Term	Meaning
Rock emplacement area	Land area identified for the placement and storage of excavated rock from Exploratory Works
Sediment laden water	Surface water runoff from construction disturbance and unsealed access roads. Sediment laden water is likely to contain elevated suspended sediment levels and requires sedimentation treatment prior to release.
Snowy 2.0	A pumped-hydro expansion of the Snowy Scheme that will link the two existing reservoirs of Tantangara and Talbingo through underground tunnels, and include a new underground power station with pumping capabilities.
Spillway	Structure used to provide the controlled release of flows from Talbingo Dam into the reservoir
Spillway Road	The access road to Talbingo barge ramp
Stormwater	Runoff from the accommodation camp and portal compound. Stormwater may contain elevated concentrations of suspended sediment and nutrients
Study area	Define if appropriate for the technical study (ie. Is different to the Exploratory Works project area)
Subaqueous rock emplacement area	The location for rock emplacement within Talbingo Reservoir
Talbingo barge ramp	Location of barge access infrastructure at the northern end of Talbingo Reservoir
Talbingo Spillway	Structure used to provide the controlled release of flows from Talbingo Dam into the reservoir
Temporary bridge	A temporary structure or causeway across a watercourse to allow construction of permanent bridges
Tunnel affected water	Intercepted groundwater and all other water that is dewatered from the exploratory tunnel (a component of process water)
Tumut 3 power station	Power station at the northern end of Talbingo Reservoir
Upper Lobs Hole Ravine Road	The section of Lobs Hole Ravine Road from where it crosses the transmission easement to Lobs Hole
Wallaces Creek Bridge	The permanent bridge structure across Wallaces Creek
Water services pipeline	Utility pipeline for Exploratory Works providing water supply and waste water discharge between accommodation camp, portal construction pad and Talbingo Reservoir
Waste water	Waste water generated from the accommodation camp and other onsite amenities

Abbreviations

AC	*Acid consuming*
AEP	*Annual Exceedance Probability*
ANC	*Acid Neutralising Capacity*
ANZECC	*Australian and New Zealand Environmental Conservation Council*
ARD	*Acid Rock Drainage*
ARR2016	*Australian Rainfall and Runoff (2016)*
BoM	*Bureau of Meteorology*
DECC	*(former) NSW Department of Environment and Climate Change*
DPE	*Department of Planning and Environment*
DoI – Water	*Department of Industry - Water*
EC	*Electrical Conductivity*
EIS	*Environmental Impact Statement*
EPA	*NSW Environment Protection Authority*
ESCP	*Erosion and Sediment Control Plan*
FFA	*Flood Frequency Analysis*
KNP	*Kosciuszko National Park*
PAF	*Potentially Acid Forming*
POEO	*Protection of the Environment Operations Act 1997*
PMF	*Probable Maximum Flood*
SEARs	*Secretary's Environmental Assessment Requirements*
SHC Act	*The NSW Snowy Hydro Corporatisation Act 1997*
VD	*Velocity Depth product*
WAL	*Water Access License*
WA 1912	*Water Act 1912*
WMA 2000	*Water Management Act 2000*
WSP	*Water Sharing Plan*
WUA	*Work and Use Approval*