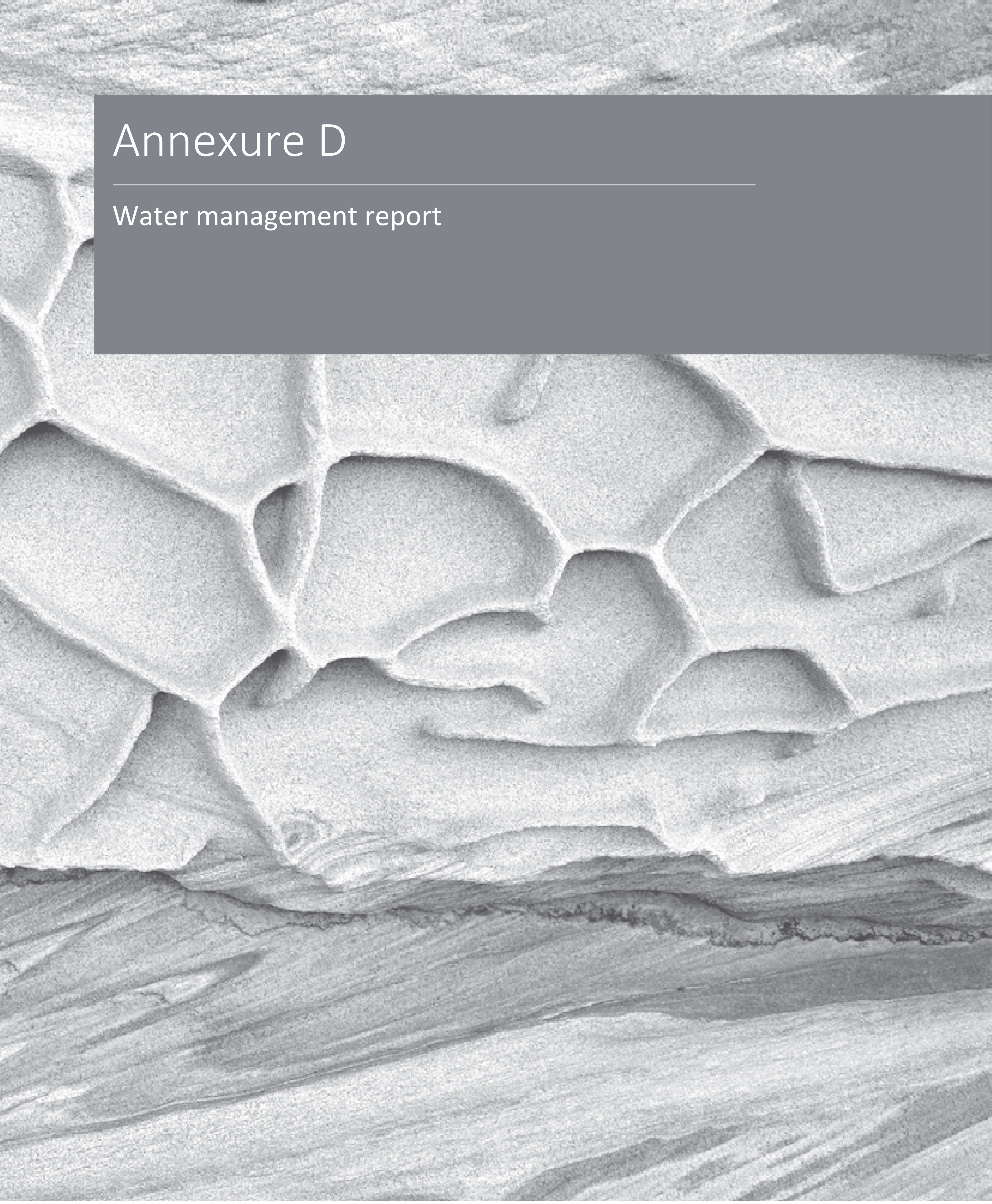
APPENDIX J

WATER ASSESSMENT

ANNEXURE D – WATER MANAGEMENT REPORT

Annexure D

Water management report



Water management report

Annexure D to water assessment

Prepared for Snowy Hydro Limited
September 2019

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Water management report

Annexure D to water assessment

Report Number

J17188 RP85

Client

Snowy Hydro Limited

Date

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Version

v1 Final

Prepared by	Approved by
Chris Kuczera Associate Water Resources Engineer 13 September 2019	**Liz Webb** Principal Hydrogeologist 13 September 2019

This report has been prepared in accordance with the brief provided by the client and has relied upon the information collected at the time and under the conditions specified in the report. All findings, conclusions or recommendations contained in the report are based on the aforementioned circumstances. The report is for the use of the client and no responsibility will be taken for its use by other parties. The client may, at its discretion, use the report to inform regulators and the public.

Executive Summary

ES1 Introduction

Snowy Hydro Limited (Snowy Hydro) proposes to develop Snowy 2.0, a large-scale pumped hydro-electric storage and generation project which would increase hydro-electric capacity within the existing Snowy Mountains Hydro-electric Scheme (Snowy Scheme). Snowy 2.0 is the largest committed renewable energy project in Australia and is critical to underpinning system security and reliability as Australia transitions to a decarbonised economy.

Snowy 2.0 will link the existing Tantangara and Talbingo reservoirs within the Snowy Scheme through a series of underground tunnels and a new hydro-electric power station will be built underground. The major construction elements of Snowy 2.0 include permanent infrastructure, temporary construction infrastructure, management and storage of extracted rock material and establishing supporting infrastructure. Snowy 2.0 Main Works also includes the operation of Snowy 2.0.

ES2 Report purpose

In order to assess potential groundwater and surface water related issues from the construction and operation of Snowy 2.0, a water assessment (Appendix J to the EIS) has been prepared as an appendix to the Snowy 2.0 Main Works EIS. The water assessment has several supporting technical reports which are termed annexures. This water management report is Annexure D to the water assessment.

The purpose of this water management report is to:

- describe the proposed water management system, including management measures;
- characterise all discharge in terms of location, volume, frequency and water quality;
- describe works on waterfront land;
- provide estimates of water take to supply construction activities; and
- describe residual impacts to receiving waters due to discharges from the water management system.

ES3 Water management approach

Table ES1 provides a summary of key aspects of the proposed water management system.

Table ES1 Water management summary

Key aspect	Management approach
Stormwater management	The stormwater management approach will vary based on the type of disturbance, construction activities and environmental factors such as topography. This water management report describes the proposed management approach and discharge characteristics for each unique stormwater category. Broadly, the following measures are proposed: • management of clean water runoff from upslope areas and watercourses that traverse disturbance areas; • erosion and sediment controls for construction disturbance areas; • source controls to isolate potentially polluting construction activities (ie concrete batching) from the stormwater system; • stormwater harvesting to reduce runoff volumes; • stormwater basins to manage runoff from construction pads and accommodation camps; and • measures to manage leaks and spills.
Project water supply	• A water supply system will be established to supply water for potable water use and construction activities; • the system will most likely source water from both regional groundwater resources, and from reservoirs, either Tantangara or Talbingo reservoirs, provided relevant licences and approvals can be obtained; and • extraction from watercourses is not proposed.
Wastewater (ie sewerage) management	• All wastewater will be treated and discharged to either Tantangara or Talbingo reservoirs. • discharges to watercourses are not proposed and will be avoided.
Process water management	• A process water management system will be established to supply water to construction activities and manage water that is pumped from the sumps in subsurface excavations and large surface excavations; • all surplus process water will be treated and discharged to either Tantangara or Talbingo reservoirs; and • discharges to watercourses are not proposed and will be avoided.

ES4 Residual impacts

ES4.1 Impacts to watercourses

It is proposed to discharge all treated process and wastewater directly to reservoirs. Hence, stormwater discharges are the only discharge mechanism that can impact watercourses. The potential for stormwater discharges to change receiving water streamflow regimes and water quality will vary based on discharge characteristics and the location, area and duration of disturbance.

The potential for change is proportionally greater:

- during the initial 15 months of the project when the greatest area of disturbance and poorest water quality will occur due to surface construction activities;
- in watercourses that have small catchment areas relative to the disturbance within the catchment; and
- in summer and autumn during moderate rainfall conditions when discharges from the stormwater system may occur but there is insufficient rainfall to generate runoff from the broader catchment.

The potential for changes is proportionally lower:

- following the initial 15 months of the project when disturbance due to construction of surface infrastructure is complete;
- in watercourses that have large catchment areas relative to disturbance within the catchment;
- in winter and spring when streamflow is seasonally high; and
- in summer and autumn during significant rainfall events that result in high streamflow.

Potential changes to water quality in the Yarrangobilly River, the upper Eucumbene River and Kellys Plain Creek have been assessed using a conceptual stormwater discharge model. Table ES2 provides a summary of the estimated disturbance durations and profiles and potential magnitude of changes to receiving water quality. Potential changes to water quality are described using the following categories that represent varying magnitudes of change relative to the relevant WQO value:

- no change;
- 0 to 10% increase;
- 10 to 50% increase;
- 50 to 100% increase; and
- greater than 100% increase.

Table ES2 Summary of potential changes to water quality

	Construction phase		Operational phase
	Phase 1 (Construction of surface infrastructure)	**Phase 2** (All other construction activities)	
Disturbance duration	For the Initial 15 months of the 6 year construction program	For the majority of the 6 year construction program	For perpetuity following construction
Disturbance footprint[1]	533 ha	148 ha	55 ha
Percentage of time no change to receiving water quality is expected			
Yarrangobilly River[2]	85%	85%	85%
Upper Eucumbene River	73%	80%	85%
Kellys Plain Creek[3]	83%	76%	81%
Percentage of time concentrations of suspended solids, nutrients or metals in receiving waters may increase by between 0 to 10% of WQO values[4]			
Yarrangobilly River[2]	2%	12%	13%
Upper Eucumbene River	6%	8%	7%
Kellys Plain Creek[3]	0%	8%	7%

Table ES2 Summary of potential changes to water quality

	Construction phase		Operational phase
	Phase 1 (Construction of surface infrastructure)	**Phase 2** (All other construction activities)	
Percentage of time concentrations of suspended solids, nutrients or metals in receiving waters may increase by between 10 to 50% of WQO values[4]			
Yarrangobilly River[2]	7%	3%	2%
Upper Eucumbene River	6%	8%	7%
Kellys Plain Creek[3]	0%	8%	7%
Percentage of time concentrations of suspended solids, nutrients or metals in receiving waters may increase by between 50 to 100% of WQO values[4]			
Yarrangobilly River[2]	3%	0%	0%
Upper Eucumbene River	5%	2%	1%
Kellys Plain Creek[3]	1%	3%	3%
Percentage of time concentrations of suspended solids, nutrients or metals in receiving waters may increase by more than 100% of WQO values[4]			
Yarrangobilly River[2]	3%	0%	0%
Upper Eucumbene River	10%	1%	0%
Kellys Plain Creek[3]	17%	5%	3%

Notes: 1. Refers the estimated actual disturbance footprint for each project phase.

2. Results for Yarrangobilly River include discharge from disturbance areas adjacent to the Yarrangobilly River arm of Talbingo Reservoir.

3. Results for Kellys Plain Creek include discharge from disturbance areas to the north of Kellys Plain Creek that also drain into the southern portion of Tantangara Reservoir.

4. WQO values refer to the Water Quality Objective values established in the water assessment.

ES4.2 Impacts to reservoirs

The following water management system discharges have potential to change reservoir water quality:

- stormwater discharges into watercourses that flow into reservoirs; and
- controlled discharges of treated wastewater and process water directly to reservoirs.

Table ES3 provides estimates of the change in median ambient salinity levels (as indicated by electrical conductivity) and total nitrogen and phosphorus concentrations in Tantangara Reservoir and the Yarrangobilly River arm of Talbingo Reservoir. It is noted that:

- The change in salinity levels and nutrient concentrations are likely to be less due to:
  - decay and assimilation (nutrients only); and
  - mixing between the Yarrangobilly River arm and the greater Talbingo Reservoir (not relevant to Tantangara Reservoir).

- Higher concentration increases may occur near treated wastewater and process water discharge locations. However, the spatial extent of higher concentrations (also referred to as a mixing zone) is expected to be within tens of metres of discharge locations.
- Additional changes to reservoir water quality may occur due to spoil management activities.

Table ES3 Summary of potential changes to ambient reservoir water quality

	Units	Summer/autumn (drought)[1]	summer/autumn (typical)	winter/spring (typical)
Tantangara Reservoir				
Construction phase 1 – Applies to the initial 15 months of the 6 year construction program				
Salinity (as indicated by EC)	µS/cm	27 to 27	27 to 27	22 to 22
Total nitrogen	mg/L	0.20 to 0.27	0.20 to 0.22	0.12 to 0.12
Total Phosphorus	mg/L	0.03 to 0.05	0.03 to 0.04	0.01 to 0.01
Construction phase 2 – Applies for the majority of the 6 year construction program				
Salinity (as indicated by EC)	µS/cm	27 to 33	27 to 28	22 to 23
Total nitrogen	mg/L	0.20 to 0.24	0.20 to 0.21	0.12 to 0.12
Total Phosphorus	mg/L	0.03 to 0.04	0.03 to 0.03	0.01 to 0.01
Operational phase – Applies for perpetuity following construction				
Salinity (as indicated by EC)	µS/cm	27 to 27	27 to 27	22 to 22
Total nitrogen	mg/L	0.20 to 0.21	0.20 to 0.20	0.12 to 0.12
Total Phosphorus	mg/L	0.03 to 0.03	0.03 to 0.03	0.01 to 0.01
Yarrangobilly River arm of Talbingo Reservoir				
Construction phase 1 – Applies to the initial 15 months of the 6 year construction program				
Salinity (as indicated by EC)	µS/cm	22 to 22	22 to 22	14 to 14
Total nitrogen	mg/L	0.20 to 0.22	0.20 to 0.21	0.11 to 0.11
Total Phosphorus	mg/L	0.03 to 0.04	0.03 to 0.03	0.01 to 0.01
Construction phase 2 – Applies for the majority of the 6 year construction program				
Salinity (as indicated by EC)	µS/cm	22 to 40	22 to 27	14 to 15
Total nitrogen	mg/L	0.20 to 0.29	0.20 to 0.23	0.11 to 0.11
Total Phosphorus	mg/L	0.03 to 0.04	0.03 to 0.03	0.01 to 0.01
Operational phase– Applies for perpetuity following construction				
Salinity (as indicated by EC)	µS/cm	22 to 22	22 to 22	14 to 14
Total nitrogen	mg/L	0.20 to 0.20	0.20 to 0.20	0.11 to 0.11
Total Phosphorus	mg/L	0.03 to 0.03	0.03 to 0.03	0.01 to 0.01

Notes: The predicted values for total nitrogen and total phosphorus make no allowance for decay and assimilation and are therefore conservative.

Ambient values refer to typical or median values

1. Calculations based on reservoir inflows and calculated stormwater discharges for the 2006/2007 summer/autumn period.

In conclusion, the combination of stormwater discharges and controlled discharges of treated wastewater and process water during the construction phase of the project have potential to increase the ambient salinity levels and nutrient concentrations. The magnitude of change is expected to be greater:

- in summer/autumn due to lower seasonal streamflow into the reservoir; and
- during drought conditions due to lower streamflow into the reservoir.

No material changes to reservoir water quality are expected due to stormwater discharges during the operational phase of the project.

No material changes to the greater Talbingo Reservoir are expected due to mixing with the significant year-round discharge from Tumut 2 power station that enters Talbingo Reservoir via the Tumut River.

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Attachments

Tables

Figures

1 Introduction

1.1 Overview

Snowy Hydro Limited (Snowy Hydro) proposes to develop Snowy 2.0, a large-scale pumped hydro-electric storage and generation project which would increase hydro-electric capacity within the existing Snowy Mountains Hydro-electric Scheme (Snowy Scheme). Snowy 2.0 is the largest committed renewable energy project in Australia and is critical to underpinning system security and reliability as Australia transitions to a decarbonised economy.

Snowy 2.0 will link the existing Tantangara and Talbingo reservoirs within the Snowy Scheme through a series of underground tunnels and a new hydro-electric power station will be built underground. The major construction elements of Snowy 2.0 include permanent infrastructure, temporary construction infrastructure, management and storage of extracted rock material and establishing supporting infrastructure. Snowy 2.0 Main Works also includes the operation of Snowy 2.0.

To assess impacts from the project, an Environmental Impact Statement (EIS) has been prepared (EMM 2019). Chapter 2 of the Snowy 2.0 Main Works EIS describes the construction and operation of the project in detail. The regional location of the Snowy 2.0 project area is shown in Figure 1.1 and the Snowy 2.0 Main Works project area in Figure 1.2.

In order to assess potential groundwater and surface water related issues from the construction and operation of Snowy 2.0, a water assessment (Appendix J to the EIS) has been prepared as an appendix to the Snowy 2.0 Main Works EIS.

The water assessment has a number of supporting technical reports which are termed annexures. Each annexure has further supporting technical reports which are termed attachments. This water management report (WMR) is an annexure to the water assessment. The document structure of the technical reports and assessments which support the overall water assessment are shown in Figure 1.3.

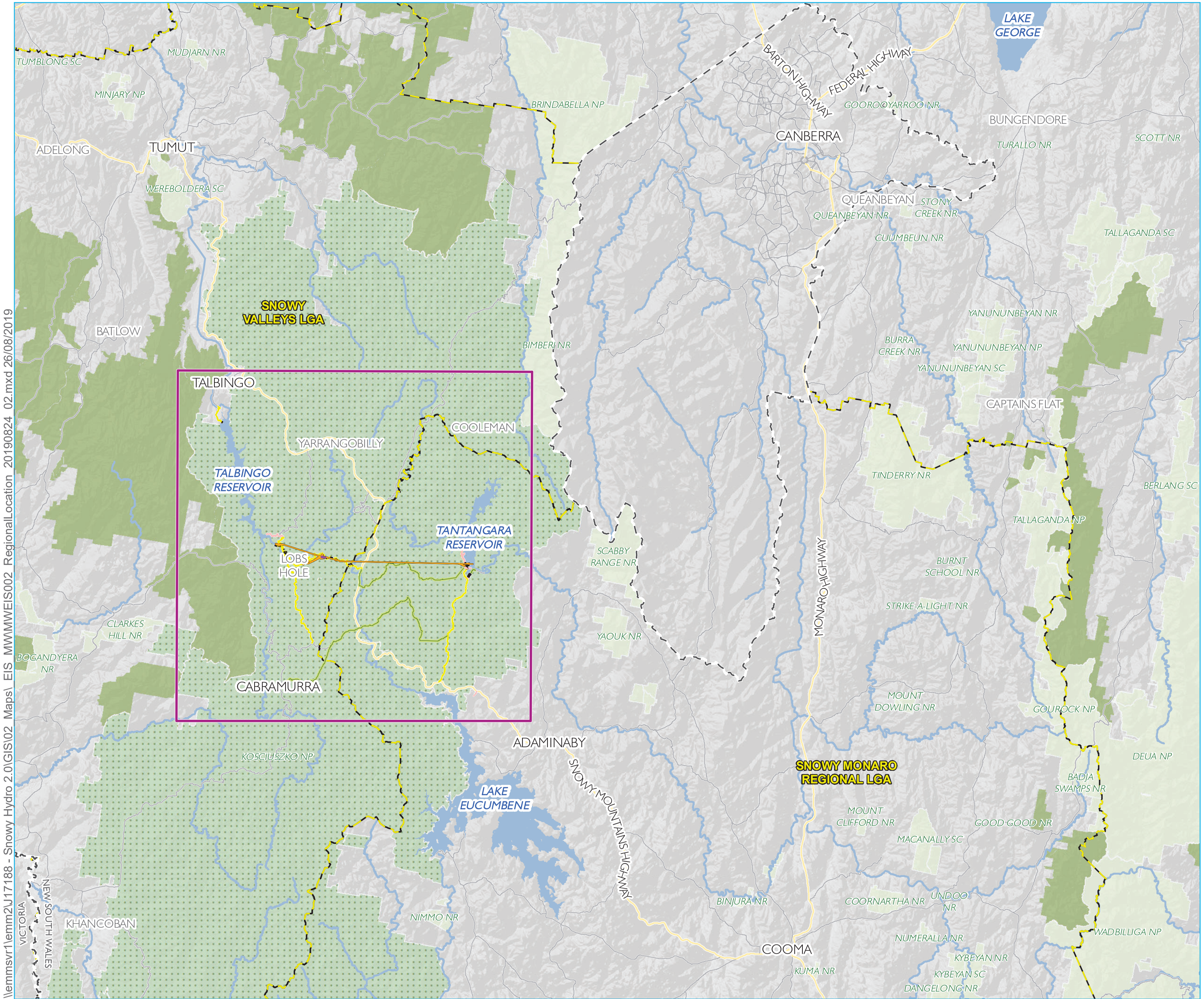
1.2 Purpose of this report

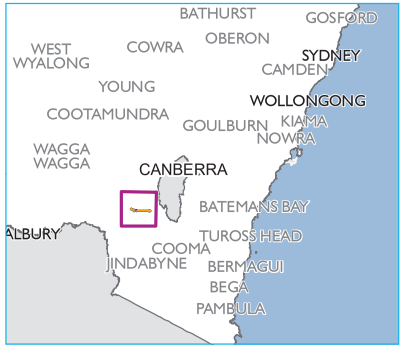
The purpose of this water management report is to:

- describe the proposed water management system, including management measures;
- characterise all discharge in terms of location, volume, frequency and water quality;
- describe works on waterfront land;
- provide estimates of water take to supply construction activities; and
- describe residual impacts to receiving waters (watercourses and reservoirs) due to discharges from the water management system.

This report references:

- information on the existing environment that is documented in the water characterisation report (WCR) (Annexure A to the water assessment);
- water quality objectives that are established in the water assessment; and
- the concept design of the project.





KEY

- Project area
- Snowy 2.0 Main Works operational elements
  - Tunnels, portals, intakes, shafts
  - Power station
  - Utilities
  - Permanent road
- Snowy 2.0 Main Works construction elements
  - Temporary construction compounds and surface works
  - Temporary access road
- Existing environment
  - Main road
  - Local road
  - Watercourse
  - Waterbodies
  - Kosciuszko National Park
  - NPWS reserve
  - State forest
  - Local government area boundary
  - State boundary

Regional location of Snowy 2.0 project area

Snowy 2.0
Water Management Report
Main Works
Figure 1.1

Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

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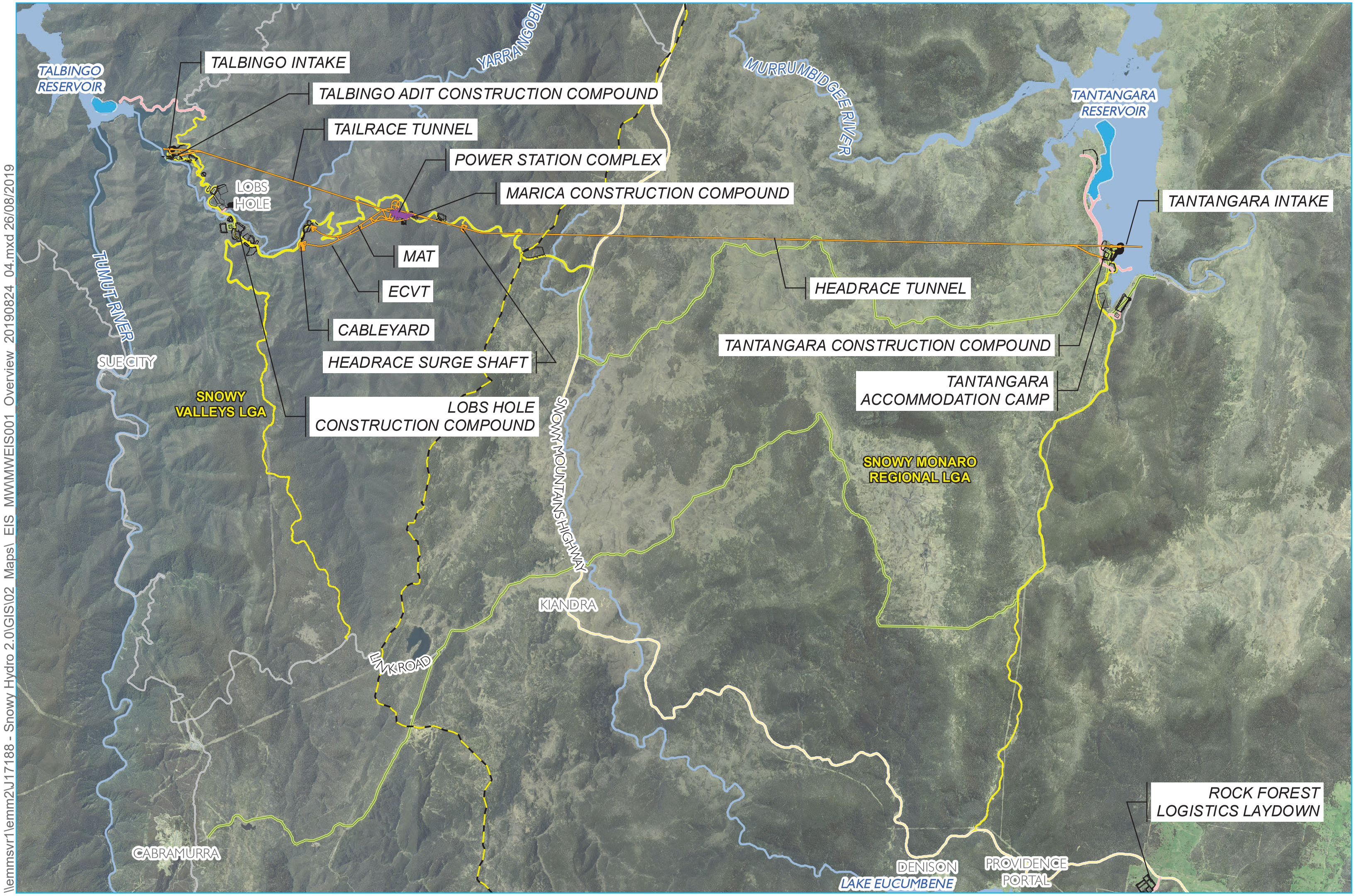

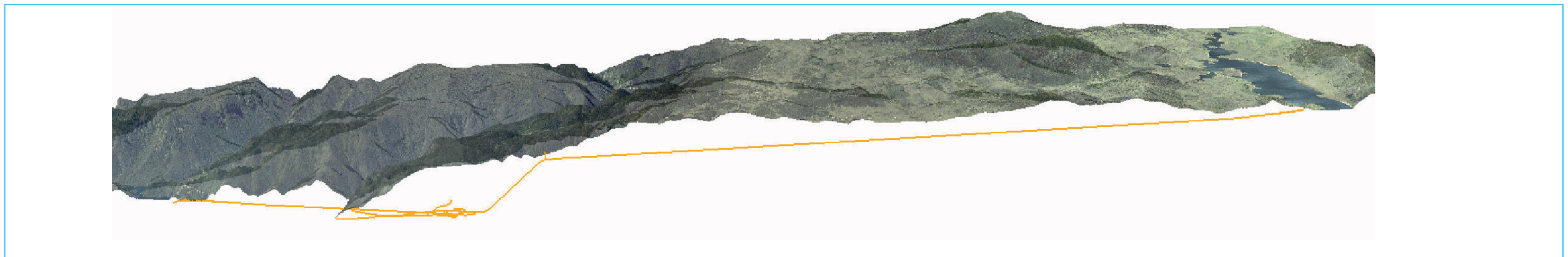

Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

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KEY

Existing environment
- Main road
- Local road
- Watercourse
- Waterbodies
- Local government area boundary

Snowy 2.0 Main Works operational elements
- Tunnels, portals, intakes, shafts
- Power station
- Utilities
- Permanent road

Snowy 2.0 Main Works construction elements
- Temporary construction compounds and surface works
- Temporary access road
- Indicative rock emplacement area

Main Works project area

Snowy 2.0
Environmental Impact Statement
Main Works
Figure 1.2

snowy 2.0 EMM creating opportunities

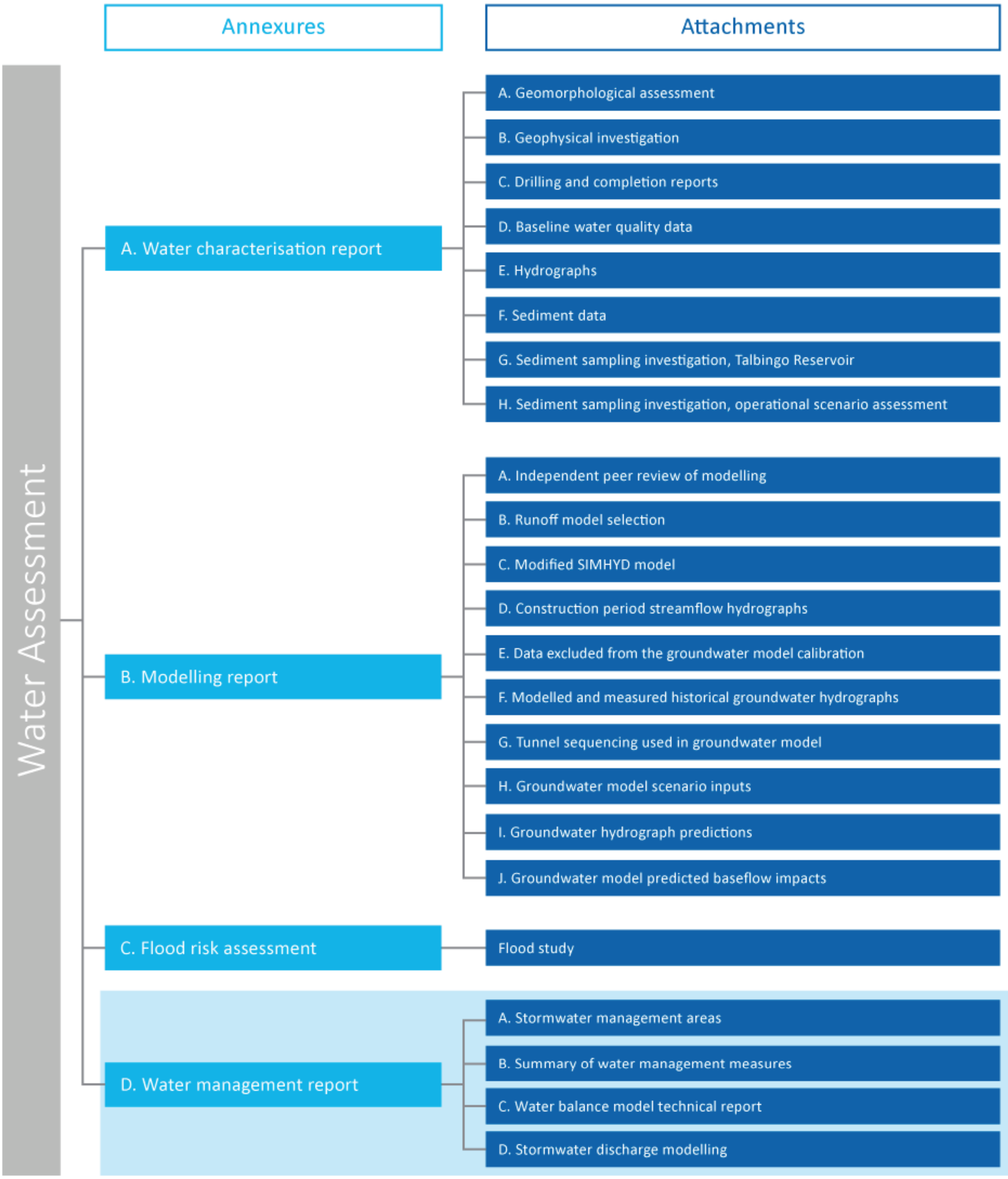


Figure 1.3 Water assessment and WMR structure

2 Report framework

2.1 Chapter structure

This chapter describes the framework of this water management report and relevant project information and is structured as follows:

- Section 2.2 describes project information that is referenced in this report;
- Section 2.3 describes the project's interfaces with the water cycle (ie both groundwater and surface water) during the construction and operational project phases;
- Section 2.4 describes terminology that is used to describe the water management system; and
- Section 2.5 describes relevant guidelines that are referenced in this report.

2.2 Project information

The EIS is informed by the project concept design. This section describes relevant information that is referenced in this report.

2.2.1 Project phases

Snowy 2.0 Main Works will comprise a construction phase and an operational phase. Chapter 2 of the EIS describes the Snowy 2.0 Main Works construction phase comprising three broad but overlapping sub-phases, being pre-construction works, construction works (including progressive rehabilitation) and testing and commissioning of permanent infrastructure.

For the purpose of describing the water management approach in this report, the terminology of project phasing has been adapted to differentiate between the initial ground disturbance activities (ie clearing and earthworks) and subsequent activities. The project phases, as they apply to the water management approach, are as follows:

- Construction phase – refers to the construction of Snowy 2.0 Main Works, including the following sub-phases:
  - Construction phase 1 – Construction of surface infrastructure – refers to the construction of access roads, service trenches, accommodation camps, construction pads, tunnel portals and other surface infrastructure.
  - Construction phase 2 – All other construction activities – refers to the construction of subsurface infrastructure and tunnel intakes and the use of surface infrastructure such as access roads, construction pads and accommodation camps to support construction activities.

  It is noted that at a project level (refer Figure 2.1) the two construction sub-phases will occur concurrently during the initial years of the project schedule, but at a local level, the phases would occur sequentially.
- Operational phase – refers to the operational phase of Snowy 2.0 Main Works. The operational phase is referred to as phase 3.

2.2.2 Construction activities and schedule

Snowy 2.0 Main Works will require multiple construction activities to be carried out concurrently, and across several different sites. Specific details on all Snowy 2.0 Main Works construction activities, as well as a detailed indicative schedule, is provided in Chapter 2 (project description) of the EIS.

The key components, locations and typical activities from Chapter 2 of the EIS are reproduced in Table 2.1, along with the corresponding project phase relevant to water management, as described in Section 2.2.1.

Table 2.1 Overview of construction activities and methods

<table>
<tr><th>Component/stage</th><th>Construction area</th><th>Phase</th><th>Typical activities</th></tr>
<tr><td>Pre-construction/site establishment</td><td>All</td><td>Construction of surface infrastructure</td><td>• Site boundary delineation and establishment of survey control network.
• Clearing and grubbing.
• Hazardous tree assessment within and adjacent to disturbance boundary.
• Drainage and environmental controls.
• Earthworks and levelling.
• Establish construction ancillary facilities and access.
• Construct water and wastewater treatment facilities.
• Construct and commission construction power.</td></tr>
<tr><td>Construction – access road and bridge work</td><td>All</td><td>Construction of surface infrastructure</td><td>• Site preparation of all roads (new or upgraded), including:
– clearing boundary is surveyed and pegged out;
– removal of any hazardous trees following pre-construction survey;
– any pre-clearing activities are completed, such as facilitating the egress of fauna; and
– erosion and sediment controls.
• Construct retaining walls where needed.
• Excavate road level.
• Lay road base, pavement and drainage.
• Construct bridges and culverts.
• Install road furniture such as signs and safety barriers.</td></tr>
<tr><td>Construction – geotechnical investigation and survey</td><td>All</td><td>Construction of surface infrastructure</td><td>• Clearing and levelling of drill pads including temporary access tracks and support infrastructure such as water supply and waste management systems.
• Drilling and in situ testing and characterisation.</td></tr>
<tr><td rowspan="2">Construction – excavation and tunnelling</td><td rowspan="2">• Talbingo Reservoir
• Lobs Hole
• Marica
• Tantangara Reservoir</td><td>Construction of surface infrastructure</td><td>• Construct adits.</td></tr>
<tr><td>All other construction activities</td><td>• Mobilisation and site setup of tunnel boring machines (TBMs) (where required).
• Excavate power waterways, power station cavern, and associated tunnel infrastructure.
• Install ground support where required.
• Lining of tunnels where required.
• Spoil management and haulage.</td></tr>
</table>

Table 2.1 Overview of construction activities and methods

Component/stage	Construction area	Phase	Typical activities
Construction – excavated rock management	• Talbingo Reservoir • Lobs Hole • Marica • Tantangara Reservoir	All other construction activities	• Transport of excavated rock from tunnels, adits, portals and surge shaft to stockpile areas. • Testing of excavated rock for suitability of placement (where required). • Transport to and filling of placement areas within the reservoirs and on-land placement for construction pads and/or permanent landforming.
Construction – intake and gate shaft construction	• Talbingo Reservoir • Tantangara Reservoir	All other construction activities	• Clearing and grubbing. • Cut excavation and benching to required depth, retaining a temporary rock plug to allow dry works zone. • Install permanent rock anchors where required. • Concrete works. • Removal of rock plug.
Construction – rehabilitation	All	All other construction activities	• Collection and storage of indigenous/native seed and alpine sods. • Progressive rehabilitation comprising: – stabilisation of slopes and preparation of sites for revegetation; – mitigation of sediment runoff; and – hydroseeding or planting of slopes. • Decommissioning of infrastructure by removal of all facilities and surfaces. • Reinstatement of topsoil and seeding and planting of vegetation. • Protection of revegetation and weed management.
Commissioning – fit-out, testing and commissioning	• Talbingo Reservoir • Lobs Hole • Marica • Tantangara Reservoir	All other construction activities	• For all permanent structures: – concrete works; – install electrical and mechanical; and – test and commission plant equipment.

To explain the temporal relationship of the project components and phases, Figure 2.1 shows a simplified indicative schedule that details the project components and phases detailed in Table 2.1. Figure 2.1 also notes the corresponding project components that will be undertaken as part of Exploratory Works, prior to the commencement of Snowy 2.0 Main Works. The schedule assumes a project approval for Snowy 2.0 Main Works at the beginning of 2020.

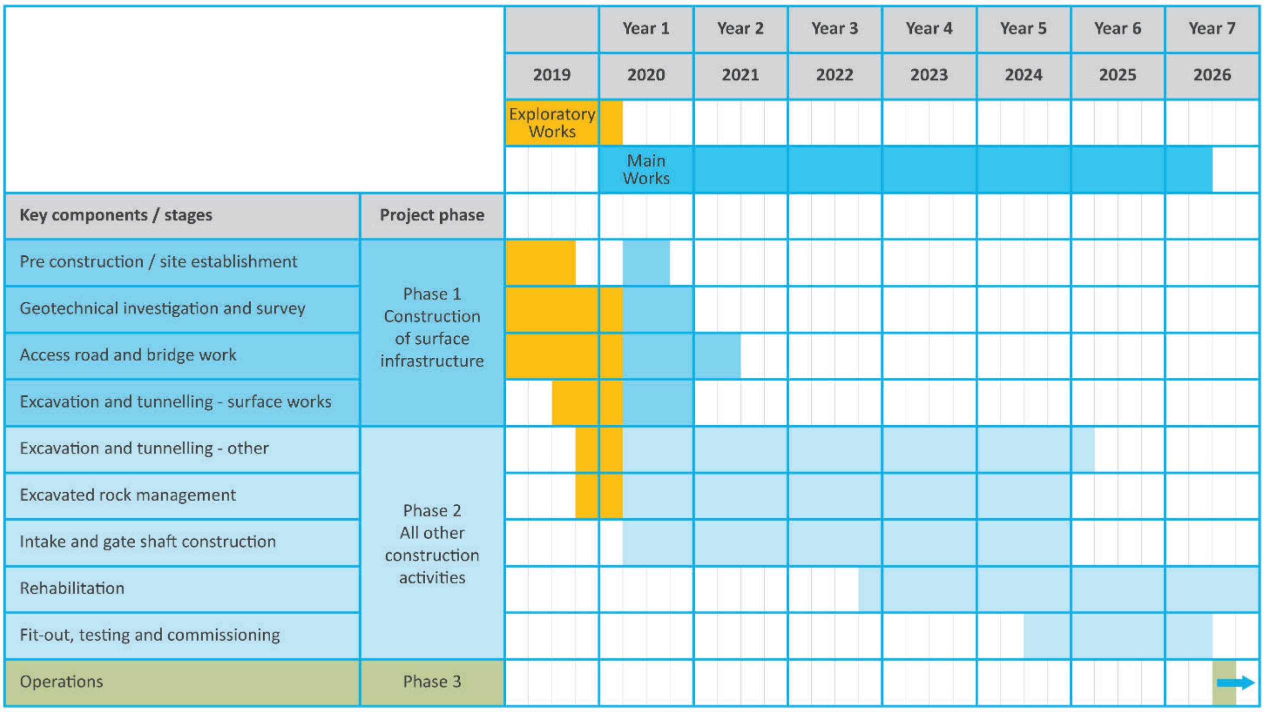


Figure 2.1 Snowy 2.0 Main Works – construction staging for key project components/phases

2.2.3 Concept design information

The following concept design information is referenced in this report:

- Disturbance area – describes the maximum extent of surface disturbance. The actual disturbance footprint is expected to be less than the disturbance area.
- Conceptual layout – describes the possible location and footprint of temporary and permanent infrastructure. The conceptual layout will be refined at detailed design but will be within the disturbance area.
- Water management system – a description of the proposed water management approach, proposed water demand and indicative controlled discharge locations.
- Rehabilitation strategy – a description of the proposed location and treatment for rehabilitation of disturbed land.

2.3 Water cycle interfaces

This section conceptually describes project interfaces with the water cycle (ie both groundwater and surface water) during the construction and operational project phases. This water management report provides detailed information on the location and mechanism (for example discharge) of each interface with the surface water environment. Residual impacts are described in Chapter 8.

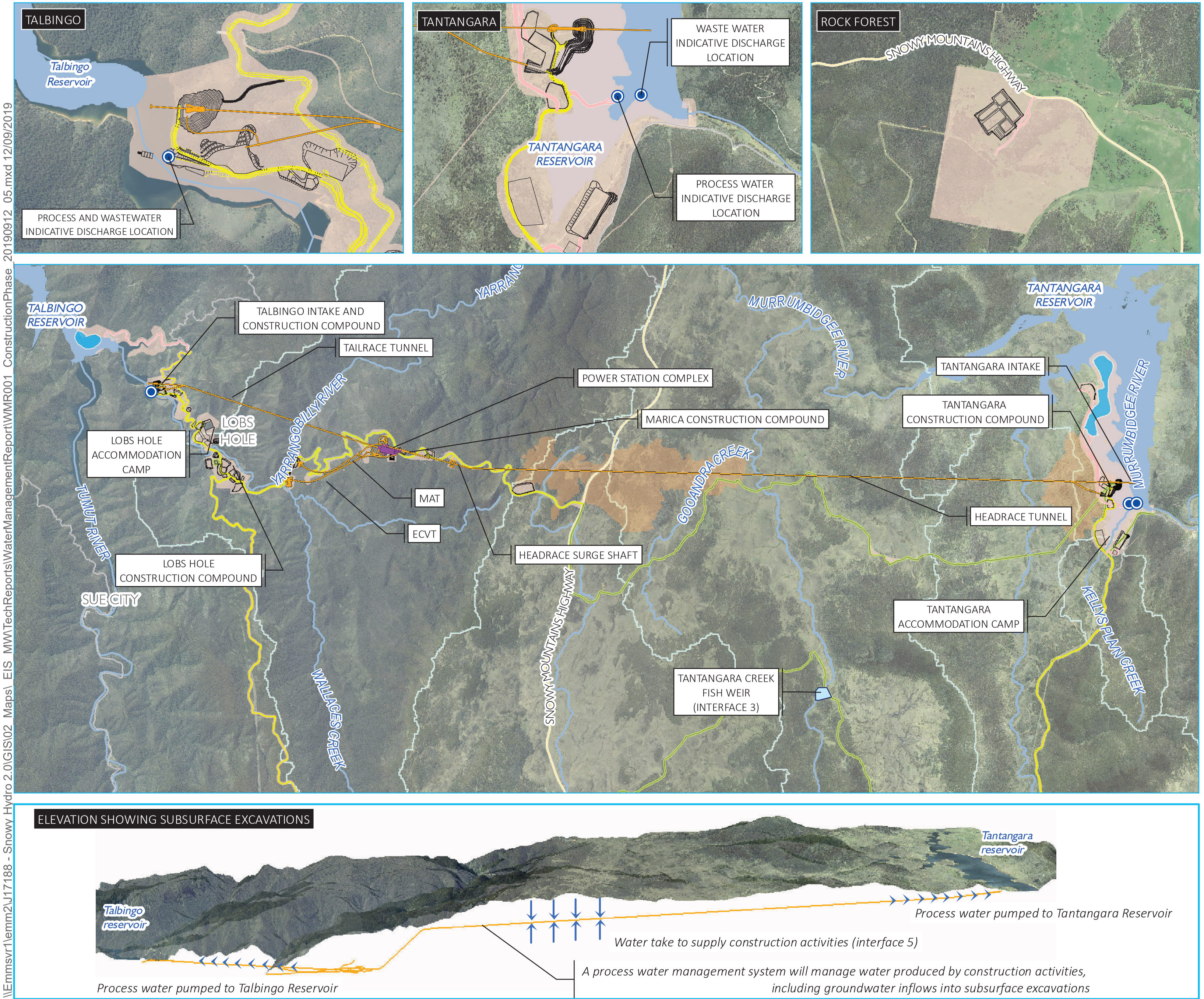
2.3.1 Construction phase

Table 2.2 describes the key water cycle interfaces during the construction phase of the project. Information on the interface locations and mechanisms is also provided. Figure 2.2 shows the location of interfaces relative to the conceptual project layout.

Table 2.2 Water cycle interfaces – construction phase

Interface	Mechanisms	Locations
1 – Impacts to groundwater and connected surface water systems due to subsurface excavations	• Impacts to the shallow groundwater system due to groundwater inflows into subsurface excavations.	• Some areas in the plateau
2 – Stormwater discharges	• Stormwater discharges from areas disturbed by construction of surface works (ie construction phase 1 • Stormwater discharges from surface infrastructure that will support broader construction activities (ie construction phase 2)	• All watercourses downstream of disturbance areas • Talbingo and Tantangara reservoirs
3 – Instream works and disturbance of waterfront land	• Watercourse diversions • Fish weir • Watercourse crossings (ie bridges and culverts) • Works within 40 m of a watercourse	• Some watercourses that are in proximity to the disturbance boundary
4 – Excavated rock placement	• Runoff and seepage from spoil placements into Talbingo and Tantangara reservoirs	• Talbingo and Tantangara reservoirs
5 – Water take to supply construction activities	• Potable water supply • Water supply to construction activities	• Talbingo and Tantangara reservoirs • Groundwater resources
6 – Controlled discharges to reservoirs	• Discharges of treated wastewater (ie sewage) • Discharges of treated process or tunnel affected water	• Talbingo and Tantangara reservoirs

Management measures and residual impacts associated with interfaces 2, 3, 5 and 6 are addressed in this report. Groundwater impacts (interface 1) and excavated rock placement (interface 4) are addressed in the water assessment.



Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

KEY

Water cycle interfaces
- Approximate groundwater drawdown extent (interface 1)
- Project disturbance area (including interfaces 2 & 3)
- Excavated rock emplacement (interface 4)
- Reservoir discharge locations (interface 6)

Existing environment
- Main road
- Local road
- Watercourse
- Regional catchment divide
- Reservoir

Snowy 2.0 Main Works operational elements
- Tunnels, portals, intakes, shafts
- Power station
- Utilities
- Permanent road

Snowy 2.0 Main Works construction elements
- Temporary construction compounds and surface works
- Temporary access road

Water cycle interfaces (construction)
1 - Impacts to groundwater and connected surface water systems due to subsurface excavations
2 - Stormwater discharges
3 - Instream works and disturbance of waterfront land
4 - Excavated rock emplacement
5 - Water take to supply construction activities
6 - Controlled discharges to reservoirs

Water cycle interfaces - construction phase

Snowy 2.0
Water Management Report
Main Works
Figure 2.2

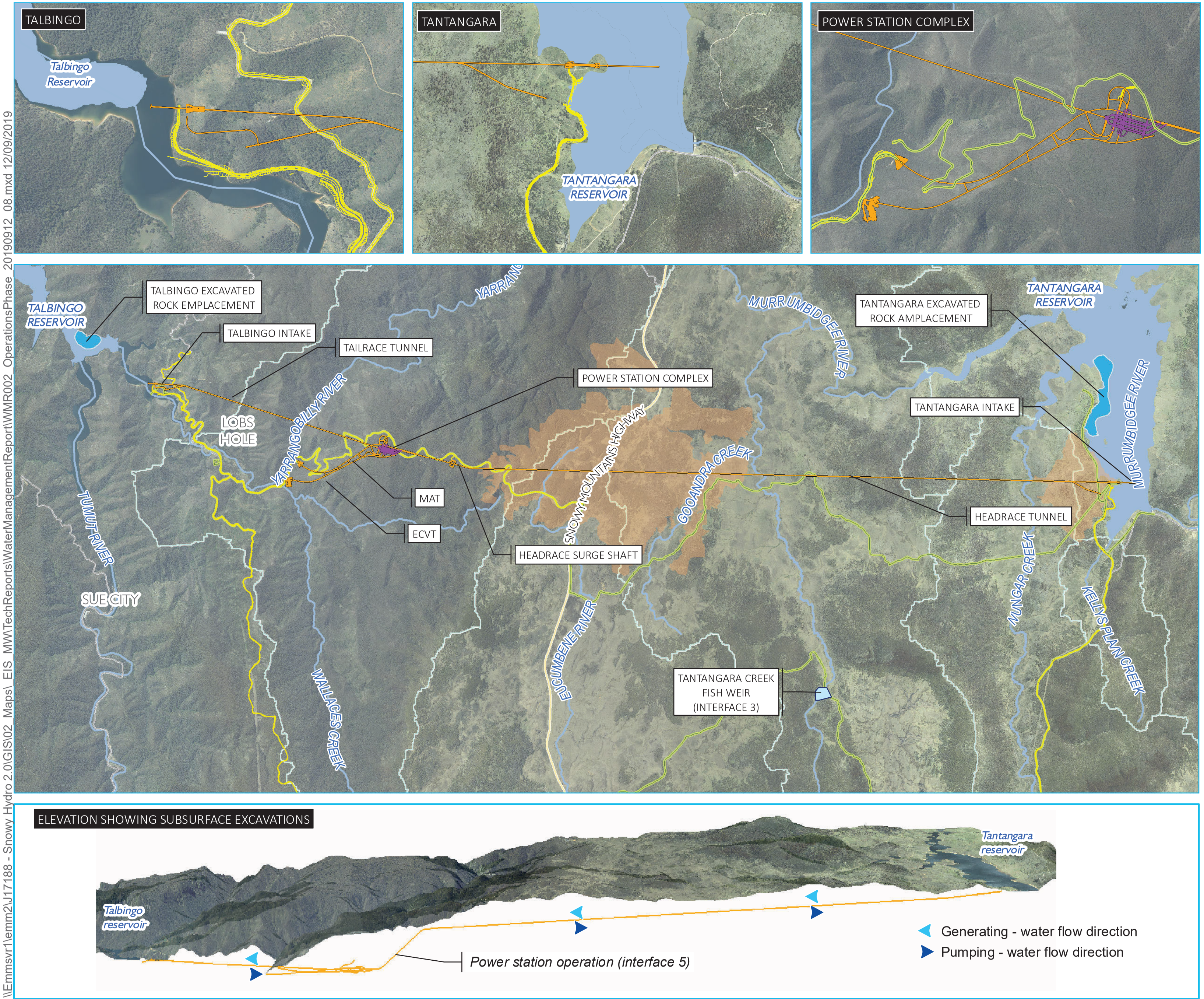
2.3.3 Operational phase

Table 2.3 describes the key water cycle interfaces during the operational phase of the project. Information on the interface locations and mechanisms is also provided. Figure 2.3 shows the location of interfaces relative to the conceptual layout of permanent infrastructure.

Table 2.3 Water cycle interfaces – operational phase

Interface	Mechanisms	Locations
1 – Groundwater inflow to subsurface excavations	• Drawdown in the watertable due to groundwater inflows into subsurface excavations • Reduced groundwater available for baseflow to surface water streams in areas of watertable drawdown	• Some localised areas in the plateau
2 – Stormwater discharges	• Stormwater discharges from permanent infrastructure (ie access roads and tunnel portals)	• All watercourses downstream of permanent infrastructure • Talbingo and Tantangara reservoirs
3 – Instream works and disturbance of waterfront land	• Permanent watercourse diversions • Fish weir • Permanent watercourse crossings (ie bridges and culverts) • Permanent works within 40 m of a watercourse	• Some watercourses that are in proximity to the disturbance boundary
4 – Excavated rock placement	• Runoff and seepage from spoil placements into Talbingo and Tantangara reservoirs	• Talbingo and Tantangara reservoirs
5 – Power station operation	• Water exchange between Talbingo and Tantangara reservoirs	• Talbingo and Tantangara reservoirs

Management measures and residual impacts associated with interfaces 2 and 3. Groundwater changes (interface 1), excavated rock placement (interface 4) and power station operation (interface 5) are addressed in the water assessment.



Source: EMM (2019); Snowy Hydro (2019); DFSI (2017); LPMA (2011)

KEY

Water cycle interfaces
- Approximate groundwater drawdown extent (interface 1)
- Excavated rock emplacement (interface 4)

Existing environment
- Main road
- Local road
- Watercourse
- Regional catchment divide
- Reservoir

Snowy 2.0 Main Works operational elements (interface 2)
- Tunnels, portals, intakes, shafts
- Power station
- Utilities
- Permanent road

Water cycle interfaces (operation)
1 - Impacts to groundwater and connected surface water systems due to subsurface excavations
2 - Stormwater discharges
3 - Instream works and disturbance of waterfront land
4 - Excavated rock emplacement
5 - Power station operation

Water cycle interfaces - operations phase

Snowy 2.0
Water Management Report
Main Works
Figure 2.3

snowy2.0
EMM creating opportunities

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2.4 Water management terminology

2.4.1 Terminology

Table 2.4 describes key terminology used in the report to describe the water management system. Broader terminology is provided in the glossary.

Table 2.4 Key terminology

Term	Description
Controlled discharge	Water management system discharges that occur via a controlled process
Clean water	Surface water runoff from catchments that are undisturbed or rehabilitated following disturbance
Discharge	A general term that refers to all discharge mechanisms
Discharge via overflow	Water management system discharges that occur via overflow from water management basin
Discharge via runoff	Water management system discharges that occur due to stormwater runoff from a water management area
Potable water	Water that has been treated to a potable water standard
Process water	Water that will be produced by or used by the proposed construction activities
Stormwater	Surface water runoff from areas disturbed by the Main Works
Receiving water	Any watercourse or waterbody that receives discharge from the water management system
Wastewater	Wastewater (or sewage) generated from the accommodation camp and other amenities
Water management category	A term used to describe a unique aspect of the water management system

2.4.2 Water management categories

For each project phase, the water management approach and discharge characteristics will vary based on the type of disturbance, construction activities and environmental factors such as topography. Receiving water impacts will vary based on discharge characteristics and the location, area and duration of disturbance.

Project level stormwater water management categories have been established to describe each unique aspect of the proposed water management system. For each category the following information is provided in this report:

- a description of the disturbance area and duration;
- proposed management measures; and
- proposed discharge characteristics, including volume, frequency and water quality.

Table 2.5 describes water management categories and provides a section reference to where each category is discussed further in this report.

Table 2.5 Water management categories

Category ID	Category name	Description	Section reference
WM 1 – Construction phase 1 – construction of surface infrastructure			
WM 1.1	Clean water management	Refers to the management of runoff from clean water catchments that traverse surface construction disturbance areas.	Section 3.3.2
WM 1.2	Minor works	Refers to the management of runoff from areas disturbed by the construction of roads, service trenches and minor works. These construction activities will typically disturb only a small portion of catchment areas to immediate receiving watercourses for a short period of time (typically less than 3 months). Construction will often occur in areas that are constrained by steep terrain and environmental and geotechnical constraints.	Section 3.3.3
WM 1.3	Major works	Refers to the management of runoff from areas disturbed by the construction of tunnel portals, construction pads, accommodation camps and other major surface works. These construction activities will typically require large scale clearing, earthworks and other construction activities and in some locations will disturb a material portion of a catchment area to an immediate receiving watercourse.	Section 3.3.4
WM 1.4	Water supply system	Refers to a system that will supply water to the project.	Section 6.1
WM 2 – Construction phase 2 – all other construction activities			
WM 2.1	Temporary watercourse diversions	Refers to temporary clean water diversions around temporary surface infrastructure.	Section 3.4.2
WM 2.2	Accommodation camps	Refers to the management of runoff from accommodation camp facilities once operational. Accommodation camps will comprise road and carparks and other hardstand areas, buildings and landscaped areas.	Section 3.4.3
WM 2.3	Construction pads	Refers to the management of runoff from construction pads and tunnel portals during their use to support broader construction activities. These areas will facilitate a range of activities including equipment assembly, material handling, concrete batching, fuel storage and refuelling and workshops.	Section 3.4.4
WM 2.4	Access roads	Refers to the management of runoff from access roads during their use to support broader construction activities.	Section 0
WM 2.5	Large temporary stockpiles	Refers to the management of runoff and seepage from large temporary stockpiles of material produced by earthworks (ie road cuttings, topsoil stockpiling).	Section 3.4.6
WM 2.6	Large surface excavations	Refers to the management of water pumped from the sumps of large surface excavations (ie excavations of the headrace and tailrace intakes).	Section 3.4.7
WM 2.7	Process water	Refers to the process water system, which will manage water produced by and used by construction activities.	Chapter 4
WM 2.8	Potable water	Refers to the potable water supply system.	Section 5.2
WM 2.9	Wastewater	Refers to the management of wastewater (ie sewage) produced from accommodation camps and other facilities that have amenities.	Section 5.3
WM 2.10	Tunnel inflows	Refers to the management of groundwater during excavation to maintain tunnel stability and reduce groundwater inflows.	Section 7.2

Table 2.5 Water management categories

Category ID	Category name	Description	Section reference
WM 3 – operational phase (phase 3)			
WM 3.1	Permanent watercourse diversions	Refers to permanent clean water diversions and the re-establishment of watercourses following disturbance.	Section 3.5.1
WM 3.2	Permanent surface infrastructure	Refers to the management of runoff from permanent surface infrastructure, such as tunnel portals and substations.	Section3.5.2
WM 3.3	Permanent access roads	Refers to the management of runoff from permanent access roads.	Section 3.5.3
WM 3.4	Tailrace tunnel dewatering	Refers to the management of water pumped from the tailrace tunnel to enable maintenance access.	Section 7.3
WM 3.5	Management of groundwater inflows	Refers to the management of groundwater inflows into the power station cavern, access tunnels and any other excavation that will not be flooded	Section 6.4

2.5 Relevant guidelines

The following guidelines are referenced in this report.

2.5.1 Australian Rainfall and Runoff

Australian Rainfall and Runoff (Ball et al 2019) 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 ARR2019 in the remainder of this document.

2.5.2 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 2A – Installation of services* (DECC 2008); and
- *Managing Urban Stormwater: Soils and Construction – Volume 2C – Unsealed roads* (DECC 2008).

3 Stormwater

3.1 Overview

This chapter describes the stormwater management approach and discharge characteristics for the construction and operational phases of Snowy 2.0 Main Works. The stormwater management approach is described separately for the three project phases established in Section 2.2.1. For each phase, the stormwater management approach and discharge characteristics vary based on the type of disturbance, construction activities and environmental factors such as topography. Receiving water impacts vary based on discharge characteristics and the location, area and duration of disturbance.

Project level stormwater management categories that are established in Section 2.4 describe each unique aspect of the proposed stormwater system. For each stormwater category the following information is provided in this chapter:

- a description of the disturbance area and duration;
- proposed management measures; and
- proposed discharge characteristics.

Section 3.2 describes information from this chapter that has been applied to the assessment of residual impacts (Chapter 8). The water management approach for the construction phase 1, construction phase 2 and the operational phase is described in Sections 3.3 to 3.5.

3.2 Information applied to residual impacts assessment

The residual impacts of stormwater discharges are described in Chapter 8. The following information presented in this chapter has been applied to assess residual impacts:

- Disturbance profiles – refers to the area and duration of disturbance applicable to each stormwater management category.
- Discharge characteristics – refers to the discharge regimes and water quality from each stormwater management category.

The following sections describe the approach and assumptions applied to establishing this information.

3.2.1 Disturbance profiles

The area and duration of disturbance for each stormwater management category has been established based on the disturbance area, conceptual layout and project schedule (as described in Section 2.2). This spatial and temporal information is presented for the following catchments:

- Yarrangobilly River catchment – includes proposed surface works at Lobs Hole and Marica;
- Upper Eucumbene River catchment – includes proposed surface works between Marica and the Snowy Mountains Highway that are within the Eucumbene River catchment;
- Tantangara construction compound – includes proposed surface works adjacent to the southern portion of Tantangara Reservoir; and

- Other areas – all disturbance areas that are outside the above catchments.

Attachment A provides a break-down of disturbances areas and durations within the above catchment areas for each stormwater management category.

3.2.2 Characterising discharge

Discharge characteristics (volume and quality) will be a function of many factors including soil characteristics, constructed surfaces, construction activities, weather and the water management system. Table 3.1 provides a summary of available information and describes the approach applied to accounting for each factor when characterising discharge.

Table 3.1 Factors that will influence discharge characteristics

Factor	Available information	Approach to characterising discharges
Soil characteristics	• The Soils and Land Assessment (Appendix N.2 to the EIS) describes soils within the project area. The description is based on desk top analysis, site observations and soil sampling undertaken for the Exploratory Works EIS. • Water quality characteristics of runoff from existing disturbed areas[1] such as access tracks in Lobs Hole (WCR Section 7.3.3).	The Soils and Land Assessment (Appendix N.2 to the EIS) describes soils within the project area as likely to have low to moderate erodibility, with some localised areas of highly erodible and dispersive soils. It is noted that limited soil sampling was undertaken in Lobs Hole and no sampling has been undertaken in other project areas (mainly to minimise soil disturbance within KNP). The runoff water quality from existing disturbed areas[1] in Lobs Hole is characterised as being mildly acidic and having elevated turbidity and concentrations of suspended solids and nutrients. Samples from some locations contained concentrations of aluminium and copper that exceed WQO values by one to two orders of magnitude (WCR Section 7.3.3). These results, while not necessarily representative of runoff from construction disturbance areas, indicate that poorer water quality can be expected from some soils that are disturbed by construction activities. The spatial variability of higher risk soils and the effectiveness of the proposed stormwater management measures to manage risks is poorly understood. Hence, a conservative approach has been applied to establishing discharge characteristics for use in the residual impact assessment.
Constructed surfaces	• Concept design	The concept design includes indicative extents of constructed surfaces such as roads, batters and hardstands. This information has been applied to establish a hydrologic category and inform a water quality profile for each stormwater management category.
Construction activities	• Concept design	The concept design includes information on proposed construction activities that are expected to occur in different areas of Main Works. This information has been used to inform a water quality profile for each stormwater management category.
Weather	• Data from regional weather stations (WCR Chapter 4). • Data from online databases (WCR Chapter 4).	The spatial and temporal variation in weather characteristics across the project area is well understood. Data from regional gauges and online databases (ie SILO and ARR data hub) have been applied to establish discharge regimes for each stormwater management category (across the project area) and assess residual impacts.
Water management system	• Water management measures were developed as part of the concept design.	The concept design includes information on proposed stormwater management measures. The following approach has been applied to account for water management system benefits when establishing discharge characteristics: • stormwater capture in basins and subsequent harvesting and treatment is accounted for when characterising discharge regimes; and • the water quality benefits of proposed measures have been estimated based on the expected untreated water quality profile and the physical and chemical processes provided by the stormwater controls.

Notes: 1. The term 'existing disturbed areas' refers to areas such as access roads that were constructed/disturbed prior to activities associated with the project.

Project level discharge characteristics have been estimated for each water management category using available information. The following information is provided for each category (Sections 3.3 to 3.5):

- Discharge regimes are described with reference to expected constructed surfaces, weather and proposed stormwater management measures.
- Discharge water quality characteristics are described using available information and typical values. The characteristics are presented as:
  - Likely ranges – describes the likely water quality range for each category.
  - Value applied to the residual impact assessment – considers the likely range and potential spatial variability of factors that influence water quality. These values represent a conservative estimate of typical or median discharge water quality from a project level water management category.
- Contributing factors, assumptions and associated limitation are noted for each category.

3.3 Stormwater management – construction phase 1

3.3.1 Overview

Four water management categories were established in Table 2.5 to describe water management for construction phase 1. The following sections describe proposed management measures and discharge characteristics (where relevant) for:

- WM 1.1 – clean water management;
- WM 1.2 – minor works; and
- WM 1.3 – major works.

The water supply system (WM 1.4) is described in Section 6.1.

Phase 1 stormwater management concept figures are provided at the end of this section. The figures show the disturbance area, conceptual layout and approximate extents of WM 1.2 and WM 1.3. The following figures are provided:

- Lobs Hole – Figure 3.1;
- Marica – Figure 3.2; and
- Tantangara –Figure 3.3.

3.3.2 Management approach – WM 1.1 clean water

i Overview

As described in Table 2.5, the following water management categories describe clean water management:

- WM 1.1 describes the management approach for runoff from clean water catchments that traverse surface construction disturbance areas;

- WM 2.1 describes the management approach for temporary watercourse diversions around temporary surface infrastructure; and
- WM 3.1 describes the management approach for permanent watercourse diversions and the re-establishment of watercourses following disturbance.

This section describes WM 1.1.

ii Water management risks

Risks associated with the management of clean water around construction disturbance areas include:

- potential for clean water runoff to enter disturbance areas resulting in an increase to the volume of water that requires management and reduced effectiveness of management measures;
- potential for changes and increased flow to adjoining watercourses if diversion works increase an effective catchment area to an adjoining watercourse; and
- potential for erosion at the upstream and downstream interfaces of diversion works with undisturbed watercourses.

iii Mitigation and management

Where practical, clean water will be diverted around or through construction disturbance areas. The most appropriate design for each diversion system will be established on a case-by-case basis. Table 3.2 describes proposed management measures (or design principles) for clean water management.

Table 3.2 Proposed management measures: WM 1.1 – clean water management

Measure[1]	Description
WM 1.1.1	Where practical, clean water will be diverted around or through construction areas. Runoff from clean water areas that cannot be diverted will be accounted for in the design of water management systems. Temporary clean water drainage will be designed to have non-erosive hydraulic capacity. The design event will be established based on disturbance duration and other relevant factors.
WM 1.1.2	Where practical, clean water diversions will seek to avoid increasing flow rates in adjoining watercourses.

Notes: 1. The management measures presented are principles or design objectives, that will be further developed in the detailed design of Main Works. The measures implemented may vary from those presented but will meet the proposed discharge characteristics or other stated objectives.

3.3.3 Management approach – WM 1.2 minor works

i Overview

As described in Table 2.5, WM 1.2 (minor works) refers to the management of runoff from areas disturbed by the construction of roads, service trenches and minor works. These construction activities will typically disturb only a small portion of catchment areas to immediate receiving watercourses for a short period of time (typically less than 3 months). Construction will often occur in areas that are constrained by steep terrain and environmental and geotechnical constraints.

ii Water management risks

The construction of minor surface works will require clearing of vegetation, earthworks, drill and blasting in select areas and other construction activities. Key water management risks include:

- sedimentation in receiving waters due to runoff from construction areas laden with coarse sediment;
- discharge of runoff laden with fine and/or dispersive material that will not readily settle under gravity in receiving waters;
- other changes to water chemistry associated with stormwater contact with disturbed soils and/or construction materials; and
- accidental leaks and spills.

iii Mitigation and management

The following mitigation and management measures are proposed:

- drainage controls to minimise slope lengths and divert clean water around or through disturbance areas;
- source controls to:
    - reduce soil loss rates and capture coarse sediment; and
    - manage risks associated with storing and handling chemicals that have potential to pollute receiving waters;
- where possible managing works to minimise the area disturbed at any given time; and
- progressive rehabilitation to minimise the duration of disturbance and the area disturbed at any given time.

Table 3.3 describes proposed management measures (or design principles).

Table 3.3 Proposed management measures: WM 1.2 – minor works

Measure[1]	Description
WM 1.2.1	An Erosion and Sediment Control Plan (ESCP) will be prepared for each construction area. Each ESCP will: • apply the methods and principles provided in *Managing Urban Stormwater: Soils and Construction:* – *Volume 1 – Soils and construction* (Landcom 2004); and/or – *Volume 2A – Installation of services* (DECC 2008); and/or – *Volume 2C – Unsealed roads* (DECC 2008); unless stated below; • consider local soil characteristics, topography and environmental constraints and proposed construction methods; • apply clean water management controls as per: – WM 1.1 for clean water management during surface construction disturbance; – WM 2.1 for temporary watercourse diversions around temporary surface infrastructure; and – WM 3.1 for permanent watercourse diversions. • all temporary drainage and sediment control measures will be designed to have non-erosive hydraulic capacity and be structurally sound for a design event. The design event will be established based on the disturbance duration and other relevant factors; • consider all practical erosion control and rehabilitation methods and apply the most appropriate method; • consider all practical methods to stabilise small temporary stockpiles and apply the most appropriate method. Apply management controls as per WM 2.5 for the management of large temporary stockpiles; • apply enhanced erosion controls where significant risks are identified; and • be progressively amended as required during construction.
WM 1.2.2	The following will be implemented: • measures to manage the storage and handling of hydrocarbons and other chemicals that have potential to pollute receiving waters; and • measures to manage accidental leaks and spills.
WM 1.2.3	Suitably qualified erosion and sediment control professional(s) will be commissioned to: • oversee the development of ESCPs; • inspect and audit controls; • train relevant staff; and • progressively improve methods and standards as required.

Notes: 1. The management measures presented are principles or design objectives, that will be further developed in the detailed design of Main Works. The measures implemented may vary from those presented but will meet the proposed discharge characteristics or other stated objectives.

iv Discharge characteristics

The following sections provide a summary of expected discharge regimes and water quality characteristics. Discharge characteristics for each stormwater management category have been applied to assess residual impacts in Chapter 8.

a Discharge regimes

Table 3.4 describes expected discharge regimes and notes contributing factors. Refer to table notes for assumptions and terminology clarifications.

Table 3.4 Discharge regimes: WM 1.2 – minor works

Aspect		Description
Contributing factors	As described in Table 3.1	Soil characteristics, weather characteristics, water management system.
Functionality	Basins	No basins are proposed for the minor works category due to topography and environmental constraints.
	Water harvesting	No water harvesting is proposed as no runoff will be captured.
	Discharge mechanism	Runoff from the water management area.
Runoff characteristics	Catchment characteristics	Primarily cleared land with exposed soils and bedrock.
	Hydrologic category[2]	Type C – moderate to high runoff potential.
	Runoff volumes[3]	Annualised runoff volumes are expected to be approximately 40% of rainfall.
Water harvesting	Water harvesting volume	nil
	Reduction in discharge volumes	nil
Discharge regime	Discharge frequency[3]	Following any material rainfall[1] – approximately 50 days per year.
	Discharge volumes[3]	As per runoff volumes.

Notes: 1. Material rainfall refers to 5 mm or more in a day.

2. Refers to the Soil Hydrologic Group referenced in Appendix F of *Managing Urban Stormwater: Soils and Construction – Volume 1* (Landcom 2004).

3. Calculated using the stormwater discharge model (described in Attachment D) that was parameterised to achieve event-based runoff coefficients that are similar to the specified hydrologic category (note 2).

b Discharge quality

Table 3.5 describes the expected discharge quality characteristics and notes contributing factors and limitations. Refer to table notes for assumptions and terminology clarifications.

Table 3.5 Discharge quality characteristics: WM 1.2 – minor works

Analyte	Units	WQO value	Discharge characteristics		Comments
			Likely range[1]	Value applied to RIA[2]	
Contributing factors – soil characteristics and water management system.					
Limitations – the spatial variation of soil characteristics and associated water management risks are poorly understood.					
Discharge mechanism – discharge via runoff					
pH	-	6.5–8.0	4.0–8.0	5.0	Mildly acidic runoff may occur in areas that have naturally acidic soils. No pH adjustment is proposed.
Turbidity	NTU	2–25	200–1000	250	Elevated turbidity and suspended solids are expected to occur in areas that have highly erodible and/or dispersive soils.
Suspended sediment	mg/L	-	25–300	50	Proposed controls are expected to effectively manage coarse sediment.

Table 3.5 Discharge quality characteristics: WM 1.2 – minor works

Analyte	Units	WQO value	Discharge characteristics		Comments
			Likely range[1]	Value applied to RIA[2]	
Hydrocarbons	mg/L	-	No visible oil and grease		Appropriate storage and handling of hydrocarbons and management of leaks and spills is expected to minimise the risk of hydrocarbon contamination in discharge.
Total nitrogen	mg-N/L	0.25	0.1–5.0	1.0	If total nitrogen is elevated it is expected to be primarily in organic form (ie total kjeldahl nitrogen (TKN)). Organic nitrogen is less bioavailable than inorganic forms of nitrogen (oxidised nitrogen and ammonia).
Total phosphorus	mg-P/L	0.02	0.01–1.00	0.2	If total phosphorous is elevated it is expected to be primarily in non-reactive form. Non-reactive phosphorus is less bioavailable than reactive forms.
Aluminium	mg/L	0.027[3]	0–100 x WQO value[4,5]	20 x WQO value[4,5]	Some soils and geology within the project area are known to have naturally high concentrations of aluminium and copper. This can unavoidably result in elevated concentrations of aluminium and copper in stormwater that contacts disturbed soils. Erosion controls that minimise soil loss rates are expected to provide some mitigation relative to runoff from disturbed areas that have no controls.
Copper	mg/L	0.001[3]	0–500 x WQO value[4,5]	10 x WQO value[4,5]	
Other metals and toxicants	mg/L	Note 3	WQO values occasionally exceeded[3]	< WQO values[3]	Some metals such as iron and zinc are expected to occasionally exceed WQO values. However, typical or median concentrations are expected to be less than WQO values.

Notes: 1. Likely range refers to the estimated range of concentrations that could occur from the project level water management category during typical discharge conditions. The range and values were established based on a review of available data and the effectiveness of the proposed controls and considers the spatial variability of contributing factors, such as soil characteristics.

2. RIA refers to residual impact assessment. RIA values have been established qualitatively considering available data and the spatial variability in soil conditions. The value represents a conservative estimate of typical or median values in discharge from a project level water management category.

3. Default trigger values for 99% level of species protection apply. Refer to the water assessment for WQOs.

4. Concentrations refer to laboratory analysis of a 0.45 µm field filtered sample. Some of the metal concentration may be mineral or organic bound and may have lower eco-toxicology risks than similar concentrations of dissolved metals.

5. Available information indicates that elevated copper concentrations are confined to the area around Lick Hole Gully (southern side of the Yarrangobilly River) and elevated aluminium is more widespread. However, this has not been verified and the distribution of soils with naturally high concentrations of aluminium and copper is poorly understood. The RIA values are conservative estimates given that all soils that will be disturbed are unlikely to have naturally high concentrations of aluminium and copper.

3.3.4 Management approach – WM 1.3 major works

i Overview

As described in Table 2.5, WM 1.3 (major works) refers to the management of runoff from areas disturbed by the construction of tunnel portals, construction pads, accommodation camps and other major surface works. These construction activities will typically require large scale clearing, earthworks and other construction activities and in some locations will disturb a material portion of a catchment area to an immediate receiving watercourse.

ii Water management risks

The construction of major surface works will require clearing of vegetation, earthworks, drill and blasting in select areas and other civil works such as concreting and service installations and construction of buildings. Key water management risks include:

- sedimentation in receiving waters due to runoff from disturbance areas laden with coarse sediment;
- discharge of runoff laden with fine and/or dispersive material that will not readily settle under gravity in receiving waters;
- other changes to water chemistry associated with stormwater contact with disturbed soils and/or construction materials; and
- accidental leaks and spills.

iii Mitigation and management

The following mitigation and management measures are proposed:

- drainage controls to minimise slope lengths and divert clean water around or through disturbance areas;
- source controls to:
  - reduce soil loss rates and capture coarse sediment; and
  - manage risks associated with storing and handling chemicals that have potential to pollute receiving waters;
- sedimentation basins to:
  - enable harvesting of captured water to reduce discharge volumes and frequency; and
  - provide sedimentation treatment during discharge (via overflow); and
- progressive rehabilitation to minimise the duration of disturbance and the area disturbed at any given time.

Table 3.6 describes proposed management measures (or design principles).

Table 3.6 Proposed management measures: WM 1.3 – major works

Measure[1]	Description
WM 1.3.1	An ESCP will be prepared for each construction area. Each ESCP will: • apply the methods and principles provided in *Managing Urban Stormwater: Soils and Construction:* – *Volume 1 – Soils and construction* (Landcom 2004); and/or – *Volume 2A – Installation of services* (DECC 2008); and/or – *Volume 2C – Unsealed roads* (DECC 2008); and unless stated below; • consider local soil characteristics, topography and environmental constraints and proposed construction methods; • apply clean water management controls as per: – WM 1.1 for clean water management during surface construction disturbance; – WM 2.1 for temporary watercourse diversions around temporary surface infrastructure; and – WM 3.1 for permanent watercourse diversions. • consider all practical source control and rehabilitation methods and apply the most appropriate methods; • consider all practical methods to stabilise small temporary stockpiles and apply the most appropriate method. Apply management controls as per WM 2.5 for the management of large temporary stockpiles; • all temporary drainage and sediment control measures will be designed to have non-erosive hydraulic capacity and be structurally sound for a design event. The design event will be established based on the disturbance duration and other relevant factors; • where practical, all runoff from disturbance areas will be directed to sedimentation basins designed to capture the 85th percentile 5-day rainfall event. Captured water will be harvested and used for dust suppression; and • be progressively amended as required during construction.
WM 1.3.2	The following will be implemented: • measures to manage the storage and handling of hydrocarbons and other chemicals that have potential to pollute receiving waters; and • measures to manage accidental leaks and spills.
WM 1.3.3	Suitably qualified erosion and sediment control professional(s) will be commissioned to: • oversee the development of ESCPs; • inspect and audit controls; • train relevant staff; and • progressively improve methods and standards as required.

Notes: 1. The management measures presented are principles or design objectives, that will be further developed in the detailed design of Main Works. The measures implemented may vary from those presented but will meet the proposed discharge characteristics or other stated objectives.

iv Discharge characteristics

The following sections provide a summary of expected discharge regimes and water quality characteristics.

a Discharge regimes

Table 3.7 describes discharge regimes and notes contributing factors. Refer to table notes for assumptions and terminology clarifications.

Table 3.7 Discharge regimes: WM 1.3 – major works

Aspect		Description
Contributing factors	As described in Table 3.1	Soil characteristics, weather characteristics, water management system.
Functionality	Basin volume	Sedimentation basins will be designed to capture the 85th percentile 5-day rainfall event.
	Water harvesting/ treatment	Water captured in basins will be used for dust suppression.
	Discharge mechanisms	Discharge via overflow or other outlet once the basin is full (for rainfall events greater than the 85th percentile 5-day rainfall event).
Runoff characteristics	Catchment characteristics	Primarily cleared land with exposed soils.
	Hydrologic category[2]	Type C – moderate to high runoff potential.
	Runoff volumes	Annualised runoff volumes are expected to be approximately 40% of rainfall.
Water harvesting/ treatment	Water harvesting/ treatment volume	Approximately 50% of runoff.
	Reduction in basin overflow volumes	Approximately 50% of runoff.
Discharge regime	Overflow frequency	Overflows will occur approximately 4-6 times per year[1] during and following intense or prolonged periods of wet weather.
	Overflow volumes[3]	Approximately 50% of runoff.

Notes: 1. Indicative average annual discharge frequency for an 85th percentile 5-day sedimentation basin provided in Table 6-2 from *Managing Urban Stormwater: Soils and Construction – Volume 2D – Main road construction* (DECC 2008).

2. Refers to the Soil Hydrologic Group referenced in Appendix F of *Managing Urban Stormwater: Soils and Construction – Volume 1* (Landcom 2004).

3. Calculated using the stormwater discharge model (described in Attachment D) that was parameterised to achieve event-based runoff coefficients that are similar to the specified hydrologic category (note 2).

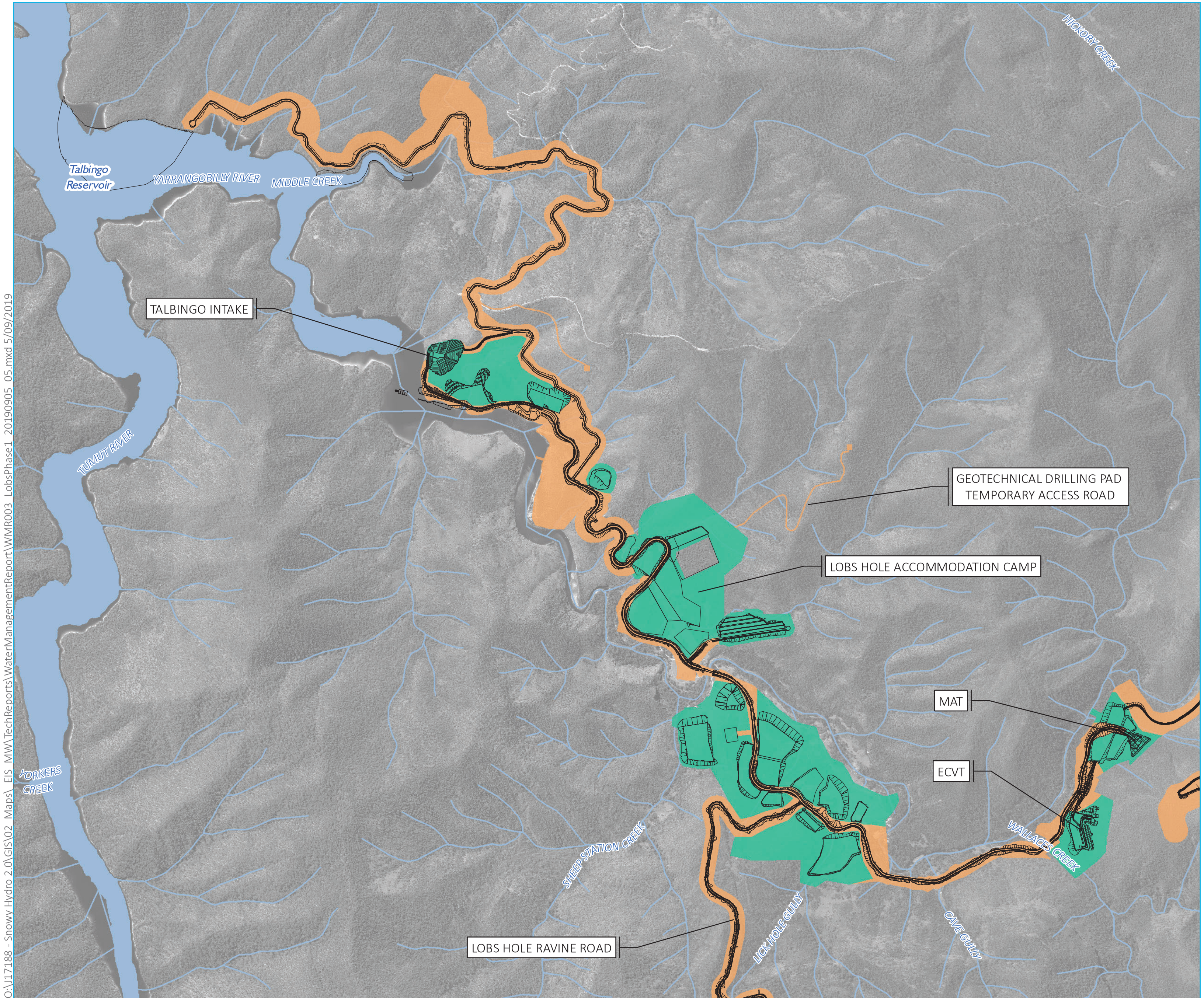
b Discharge quality

Table 3.8 describes the expected water quality characteristics of basin overflows and notes contributing factors and limitations. Refer to table notes for assumptions and terminology clarifications. As noted in Table 3.6, runoff captured in sedimentation basins that is treated prior to discharge is expected to have similar water quality to receiving waters in terms of pH and turbidity. Nutrients and metals may be elevated relative to WQOs but are expected to be lower than the values estimated for basin overflows (as described in Table 3.8) due to some beneficial treatment.

Table 3.8 Discharge quality characteristics: WM 1.3 – major works

Analyte	Units	WQO value	Discharge characteristics		Comments
			Likely range[1]	Value applied to RIA[2]	
Contributing factors – soil characteristics, construction activities and the water management system.					
Limitations – the spatial variation soil characteristics and associated water management risks are poorly understood.					
Discharge mechanism – applies to basin overflows (see Table 3.7).					
pH	-	6.5–8.0	4.0–8.0	5.0	Mildly acidic runoff may occur in areas that have naturally acidic soils. No pH adjustment is proposed.
Turbidity	NTU	2–25	200–1000	250	Elevated turbidity and suspended solids are expected to occur in areas that have highly erodible and/or dispersive soils.
Suspended sediment	mg/L	-	25–300	50	Proposed controls are expected to effectively manage coarse sediment.
Hydrocarbons	mg/L	-	No visible oil and grease		Appropriate storage and handling of hydrocarbons and management of leaks and spills is expected to minimise the risk of hydrocarbon contamination in receiving waters.
Total nitrogen	mg-N/L	0.25	0.1–5.0	1.0	If total nitrogen is elevated it is expected to be primarily in organic form (ie TKN). Organic nitrogen is less bioavailable than inorganic forms of nitrogen (oxidised nitrogen and ammonia).
Total phosphorus	mg-P/L	0.02	0.01–1.00	0.2	If total phosphorous is elevated it is expected to be primarily in non-reactive form. Non-reactive phosphorus is less bioavailable than reactive forms.
Aluminium	mg/L	0.027[3]	0–100 x WQO value[4,5]	20 x WQO value[4,5]	Some soils and geology within the project area are known to have naturally high concentrations of aluminium and copper. This can unavoidably result in elevated concentrations of aluminium and copper in stormwater that contacts disturbed soils. Source controls that minimise soil loss rates are expected to provide some mitigation relative to runoff from disturbed areas that have no controls.
Copper	mg/L	0.001[3]	0–500 x WQO value[4,5]	10 x WQO value[4,5]	
Other metals and toxicants	mg/L	Note 3	WQO values occasionally exceeded[4]	< WQO values[4]	Some metals such as iron and zinc are expected to occasionally exceed WQO values. However, typical or median concentrations are expected to be less than WQO values.

Notes:
1. Likely range refers to the estimated range of concentrations that could occur from the project level water management category during typical discharge conditions. The range and values were established based on a review of available data and the effectiveness of the proposed controls and considers the spatial variability of contributing factors, such as soil characteristics.
2. RIA refers to residual impact assessment. RIA values have been established qualitatively considering available data and the spatial variability in soil conditions. The value represents a conservative estimate of typical or median values in discharge from a project level water management category.
3. Default trigger values for 99% level of species protection apply. Refer to the water assessment for WQOs.
4. Concentrations refer to laboratory analysis of a 0.45 µm field filtered sample. Some of the metal concentration may be mineral or organic bound and may have lower eco-toxicology risks than similar concentrations of dissolved metals.
5. Available information indicates that elevated copper concentrations are confined to the area around Lick Hole Gully (southern side of the Yarrangobilly River) and elevated aluminium is more widespread. However, this has not been verified and the distribution of soils with naturally high concentrations of aluminium and copper is poorly understood. The RIA values are conservative estimates given that all soils that will be disturbed are unlikely to have naturally high concentrations of aluminium and copper.



Source: EMM (2019); DFSI (2017); GA (2011)

KEY

- Conceptual layout
- Watercourse
- Reservoir minimum operating level

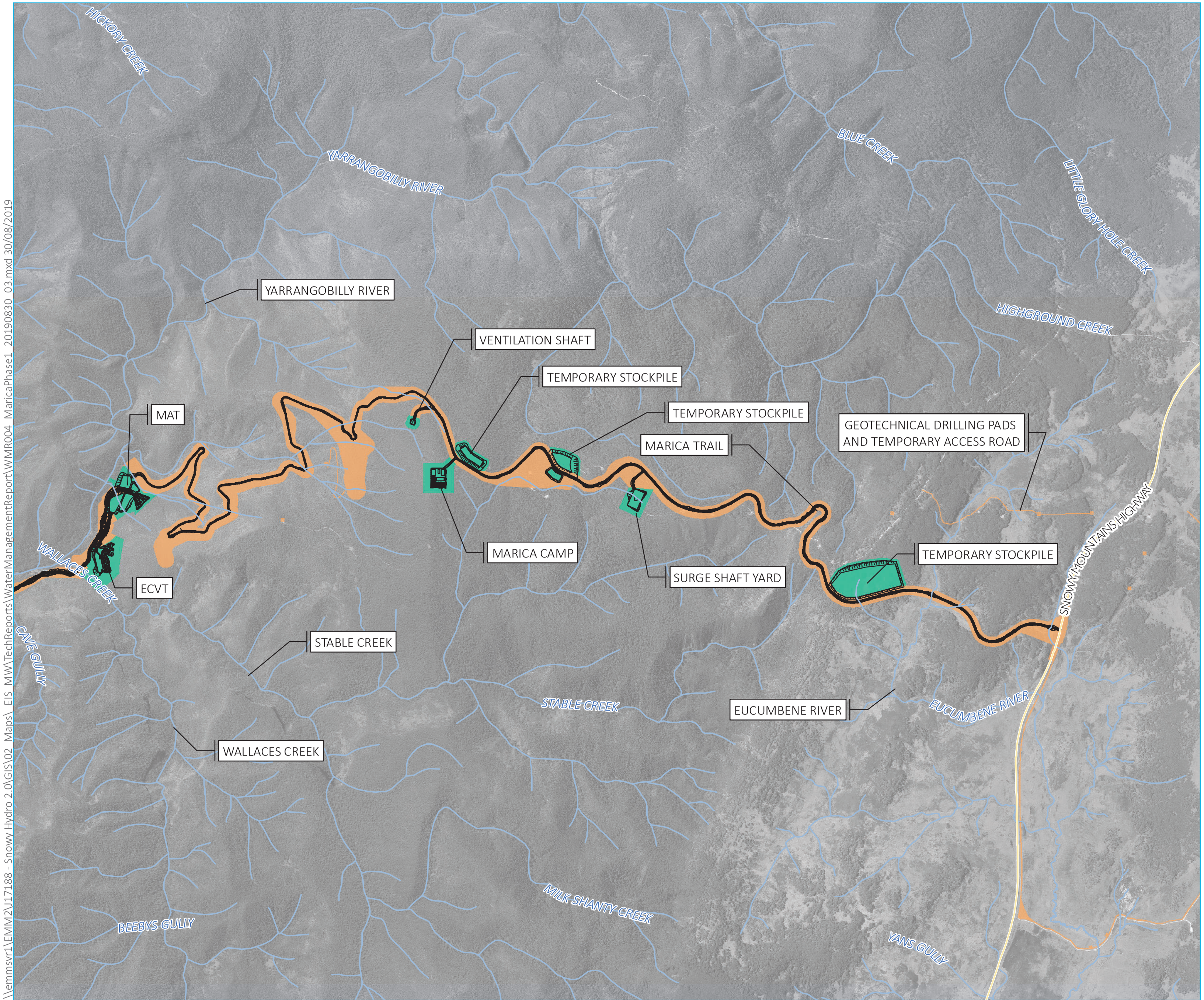
Water management categories

- WM 1.2 - Minor works
- WM 1.3 - Major works

Notes:
1) WM refers to water management category. Refer to the WMR for proposed management measures and discharge characteristics for each category.
2) The conceptual layout will be further developed at detailed design. The details may vary from those presented but will be within the disturbance boundary.
3) Any watercourses or waterfront land that is within the project boundary may be impacted. Refer to the relevant water management category for management measures for imapcted watercourses.
4) The disturbance area shows the maximum extent of surface disturbance. The actual footprint is expected to be less than the disturbance area. Water management measures are only required for areas that will be disturbed.
5) The extents of WM 1.2 and WM 1.3 are indicative and will be refined at detailed design in accordance with the descriptions provided in WMR Table 3.2.

Lobs Hole Phase 1 water management concept

Snowy 2.0
Water Management Report
Main Works
Figure 3.1



Source: EMM (2019); DFSI (2017); GA (2011)

KEY

- Conceptual layout
- Main road
- Watercourse

Water management categories

- WM 1.2 - Minor works
- WM 1.3 - Major works

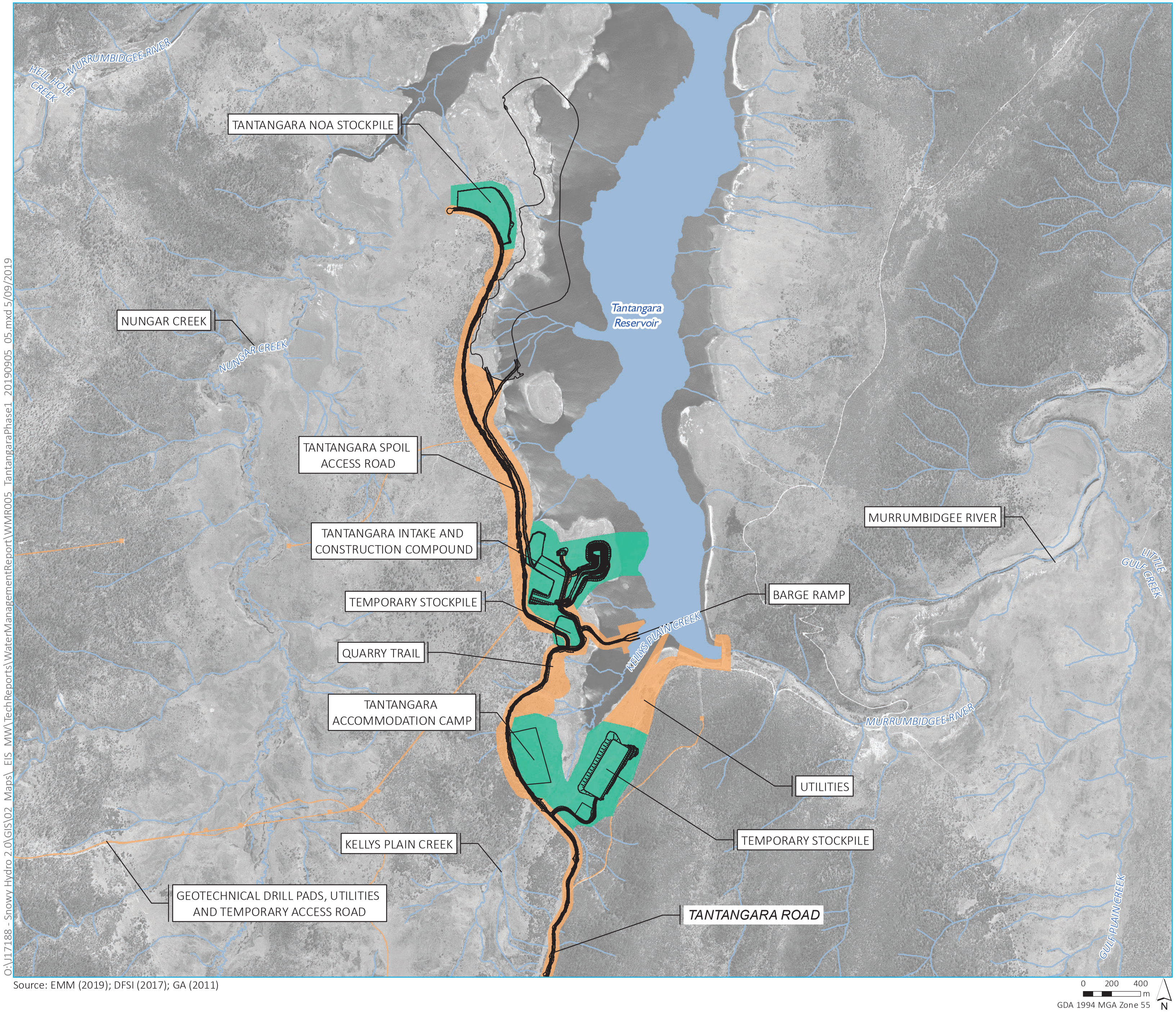
Notes:
1) WM refers to water management category. Refer to the WMR for proposed management measures and discharge characteristics for each category.
2) The conceptual layout will be further developed at detailed design. The details may vary from those presented but will be within the disturbance boundary.
3) Any watercourses or waterfront land that is within the project boundary may be impacted. Refer to the relevant water management category for management measures for imapcted watercourses.
4) The disturbance area shows the maximum extent of surface disturbance. The actual footprint is expected to be less than the disturbance area. Water management measures are only required for areas that will be disturbed.
5) The extents of WM 1.2 and WM 1.3 are indicative and will be refined at detailed design in accordance with the descriptions provided in WMR Table 3.2.

Marica Phase 1 water management concept

Snowy 2.0
Water Management Report
Main Works
Figure 3.2

snowy 2.0

EMM creating opportunities



Source: EMM (2019); DFSI (2017); GA (2011)

Notes:
1) WM refers to water management category. Refer to the WMR for proposed management measures and discharge characteristics for each category.
2) The conceptual layout will be further developed at detailed design. The details may vary from those presented but will be within the disturbance boundary.
3) Any watercourses or waterfront land that is within the project boundary may be impacted. Refer to the relevant water management category for management measures for imapcted watercourses.
4) The disturbance area shows the maximum extent of surface disturbance. The actual footprint is expected to be less than the disturbance area. Water management measures are only required for areas that will be disturbed.
5) The extents of WM 1.2 and WM 1.3 are indicative and will be refined at detailed design in accordance with the descriptions provided in WMR Table 3.2.

Tantangara Phase 1 water management concept

Snowy 2.0
Water Management Report
Main Works
Figure 3.3

3.4 Stormwater management – construction phase 2

3.4.1 Overview

Several water management categories are established in Table 2.5 to describe water management for construction phase 2. The following sections describe proposed management measures and discharge characteristics (where relevant) for:

- WM 2.1 – clean water management;
- WM 2.2 – accommodation camps;
- WM 2.3 – construction pads;
- WM 2.4 – access roads;
- WM 2.5 – large temporary stockpiles; and
- WM 2.6 – large surface excavations.

Process water management (WM 2.7) is described in Chapter 4 and potable (WM 2.8) and wastewater (WM 2.9) management are described in Chapter 5.

Construction phase 2 stormwater management concept figures are provided at the end of this section. The figures show the disturbance area, conceptual layout and applicable water management categories. The following figures are provided:

- Lobs Hole – Figure 3.4 to Figure 3.7;
- Marica – Figure 3.8 and Figure 3.9;
- Tantangara – Figure 3.10 and Figure 3.11; and
- Rock forest – Figure 3.12.

3.4.2 Management approach – WM 2.1 temporary watercourse diversions

i Overview

As described in Table 2.5, the following water management categories describe clean water management:

- WM 1.1 describes the management approach for runoff from clean water catchments that traverse surface construction disturbance areas;
- WM 2.1 describes the management approach for temporary watercourse diversions around temporary surface infrastructure; and
- WM 3.1 describes the management approach for permanent watercourse diversions and the re-establishment of watercourses following disturbance.

This section describes WM 2.1.

ii Water management risks

Risks associated with the temporary diversion of watercourses around or through temporary surface works include:

- potential for damage or failure of road embankments and other infrastructure;
- potential for clean water to enter a water management system resulting in an increase in the volume of water that requires management and reduced effectiveness of management measures;
- potential for impacts to adjoining watercourses if diversion works increase an effective catchment area to an adjoining watercourse; and
- potential for erosion at the upstream and downstream interfaces of diversion works with undisturbed watercourses.

iii Mitigation and management

Temporary watercourse diversions will be required for some watercourses within the project disturbance area that may be impacted by the project. The most appropriate design for each diversion will be established on a case-by-case basis. Table 3.9 describes proposed management measures (or design principles) that will be applied.

Table 3.9 Proposed management measures: WM 2.1 – temporary watercourse diversions

Measure[1]	Description
WM 2.1.1	Where practical, all temporary watercourse diversions will: • be piped and/or surface drainage systems; • be designed and constructed to have non-erosive hydraulic capacity and be structurally sound for a design event that will be established by a risk assessment (described below); and • have adequate scour protection at the system inlets and outlets. During detailed design a risk assessment will be undertaken to identify risks associated with by-pass flows that may occur as a result of system blockage or an event greater than the design event. This process will establish the: • design capacity of the diversion; and • need for and capacity of overland flow paths or other measures to manage bypass flows.
WM 2.1.2	Where practical, temporary watercourse diversions will seek to avoid increasing flow rates in adjoining watercourses.
WM 2.1.3	All temporary watercourse diversions will be decommissioned following the completion of works. WM 3.1 applies to any permanent watercourse diversion or re-established watercourse.

Notes: 1. The management measures presented are principles or design objectives, that will be further developed in the detailed design of Main Works. The measures implemented may vary from those presented but will meet the proposed discharge characteristics or other stated objectives.

3.4.3 Management approach – WM 2.2 accommodation camps

i Overview

As described in Table 2.5, WM 2.2 (accommodation camps) refers to the management of runoff from accommodation camp facilities once operational. Accommodation camps will comprise road and carparks and other hardstand areas, buildings and landscaped areas and are expected to be operational for most of the construction phase of the project (6 years).

ii Water management risks

Accommodation camps will provide accommodation and supporting services for workers. Construction activities will predominantly occur within construction pads (WM 2.3). Key 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 surfaces; and
- increased concentrations and loads of suspended solids and nutrients in runoff from impervious surfaces.

It is noted that wastewater (ie sewage) management (WM 2.9) is described separately in Section 5.3.

iii Mitigation and management

The following mitigation and management measures are proposed:

- source controls such as native endemic landscaping and vegetated swales will be implemented where practical to reduce runoff volumes and improve runoff quality;
- drainage controls to convey stormwater through the camp area to downstream controls; and
- sedimentation or biofiltration basins will treat runoff and attenuate peak flows prior to discharge.

Table 3.10 describes proposed management measures (or design principles).

Table 3.10 Proposed management measures: WM 2.2 – accommodation camps

Measure[1]	Description
WM 2.2.1	Where practical, the following source controls will be applied: • the storage and handling of chemicals that have potential to contaminate the stormwater system will be undertaken in bunded areas. Any liquid waste stream will be disposed to an appropriate facility; • landscaped areas will be predominately vegetated with endemic native vegetation; and • runoff from road and other hardstand areas will be treated in vegetated swales.
WM 2.2.2	Runoff from accommodation camps will be managed by drainage systems that have a 20% AEP capacity. Overland flow paths will be provided as required.
WM 2.2.3	Runoff from accommodation camps will be treated in either sedimentation or bioretention basins. The most appropriate control will be established at detailed design with consideration of topography, soil conditions and other relevant factors.
WM 2.2.4	Overall, the stormwater management system for accommodation camps will be designed and operated to achieve the water quality characteristics described in Table 3.12.

Notes: 1. The management measures presented are principles or design objectives, that will be further developed in the detailed design of Main Works. The measures implemented may vary from those presented but will meet the proposed discharge characteristics or other stated objectives.

iv Discharge characteristics

The following sections provide a summary of expected discharge regimes and water quality characteristics.

a Discharge regimes

Table 3.11 describes discharge regimes and notes contributing factors. Refer to table notes for assumptions and terminology clarifications.

Table 3.11 Discharge regimes: WM 2.2 – accommodation camps

Aspect		Description
Contributing factors	As described in Table 3.1	Constructed surfaces, weather characteristics, water management system.
Functionality	Water management system	Runoff from accommodation camps will be treated in source controls (ie vegetated swales) and either sedimentation or biofiltration basins.
	Water harvesting	Water harvesting may occur from sedimentation basins.
	Discharge mechanisms	• Discharge via overflow from either sedimentations or biofiltration basins via either; and • discharge through a filtration medium (biofiltration basins only).
Runoff characteristics	Catchment characteristics	Buildings, roads and carparks and other hardstand areas and landscaped areas. The impervious area is expected to be 60 to 70% of the total area.
	Hydrologic category	Impervious areas – High runoff potential Landscaped areas – Type B[2] – Low to moderate runoff potential.
	Runoff volumes	Annualised runoff volumes are expected to be approximately 48% of rainfall.
Water harvesting	Water harvesting/ treatment volume	• Sedimentation basins – approximately 60% of runoff. • Biofiltration basins – nil[4].
	Reduction in discharge volumes	• Sedimentation basins – approximately 60% of runoff. • Biofiltration basins – nil[4].
Discharge regime	Discharge frequency	• Sedimentation basins – overflows will occur approximately 4-6 times per year[1] during and following intense or prolonged periods of wet weather. • Biofiltration basins – Following and material rainfall[1] – approximately 50 days per year[4].
	Discharge volumes[3]	• Sedimentation basins – approximately 40% of runoff. • Biofiltration basins – 100% of runoff[4].

Notes: 1. Indicative average annual discharge frequency for an 85th percentile 5-day sedimentation basin provided in Table 6-2 from *Managing Urban Stormwater: Soils and Construction – Volume 2D – Main road construction* (DECC 2008).

2. Refers to the Soil Hydrologic Group referenced in Appendix F of *Managing Urban Stormwater: Soils and Construction – Volume 1* (Landcom 2004).

3. Calculated using the stormwater discharge model (described in Attachment D) that was parameterised to achieve event-based runoff coefficients that are similar to the specified hydrologic category (note 2).

4. Assumes no infiltration losses from the base of the filtration media.

b Discharge quality

Table 3.12 describes the expected water quality characteristics of basin overflows and notes contributing factors and limitations. Refer to table notes for assumptions and terminology clarifications.

Table 3.12 Discharge quality characteristics: WM 2.2 – accommodation camps

Analyte	Units	WQO value	Discharge characteristics		Comments
			Likely range[1]	Value applied to RIA[2]	
Contributing factors – constructed surfaces, weather characteristics, water management system.					
Limitations – no significant limitations have been identified.					
Discharge mechanism – applies to either basin overflow or discharge through a filtration medium (biofiltration basins only) – as described in Table 3.11.					
pH	-	6.5–8.0	6.5–8.0	6.5–8.0	The pH of runoff will be managed by source controls.
Turbidity	NTU	2–25	2–50	25	Turbidity and suspended sediments will be managed by source controls and the proposed stormwater treatment controls.
Suspended sediment	mg/L	-	10–50	25	
Hydrocarbons	mg/L	-	No visible oil and grease	No visible oil and grease	Hydrocarbons will be managed by appropriate storage and handling of hydrocarbons and management of leaks and spills. Stormwater controls will also provide treatment for minor leaks that may occur from parked vehicles.
Total nitrogen	mg-N/L	0.25	0.1–1.0	0.4	Nutrients will be managed by source controls and the proposed stormwater treatment controls.
Total phosphorus	mg-P/L	0.02	0.01–0.1	0.05	
Metals and toxicants	mg/L	Note 3	WQO values occasionally exceeded	< WQO values	Metals and toxicants will be managed by source controls and the proposed stormwater treatment controls. Notwithstanding, some metals and toxicants are expected to occasionally exceed WQO values. However, median concentrations are expected to be less than WQO values.

Notes: 1. Likely range refers to the estimated range of concentrations that could occur from the project level water management category during typical discharge conditions. The range and values were established based on the estimated runoff quality the effectiveness of the proposed controls.

2. RIA refers to residual impact assessment. RIA values have been established qualitatively considering typical industry values and the effectiveness of the proposed controls. The value represents a conservative estimate of typical or median values in discharge from a project level water management category.

3. Default trigger values for 99% level of species protection apply. Refer to the water assessment for WQOs.

3.4.4 Management approach – WM 2.3 construction pads

i Overview

As described in Table 2.5, WM 2.3 (construction pads) refers to the management of runoff from construction pads and tunnel portals during their use to support broader construction activities. These areas will facilitate a range of activities including equipment assembly, material handling, concrete batching, fuel storage and refuelling, waste management and workshops. Construction pads are expected to be operational for most of the construction phase of the project (approximately 5 to 6 years).

ii Water management risks

Construction pads will provide secure areas for construction activities. Key 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 surfaces;
- increased concentrations and loads of suspended solids and nutrients in runoff from impervious surfaces;
- contamination of stormwater runoff due to construction activities, including incidental leaks and spills; and
- contamination of stormwater due to the unintended or unplanned discharge of untreated process water, water or chemicals used for firefighting purposes or a major leak or spill.

It is noted that wastewater (ie sewage) management (WM 2.9) is described separately in Section 5.3.

iii Mitigation and management

The following mitigation and management measures are proposed:

- drainage controls to manage stormwater runoff from the construction pad and upslope clean water areas;
- source controls to minimise the risk of contamination of stormwater from construction activities;
- sedimentation basins to:
    - enable harvesting of captured water to reduce discharge volumes and frequency; and
    - provide sedimentation treatment during discharge (via overflow).

Table 3.13 describes proposed management measures (or design principles).

Table 3.13 Proposed management measures: WM 2.3 – construction pads

Measure[1]	Description
WM 2.3.1	Where practical, activities that have potential to contaminate stormwater runoff will be isolated from the stormwater system by covering (ie by a building or roof) and /or bunding.
WM 2.3.2	Runoff from construction pads and upslope clean water areas will be managed by a drainage system. The design capacity will be established at detailed design. Overland flow paths will be provided as required.
WM 2.3.3	Runoff from construction pads will be directed to sedimentation basins. The sedimentation basins will be designed to capture runoff from the 85^{th} percentile 5-day rainfall event. Where practicable, captured water will be harvested and used for dust suppression.
WM 2.3.4	Overall, the stormwater management system for construction pads will be designed and operated to achieve the water quality characteristics described in Table 3.15.

Notes: 1. The management measures presented are principles or design objectives, that will be further developed in the detailed design of Main Works. The measures implemented may vary from those presented but will meet the proposed discharge characteristics or other stated objectives.

iv Discharge characteristics

The following sections provide a summary of expected discharge regimes and water quality characteristics.

a Discharge regimes

Table 3.14 describes discharge regimes and notes contributing factors. Refer to table notes for assumptions and terminology clarifications.

Table 3.14 Discharge regimes: WM 2.3 – construction pads

Aspect		Description
Contributing factors	As described in Table 3.1	Constructed surfaces, weather characteristics, water management system.
Functionality	Water management system	Sedimentation basins will be designed to capture the 85th percentile 5-day rainfall event.
	Water harvesting	Water captured in basins will be used for dust suppression.
	Discharge mechanisms	Discharge via overflow or other outlet once the basin is full (for rainfall events greater than the 85th percentile 5-day rainfall event).
Runoff characteristics	Catchment characteristics	Construction pads will comprise buildings and areas of concrete hardstand and stabilised soil.
	Hydrologic category	Type D[2] – High runoff potential.
	Runoff volumes	Annualised runoff volumes are expected to be approximately 50% of rainfall.
Water harvesting	Water harvesting/ treatment volume	Approximately 50% of runoff.
	Reduction in discharge volumes	Approximately 50% of runoff.
Discharge regime	Discharge frequency	Overflows will occur approximately 4-6 times per year[1] during and following intense or prolonged periods of wet weather.
	Discharge volumes[3]	Approximately 50% of runoff.

Notes: 1. Indicative average annual discharge frequency for an 85th percentile 5-day sedimentation basin provided in Table 6-2 from *Managing Urban Stormwater: Soils and Construction – Volume 2D – Main road construction* (DECC 2008).

2. Refers to the Soil Hydrologic Group referenced in Appendix F of *Managing Urban Stormwater: Soils and Construction – Volume 1* (Landcom 2004).

3. Calculated using the stormwater discharge model (described in Attachment D) that was parameterised to achieve event-based runoff coefficients that are similar to the specified hydrologic category (note 2).

b Discharge quality

Table 3.15 describes the expected water quality characteristics of basin overflows and notes contributing factors and limitations. Refer to table notes for assumptions and terminology clarifications.

Table 3.15 Discharge quality characteristics: WM 2.3 – construction compounds

Analyte	Units	WQO value	Discharge characteristics		Comments
			Likely range[1]	Value applied to RIA[2]	
Contributing factors – construction activities, constructed surfaces, weather characteristics, water management system.					
Limitations – the discharge quality estimates assume that the source controls (WM 2.3.1) will effectively manage risk associated with construction activities within construction pads that have potential to contaminate stormwater.					
Discharge mechanism – applies to basin overflows as described in Table 3.14.					
pH	-	6.5–8.0	6.5–8.0	6.5–8.0	The pH of runoff will be managed by source controls.
Turbidity	NTU	2–25	2–100	50	Turbidity and suspended sediments will be managed by source controls and the proposed stormwater treatment controls.
Suspended sediment	mg/L	-	10–100	50	
Hydrocarbons	mg/L	-	No visible oil and grease	No visible oil and grease	Hydrocarbons will be managed by appropriate storage and handling of hydrocarbons and management of leaks and spills. Stormwater controls will also provide treatment for minor leaks that may occur from parked vehicles.
Total nitrogen	mg-N/L	0.25	0.1–2.0	1.0	Nutrients will be managed by source controls and the proposed stormwater treatment controls.
Total phosphorus	mg-P/L	0.02	0.01–0.2	0.1	
Metals and toxicants	mg/L	Note 3	WQO values occasionally exceeded	< WQO values	Metals and toxicants will be managed by source controls and the proposed stormwater treatment controls. Notwithstanding, some metals and toxicants are expected to occasionally exceed WQO values. However, median concentrations are expected to be less than WQO values.

Notes: 1. Likely range refers to the estimated range of concentrations that could occur from the project level water management category during typical discharge conditions. The range and values were established based on the estimated runoff quality the effectiveness of the proposed controls.

2. RIA refers to residual impact assessment. RIA values have been established qualitatively considering typical industry values and the effectiveness of the proposed controls. The value represents a conservative estimate of typical or median values in discharge from a project level water management category.

3. Default trigger values for 99% level of species protection apply. Refer to the water assessment for information on WQO values.

3.4.5 Management approach – WM 2.4 access roads

i Overview

Access roads will be constructed (or upgraded) during construction Phase 1 to facilitate access for Phase 2 construction activities. Following construction, access roads will be either sealed, maintained as unsealed roads or rehabilitated. Table 3.16 describes the three access road categories that are referenced in this report and notes proposed roads that apply to each category. The lengths and areas of each road are provided in Attachment A.

This section describes the approach to managing runoff from access roads during construction Phase 2. The approach to managing runoff from access roads during the operational phase of the project is described in WM 3.3.

Table 3.16 Access road categories

	Road names	Construction phase	Final condition
Primary	Mine Trail and Ravine Roads	Dual lane, unsealed road	Dual lane, sealed road
Maintenance	Lobs Hole Road, Marica Trial, Pipeline Roads, Quarry Trail, Talbingo Intake Road, Tantangara Road, Wharf Road	Dual lane, unsealed road	Dual lane, unsealed road
Temporary	Camp Road, Marica West Trail, Talbingo Adit Road, Talbingo Spoil Disposal Road, Tantangara Camp Road, Tantangara Spoil Disposal Road	Dual lane, unsealed road; or Single lane, 4WD track	Rehabilitated

ii Water management risks

As described in Table 3.16, during construction Phase 2 all access roads will be maintained as unsealed roads. It is expected that most roads will be heavily used by light and heavy vehicle traffic. Key water management risks include:

- sedimentation in receiving waters due to runoff laden with coarse sediment;
- discharge of runoff laden with fine and/or dispersive material that will not readily settle under gravity in receiving waters;
- other changes to water chemistry associated with stormwater contact with road construction materials that present elevated water quality risks (ie soils with high metal concentrations); and
- erosion due to inadequate drainage design or construction.

iii Mitigation and management

The following mitigation and management measures are proposed:

- progressive rehabilitation of unused roads and cut and fill batters;
- drainage controls to manage runoff from access roads and transverse or cross drainage;
- selective use of materials to construct and maintain road surfaces to reduce water quality risks; and
- sediment traps or filters will be installed and maintained at all discharge locations to reduce coarse sediment in discharge.

Table 3.17 describes proposed management measures (or design principles).

Table 3.17 Proposed management measures: WM 2.4 – access roads

Measure[1]	Description
WM 2.4.1	Any existing access tracks that will no longer be required following the construction of the new access roads will be rehabilitated.
WM 2.4.2	All cut and fill batters will be stabilised as soon as practical following construction.
WM 2.4.3	Roads surfaces will be constructed and maintained with aggregate material to reduce soil loss rates and water quality risks. The use of material that presents elevated water quality risks relative to other material available for road construction and maintenance will be avoided.
WM 2.4.4	Where practical access roads will grade to table drains that are designed and constructed to have non-erosive hydraulic capacity for the 10% AEP event. Transverse (or cross drainage) will be constructed to have the following non-erosive hydraulic capacities: • Primary roads – 1% AEP event; • Maintenance roads – 2% AEP event; and • Temporary access roads – 10% AEP event.
WM 2.4.5	Sediment traps or filters will be installed and maintained at all discharge locations to reduce coarse sediment in discharge.
WM 2.4.6	Temporary roads will be rehabilitated as soon as they are no longer needed.

Notes: 1. The management measures presented are principles or design objectives, that will be further developed in the detailed design of Main Works. The measures implemented may vary from those presented but will meet the proposed discharge characteristics or other stated objectives.

iv Discharge characteristics

The following sections provide a summary of expected discharge regimes and water quality characteristics.

a Discharge regimes

Table 3.18 describes expected discharge regimes and notes contributing factors. Refer to table notes for assumptions and terminology clarifications.

Table 3.18 Discharge regimes: WM 2.4 – access roads

Aspect		Description
Contributing factors	As described in Table 3.1	Constructed surfaces, weather characteristics, water management system.
Functionality	Basins	No basins are proposed for access roads due to topography and environmental constraints.
	Water harvesting	No water harvesting is proposed as no runoff will be captured.
	Discharge mechanism	Runoff from the water management area.
Runoff characteristics	Catchment characteristics	Unsealed road maintenance with aggregate material.
	Hydrologic category[2]	Type D – High runoff potential.
	Runoff volumes[3]	Annualised runoff volumes are expected to be approximately 50% of rainfall.
Water harvesting	Water harvesting volume	nil
	Reduction in discharge volumes	nil
Discharge regime	Discharge frequency[3]	Following any material rainfall[1] – approximately 50 days per year.
	Discharge volumes[3]	As per runoff volumes.

Notes: 1. Material rainfall refers to 5 mm or more in a day.

2. Refers to the Soil Hydrologic Group referenced in Appendix F of *Managing Urban Stormwater: Soils and Construction – Volume 1* (Landcom 2004).

3. Calculated using the stormwater discharge model (described in Attachment D) that was parameterised to achieve event-based runoff coefficients that are similar to the specified hydrologic category (note 2).

b Discharge quality

Table 3.19 describes the expected discharge quality characteristics and notes contributing factors and limitations. Refer to table notes for assumptions and terminology clarifications.

Table 3.19 Discharge quality characteristics: WM 2.4 – access roads

Analyte	Units	WQO value	Discharge characteristics		Comments
			Likely range[1]	Value applied to RIA[2]	
Contributing factors – constructed surfaces, weather characteristics, water management system.					
Limitations – the discharge quality estimates assume that the water quality risks associated with soil disturbance that are described in WM 1.2 (Table 3.5) and WM 1.3 (Table 3.8) can be partially mitigated by the selective use of materials to construct and maintain road surfaces.					
Discharge mechanism – discharge via runoff.					
pH	-	6.5–8.0	6.5–8.0	6.5–8.0	The pH of runoff will be managed by the selective use of materials to construct and maintain road surfaces (as described in WM 2.4.3).
Turbidity	NTU	2–25	50–200	250	Turbidity and suspended sediment will be managed by the selective use of materials to construct and maintain road surfaces (as described in WM 2.4.3). Sediment traps and filters at discharge points will remove some coarse sediment
Suspended sediment	mg/L	-	25–300	50	
Total nitrogen	mg-N/L	0.25	0.1–2.0	1.0	Nutrients will be managed by the selective use of materials to construct and maintain road surfaces (as described in WM 2.4.3).
Total phosphorus	mg-P/L	0.02	0.01–0.2	0.1	
Aluminium	mg/L	0.027[3]	0–20 x WQO value[4,5]	10 x WQO value[4,5]	Aluminium has been identified as being naturally high in soils within the project area. Hence, it may not be practical to source materials for road construction and maintenance that are not a source of aluminium.
Other metals and toxicants	mg/L	Note 3	WQO values occasionally exceeded[4]	< WQO values[4]	Metals (including copper) and toxicants will be managed by the selective use of materials to construct and maintain road surfaces (as described in WM 2.4.3). Notwithstanding, some metals and toxicants are expected to occasionally exceed WQO values. However, median concentrations are expected to be less than WQO values.

Notes: 1. Likely range refers to the estimated range of concentrations that could occur from the project level water management category during typical discharge conditions. The range and values were established based on a review of available data and the effectiveness of the proposed controls and considers the spatial variability of contributing factors, such as soil characteristics.

2. RIA refers to residual impact assessment. RIA values have been established qualitatively considering available data and the spatial variability in soil conditions. The value represents a conservative estimate of typical or median values in discharge from a project level water management category.

3. Default trigger values for 99% level of species protection apply. Refer to the water assessment for information on WQO values.

4. Concentrations refer to laboratory analysis of a 0.45 µm field filtered sample. Some of the metal concentration may be mineral or organic bound and may have lower eco-toxicology risks than similar concentrations of dissolved metals.

5. Available information indicates that elevated aluminium is naturally high within the project area. However, this has not been verified and the distribution of soils with naturally high concentrations of aluminium is poorly understood. The RIA values are conservative estimates given that all soils that will be disturbed are unlikely to have naturally high concentrations of aluminium.

3.4.6 Management approach – WM 2.5 large temporary stockpiles

i Overview

Large temporary stockpiles are proposed at the Talbingo, Marica and Tantangara construction compounds. Indicative stockpile locations and footprints are provided in the Phase 2 stormwater concept figures. The stockpiles will store excess material produced by earthworks. Stockpiled material will either be used for construction, road maintenance, rehabilitation or amalgamated with subsurface spoil disposal. This section describes the management of runoff and seepage from temporary stockpiles.

ii Water management risks

The characteristics of material produced by earthworks is expected to vary. Some contaminated soils and potentially acid forming (PAF) material may be encountered. Key water management risks include:

- sedimentation in receiving waters due to runoff laden with coarse sediment;
- discharge of runoff laden with fine and/or dispersive material that will not readily settle under gravity in receiving waters;
- other changes to water chemistry associated with water contact with contaminated soils or acid metalliferous drainage (AMD); and
- erosion due to inadequate drainage design or construction.

iii Mitigation and management

The following mitigation and management measures are proposed:

- excavated material will be characterised and identified contaminated soils or PAF material will be managed separately;
- drainage controls to manage runoff from stockpiles and any upslope clean water;
- where practical, stockpiles will be temporarily stabilised to reduce soil loss rates; and
- runoff and seepage from stockpiles will be captured and treated in sedimentation basins.

Table 3.20 describes proposed management measures (or design principles).

Table 3.20 Proposed management measures: WM 2.5 – large temporary stockpiles

Measure[1]	Description
WM 2.5.1	Excavated material will be characterised and identified contaminated soils or PAF material will be managed separately.
WM 2.5.2	An ESCP will be prepared for each stockpile. Each ESCP will: • apply the methods and principles provided in *Managing Urban Stormwater: Soils and Construction – Volume 1 – Soils and construction* (Landcom 2004) unless stated below; • consider local soil characteristics, topography and environmental constraints and proposed construction methods and identify risks associated with proposed activities; • apply clean water management controls as per: – WM 1.1 for clean water management during surface construction disturbance; and – WM 2.1 for temporary watercourse diversions around temporary surface infrastructure. • consider all practical temporary stabilisation methods and apply the most appropriate methods; • where practical, all runoff and seepage from each stockpile will drain to sedimentation basins designed to capture the 85th percentile 5-day rainfall event. Captured water will be harvested and used for dust suppression; and • be progressively amended as required during construction.
WM 2.5.3	All large temporary stockpiles will be removed during the construction phase of the project and the disturbed area will be rehabilitated in accordance with the relevant rehabilitation strategy.

Notes: 1. The management measures presented are principles or design objectives, that will be further developed in the detailed design of Main Works. The measures implemented may vary from those presented but will meet the proposed discharge characteristics or other stated objectives.

iv Discharge characteristics

The following sections provide a summary of expected discharge regimes and water quality characteristics.

a Discharge regimes

Table 3.21 describes discharge regimes and notes contributing factors. Refer to table notes for assumptions and terminology clarifications.

Table 3.21 Discharge regimes: WM 2.5 – large temporary stockpiles

Aspect		Description
Contributing factors	As described in Table 3.1	Soil characteristics, weather characteristics, water management system.
Functionality	Basin volume	Sedimentation basins will be designed to capture the 85th percentile 5-day rainfall event.
	Water harvesting/ treatment	Water captured in basins will be used for dust suppression.
	Discharge mechanisms	Discharge via overflow or other outlet once the basin is full (for rainfall events greater than the 85th percentile 5-day rainfall event).
Runoff characteristics	Catchment characteristics	Primarily stockpiled material
	Hydrologic category[2]	Type B – moderate to high runoff potential.
	Runoff volumes	Annualised runoff volumes are expected to be approximately 30% of rainfall.

Table 3.21 Discharge regimes: WM 2.5 – large temporary stockpiles

Aspect		Description
Water harvesting/ treatment	Water harvesting/ treatment volume	Approximately 40% of runoff.
	Reduction in basin overflow volumes	Approximately 40% of runoff.
Discharge regime	Overflow frequency	Overflows will occur approximately 4-6 times per year[1] during and following intense or prolonged periods of wet weather.
	Overflow volumes[3]	Approximately 60% of runoff.

Notes: 1. Indicative average annual discharge frequency for an 85th percentile 5-day sedimentation basin provided in Table 6-2 from *Managing Urban Stormwater: Soils and Construction – Volume 2D – Main road construction* (DECC 2008).

2. Refers to the Soil Hydrologic Group referenced in Appendix F of *Managing Urban Stormwater: Soils and Construction – Volume 1* (Landcom 2004).

3. Calculated using the stormwater discharge model (described in Attachment D) that was parameterised to achieve event-based runoff coefficients that are similar to the specified hydrologic category (note 2).

b Discharge quality

The water quality of basin overflows is expected to be similar to, or better than, the water quality for WM 1.3 (major works) that is described in Table 3.8.

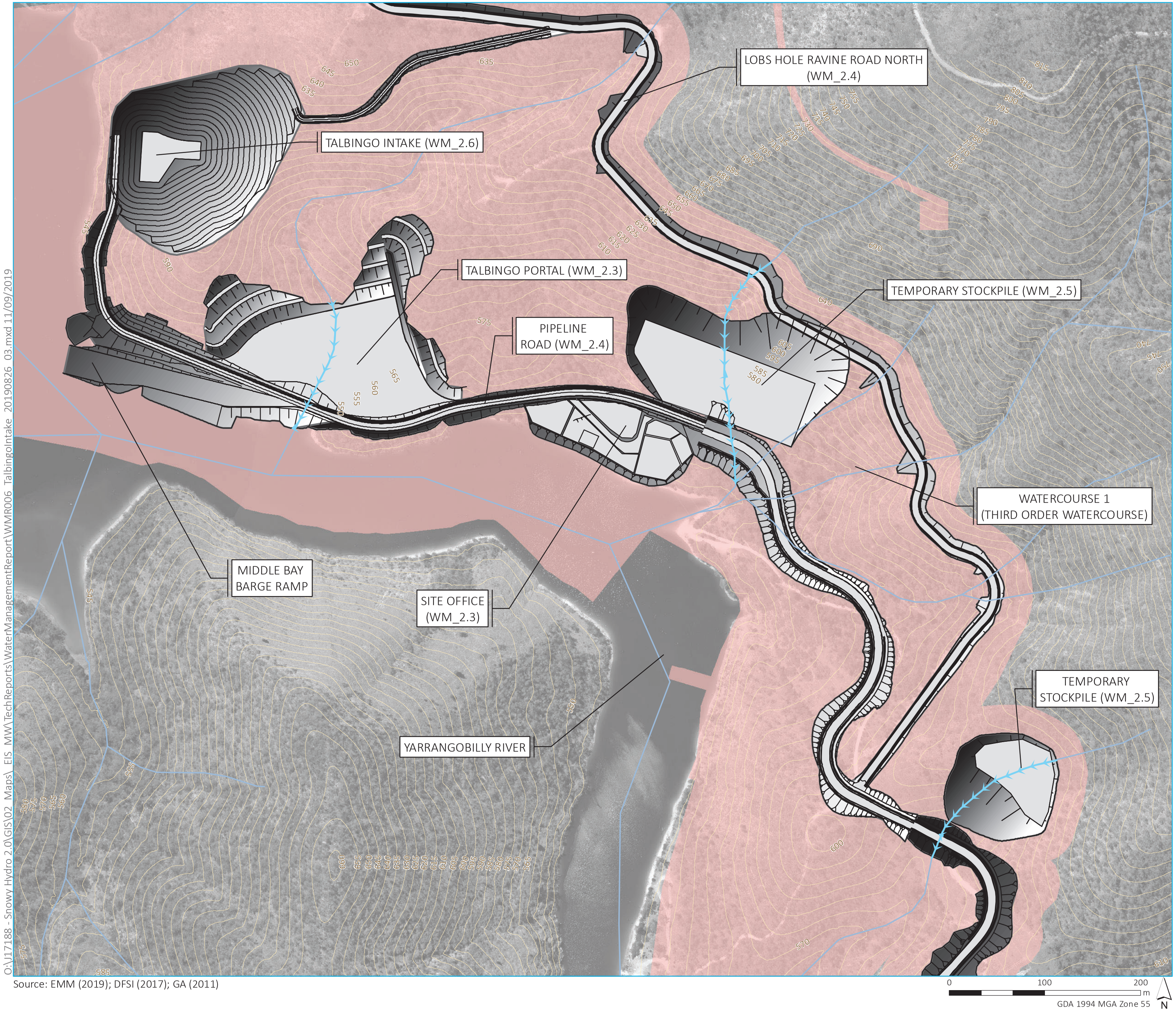
3.4.7 Management approach – WM 2.6 large surface excavations

i Overview

As described in Table 2.5, WM 2.6 (large surface excavations) refers to the management of water pumped from the sumps of large surface excavations such as the headrace and tailrace intakes.

ii Mitigation and management

Water that accumulates in the sumps of large surface excavations such as tunnel intakes may have poorer water quality due to construction activities such as blasting, concreting and spoil management. Accordingly, water will either dewatered to the process water system (WM 2.7) or used for dust suppression.



Source: EMM (2019); DFSI (2017); GA (2011)

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KEY

- Watercourse
- 5m contours
- Conceptual layout

Water management information

- Clean water diversion (WM_2.1)

Project information

- Project disturbance area
- Constructed surface
- Cut/fill batter

Notes:

1) WM refers to water management category. Refer to the WMR for proposed management measures and discharge characteristics for each category.

2) The concept layout will be further developed at detailed design. The layout may change but will be within the disturbance boundary.

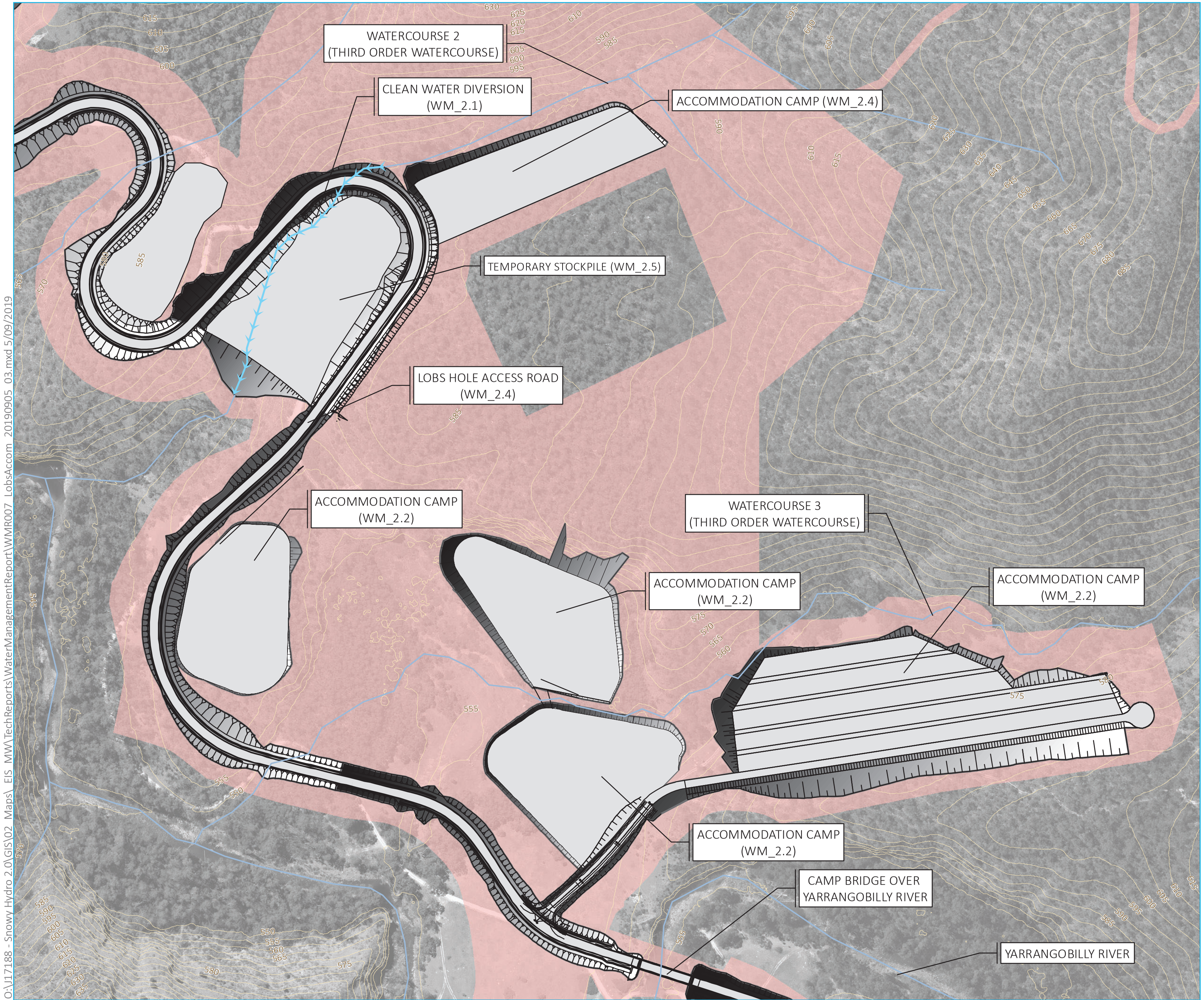
3) Any watercourses or waterfront land that is within the project boundary may be impacted. Refer to the relevant water management category for management measures for impacted watercourses.

4) The disturbance area shows the area where surface disturbance may occur. The actual disturbance footprint is expected to be less than the disturbance area. Water management measures are only required for areas that will be disturbed.

5) The indicated clean water divisions identify existing watercourse that would need to be diverted around or through proposed works based on the conceptual layout. The alignment of each diversion will be established at detailed design and may differ from the alignment indicated.

Lobs Hole 01 stormwater management concept

Snowy 2.0
Water Management Report
Main Works
Figure 3.4



Source: EMM (2019); DFSI (2017); GA (2011)

KEY

- Watercourse
- 5m contours
- Conceptual layout

Water management information

- Clean water diversion (WM_2.1)

Project information

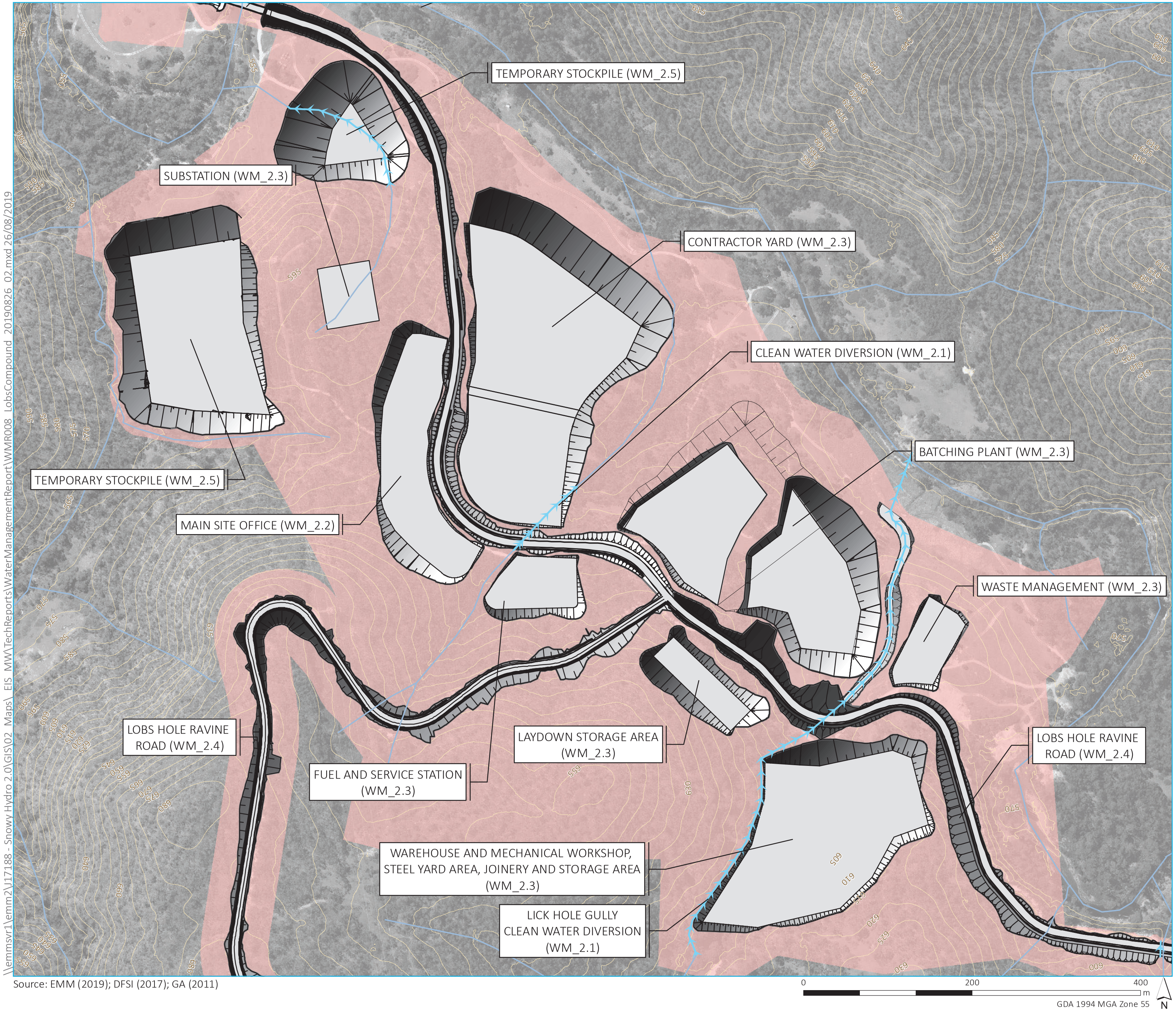
- Project disturbance area
- Constructed surface
- Cut/fill batter

Notes:

1) WM refers to water management category. Refer to the WMR for proposed management measures and discharge characteristics for each category.
2) The concept layout will be further developed at detailed design. The layout may change but will be within the disturbance boundary.
3) Any watercourses or waterfront land that is within the project boundary may be impacted. Refer to the relevant water management category for management measures for impacted watercourses.
4) The disturbance area shows the area where surface disturbance may occur. The actual disturbance footprint is expected to be less than the disturbance area. Water management measures are only required for areas that will be disturbed.
5) The indicated clean water divisions identify existing watercourse that would need to be diverted around or through proposed works based on the conceptual layout. The alignment of each diversion will be established at detailed design and may differ from the alignment indicated.

Lobs Hole 02 stormwater management concept

Snowy 2.0
Water Management Report
Main Works
Figure 3.5



Source: EMM (2019); DFSI (2017); GA (2011)

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KEY

Watercourse

5m contours

Conceptual layout

Water management information

Clean water diversion (WM_2.1)

Project information

Project disturbance area

Constructed surface

Cut/fill batter

Notes:

1) WM refers to water management category. Refer to the WMR for proposed management measures and discharge characteristics for each category.

2) The concept layout will be further developed at detailed design. The layout may change but will be within the disturbance boundary.

3) Any watercourses or waterfront land that is within the project boundary may be impacted. Refer to the relevant water management category for management measures for impacted watercourses.

4) The disturbance area shows the area where surface disturbance may occur. The actual disturbance footprint is expected to be less than the disturbance area. Water management measures are only required for areas that will be disturbed.

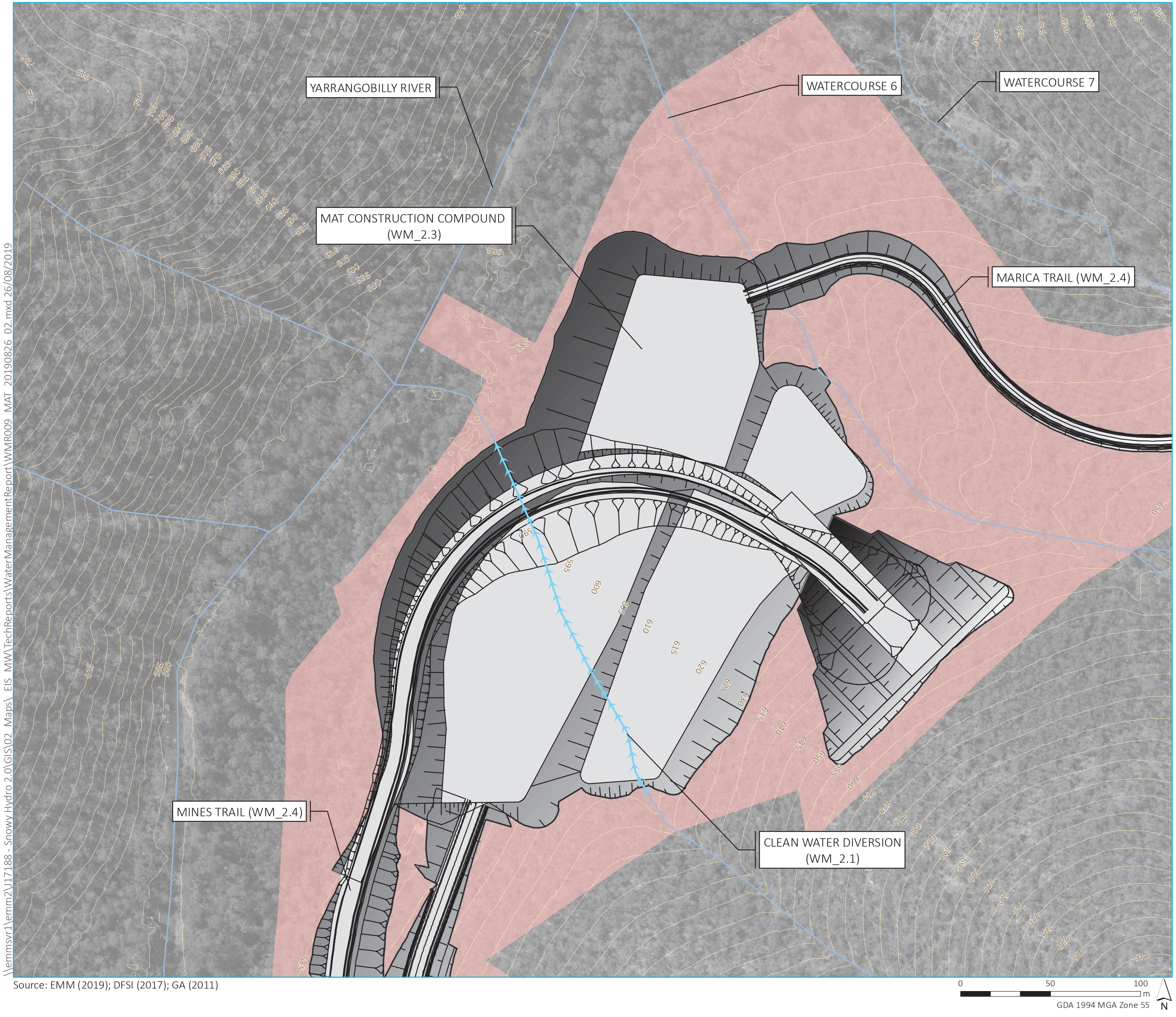
5) The indicated clean water divisions identify existing watercourse that would need to be diverted around or through proposed works based on the conceptual layout. The alignment of each diversion will be established at detailed design and may differ from the alignment indicated.

Lobs Hole 03 stormwater management concept

Snowy 2.0
Water Management Report
Main Works
Figure 3.6

snowy 2.0

EMM creating opportunities



Source: EMM (2019); DFSI (2017); GA (2011)

KEY

- Watercourse
- 5m contours
- Conceptual layout

Water management concept

- Clean water diversion (WM_2.1)

Project information

- Project disturbance area
- Constructed surface
- Cut/fill batter

Notes:
1) WM refers to water management category. Refer to the WMR for proposed management measures and discharge characteristics for each category.
2) The concept layout will be further developed at detailed design. The layout may change but will be within the disturbance boundary.
3) Any watercourses or waterfront land that is within the project boundary may be impacted. Refer to the relevant water management category for management measures for impacted watercourses.
4) The disturbance area shows the area where surface disturbance may occur. The actual disturbance footprint is expected to be less than the disturbance area. Water management measures are only required for areas that will be disturbed.
5) The indicated clean water divisions identify existing watercourse that would need to be diverted around or through proposed works based on the conceptual layout. The alignment of each diversion will be established at detailed design and may differ from the alignment indicated.

Lobs Hole 04 stormwater management concept

Snowy 2.0
Water Management Report
Main Works
Figure 3.7

snowy2.0

EMM creating opportunities

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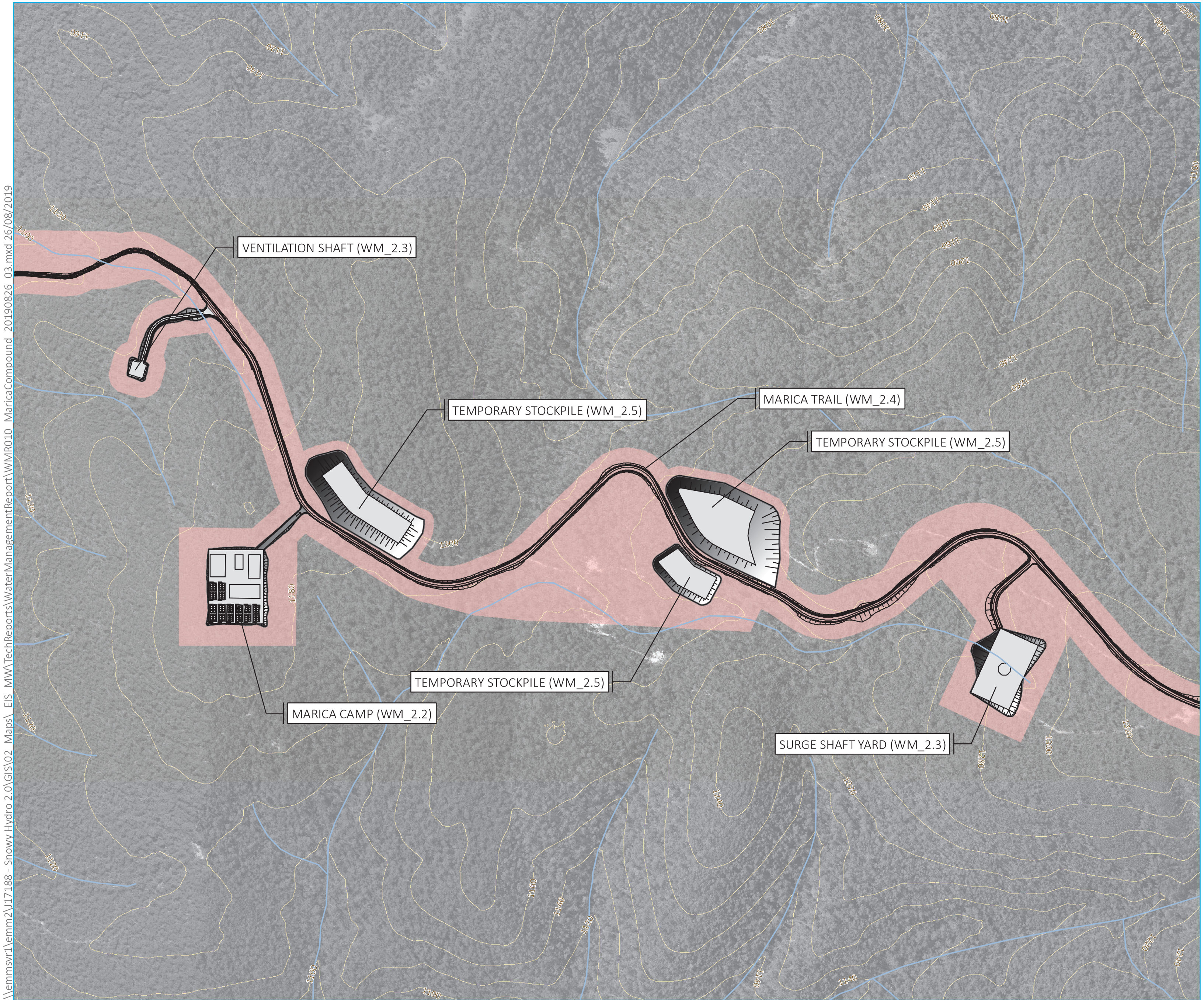

Source: EMM (2019); DFSI (2017); GA (2011)

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Notes:

1) WM refers to water management category. Refer to the WMR for proposed management measures and discharge characteristics for each category.

2) The concept layout will be further developed at detailed design. The layout may change but will be within the disturbance boundary.

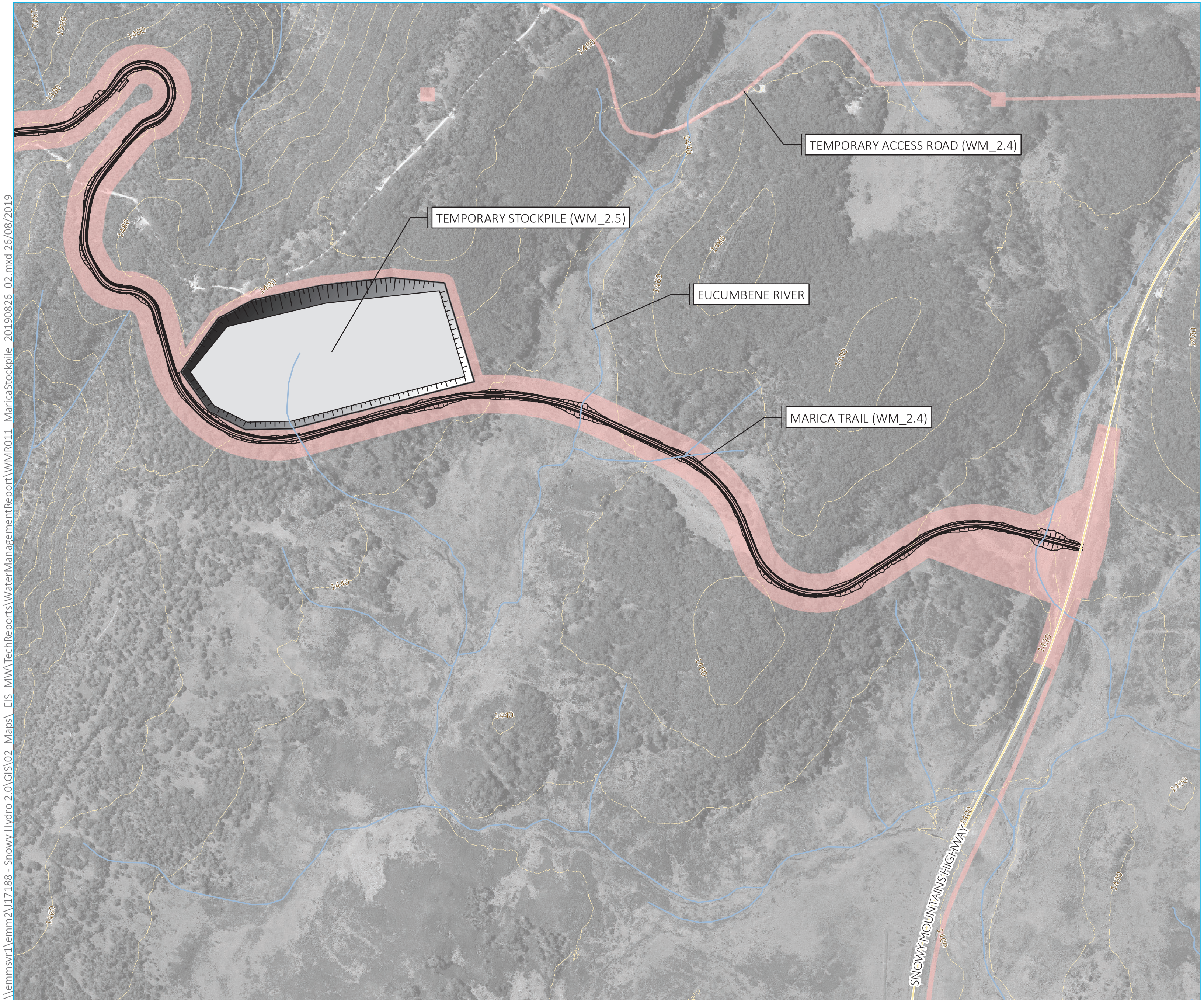
3) Any watercourses or waterfront land that is within the project boundary may be impacted. Refer to the relevant water management category for management measures for impacted watercourses.

4) The disturbance area shows the area where surface disturbance may occur. The actual disturbance footprint is expected to be less than the disturbance area. Water management measures are only required for areas that will be disturbed.

5) The indicated clean water divisions identify existing watercourse that would need to be diverted around or through proposed works based on the conceptual layout. The alignment of each diversion will be established at detailed design and may differ from the alignment indicated.

Marica Trail 01 stormwater management concept

Snowy 2.0
Water Management Report
Main Works
Figure 3.8



Source: EMM (2019); DFSI (2017); GA (2011)

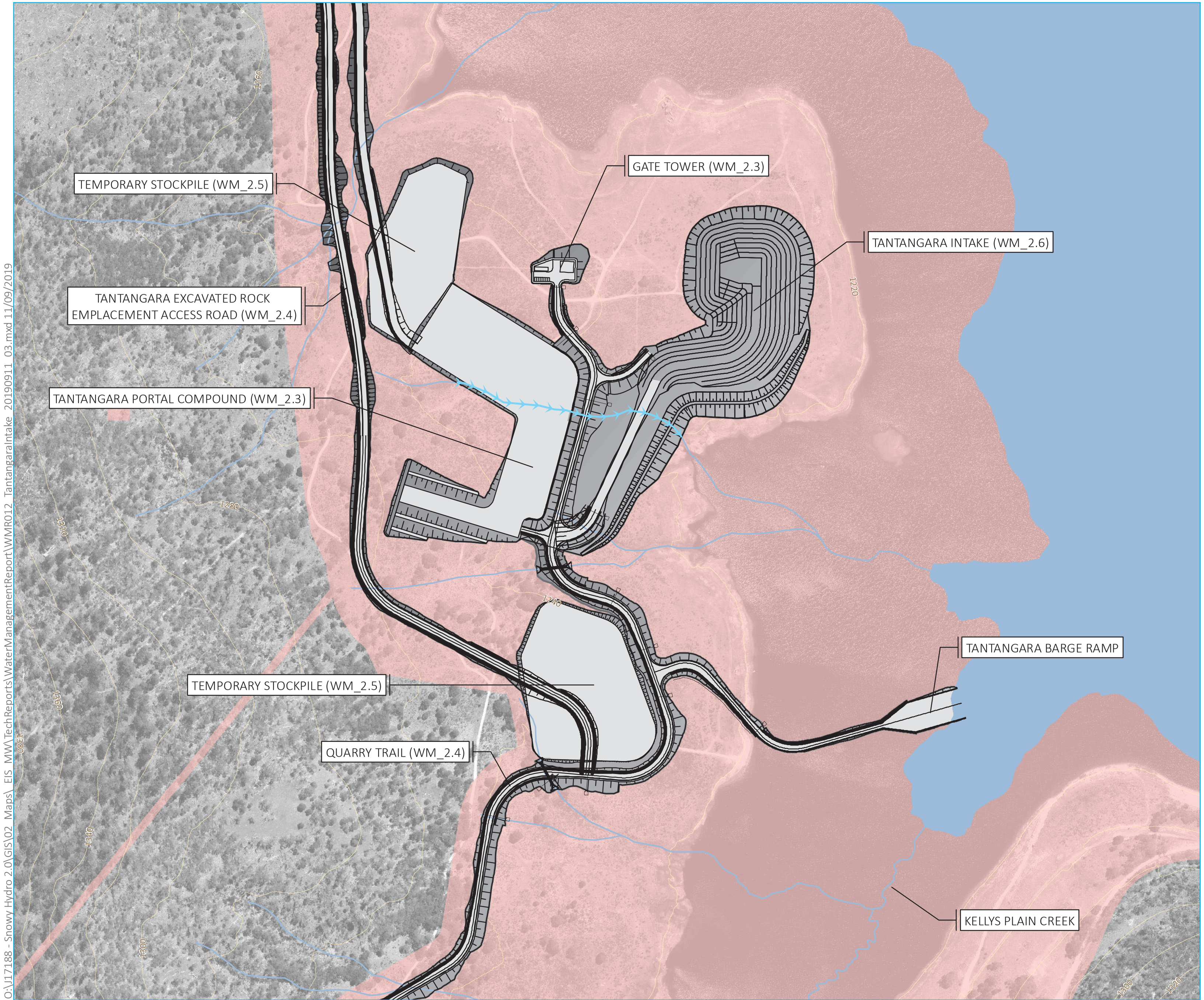
KEY
- Watercourse
- 10m contour
- Main road

Project information
- Project disturbance area
- Constructed surface
- Cut/fill batter

Notes:
1) WM refers to water management category. Refer to the WMR for proposed management measures and discharge characteristics for each category.
2) The concept layout will be further developed at detailed design. The layout may change but will be within the disturbance boundary.
3) Any watercourses or waterfront land that is within the project boundary may be impacted. Refer to the relevant water management category for management measures for impacted watercourses.
4) The disturbance area shows the area where surface disturbance may occur. The actual disturbance footprint is expected to be less than the disturbance area. Water management measures are only required for areas that will be disturbed.
5) The indicated clean water divisions identify existing watercourse that would need to be diverted around or through proposed works based on the conceptual layout. The alignment of each diversion will be established at detailed design and may differ from the alignment indicated.

Marica Trail 02 stormwater management concept

Snowy 2.0
Water Management Report
Main Works
Figure 3.9



Source: EMM (2019); DFSI (2017); GA (2011)

KEY

- Watercourse
- 10m contour
- Reservoir minimum operating level
- Conceptual layout

Water management information

- Clean water diversion (WM_2.1)

Project information

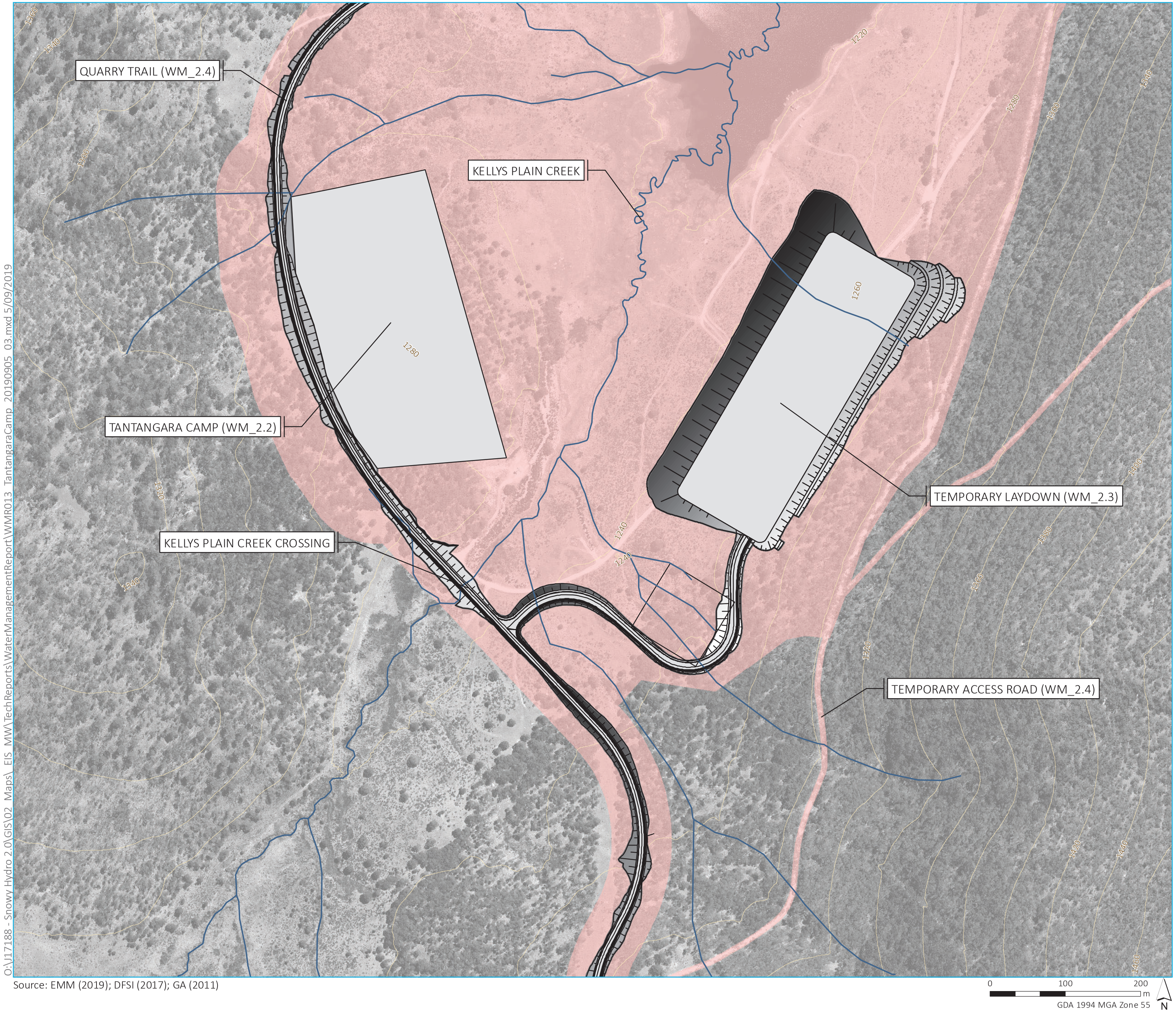
- Project disturbance area
- Constructed surface
- Cut/fill batter

Notes:

1) WM refers to water management category. Refer to the WMR for proposed management measures and discharge characteristics for each category.
2) The concept layout will be further developed at detailed design. The layout may change but will be within the disturbance boundary.
3) Any watercourses or waterfront land that is within the project boundary may be impacted. Refer to the relevant water management category for management measures for impacted watercourses.
4) The disturbance area shows the area where surface disturbance may occur. The actual disturbance footprint is expected to be less than the disturbance area. Water management measures are only required for areas that will be disturbed.
5) The indicated clean water divisions identify existing watercourse that would need to be diverted around or through proposed works based on the conceptual layout. The alignment of each diversion will be established at detailed design and may differ from the alignment indicated.

Tantangara 01 stormwater management concept

Snowy 2.0
Water Management Report
Main Works
Figure 3.10



Source: EMM (2019); DFSI (2017); GA (2011)

KEY

- Watercourse
- 10m contour
- Conceptual layout

Project information

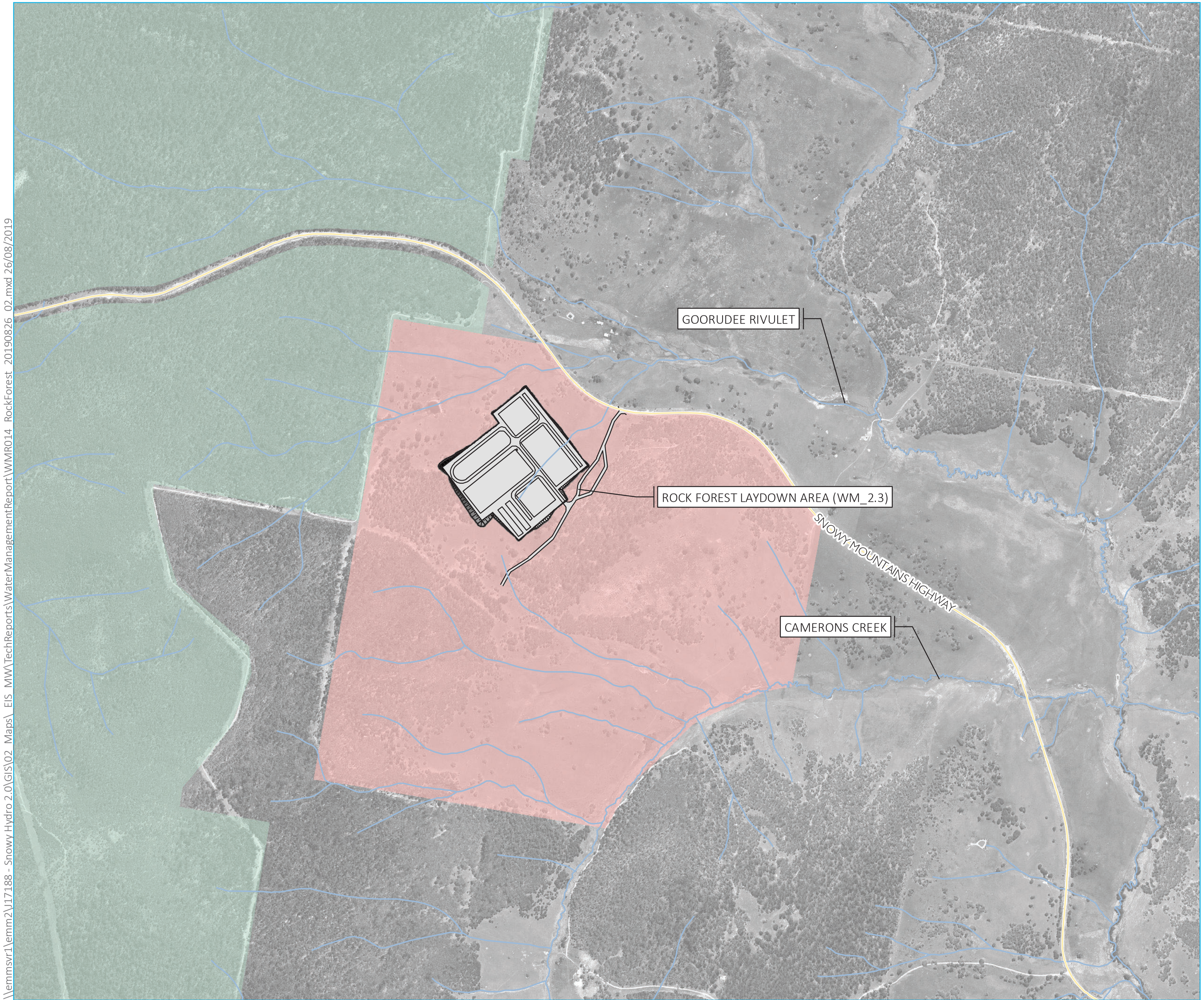
- Project disturbance area
- Constructed surface
- Cut/fill batter

Notes:

1) WM refers to water management category. Refer to the WMR for proposed management measures and discharge characteristics for each category.
2) The concept layout will be further developed at detailed design. The layout may change but will be within the disturbance boundary.
3) Any watercourses or waterfront land that is within the project boundary may be impacted. Refer to the relevant water management category for management measures for impacted watercourses.
4) The disturbance area shows the area where surface disturbance may occur. The actual disturbance footprint is expected to be less than the disturbance area. Water management measures are only required for areas that will be disturbed.
5) The indicated clean water divisions identify existing watercourse that would need to be diverted around or through proposed works based on the conceptual layout. The alignment of each diversion will be established at detailed design and may differ from the alignment indicated.

Tantangara 02 stormwater management concept

Snowy 2.0
Water Management Report
Main Works
Figure 3.11



Source: EMM (2019); DFSI (2017); GA (2011)

KEY

- Watercourse
- Main road
- Kosciuszko National Park

Project information

- Project disturbance area
- Constructed surface
- Cut/fill batter

Notes:
1) WM refers to water management category. Refer to the WMR for proposed management measures and discharge characteristics for each category.
2) The concept layout will be further developed at detailed design. The layout may change but will be within the disturbance boundary.
3) Any watercourses or waterfront land that is within the project boundary may be impacted. Refer to the relevant water management category for management measures for impacted watercourses.
4) The disturbance area shows the area where surface disturbance may occur. The actual disturbance footprint is expected to be less than the disturbance area. Water management measures are only required for areas that will be disturbed.
5) The indicated clean water divisions identify existing watercourse that would need to be diverted around or through proposed works based on the conceptual layout. The alignment of each diversion will be established at detailed design and may differ from the alignment indicated.

Rock Forest 01 stormwater management concept

Snowy 2.0
Water Management Report
Main Works
Figure 3.12

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3.5 Stormwater management – operational phase

Five water management categories are established in Table 2.5 to describe water management for the operational phase of Snowy 2.0 Main Works. The following sections describe proposed management measures and discharge characteristics (where relevant) for:

- WM 3.1 – permanent watercourse diversions;
- WM 3.2 – permanent surface infrastructure; and
- WM 3.3 – permanent access roads.

Tailrace tunnel dewatering (WM 3.4) and the management of groundwater inflows (WM 3.5) are described in Sections 6.2 and 6.4 respectively.

3.5.1 Management approach – WM 3.1 permanent watercourse diversion

As described in Table 2.5, the following water management categories describe clean water management:

- WM 1.1 describes the management approach for runoff from clean water catchments that traverse surface construction disturbance areas;
- WM 2.1 describes the management approach for temporary watercourse diversions around temporary surface infrastructure; and
- WM 3.1 describes the management approach for permanent watercourse diversions and the re-establishment of watercourses following disturbance.

This section describes WM 3.1.

i Water management risks

Risks associated with the permanent diversion of watercourses or re-establishing watercourses following diversion include:

- potential for damage or failure of road embankments and other infrastructure;
- potential for scour or erosion of the watercourse or adjoining landforms resulting in a poor environmental outcome and potentially a future maintenance burden;
- potential for impacts to adjoining watercourses if diversion works increase an effective catchment area to an adjoining watercourse; and
- potential for erosion at the upstream and downstream interfaces of diversion works with undisturbed watercourses.

ii Mitigation and management

Table 3.22 describes proposed management measures (or design principles) that will be applied to permanent watercourse diversions and any watercourse that is re-established following disturbance.

Table 3.22 Proposed management measures: WM 3.1 – permanent watercourse diversions

Measure[1]	Description
WM 3.1.1	Any watercourse that will be permanently diverted around permanent infrastructure will: • be a piped and/or surface drainage system; • be designed and constructed to have non-erosive hydraulic capacity and be structurally sound for the 1% AEP event; and • have adequate scour protection at the system inlets and outlets. During detailed design a risk assessment will be undertaken to identify risks associated with by-pass flows that may occur as a result of system blockage or an event greater than the design event. If significant risks are identified (such as embankment failures or entrainment of materials that could pollute the receiving environment), engineered overland flow paths will be established to manage by-pass flows.
WM 3.1.2	Watercourses to be reinstated into a rehabilitated landform along either its original or an alternative alignment will be designed and constructed as a physically stable naturalised watercourse that has similar environmental values to the pre-disturbed watercourse.

Notes: 1. The management measures presented are principles or design objectives, that will be further developed in the detailed design of Main Works. The measures implemented may vary from those presented but will meet the proposed discharge characteristics or other stated objectives.

3.5.2 Management approach – WM 3.2 permanent surface infrastructure

i Overview

The majority of surface infrastructure established to support construction activities such as construction pads and accommodation camps will be decommissioned and rehabilitated in accordance with the rehabilitation strategy (Appendix F to the EIS). This will substantially reduce the disturbance area and associated water management risks.

Permanent surface infrastructure will include access roads, tunnel portals, cable yards, intake gate structures and small buildings and services. This section describes stormwater management controls for all permeant surface infrastructure except for access roads, which are described in WM 3.3.

ii Water management risks

The net footprint of permanent infrastructure (excluding access roads) is 20 ha, approximately 1% of the construction disturbance area. Permanent infrastructure will primarily be used for access and occasional maintenance, which are not expected to be sources of contamination. Key water management risks include:

- stormwater flooding issues and/or erosion of the landform due to inadequate drainage system design; and
- contamination of stormwater due to the unintended leaks or spills or discharge water or chemicals used for firefighting purposes.

It is noted that wastewater (ie sewage) management (WM 2.9) is described separately in Section 5.3.

iii Mitigation and management

The following mitigation and management measures are proposed:

- drainage controls to manage stormwater runoff from infrastructure areas and upslope clean water areas; and
- measures to contain unintended leaks or spills.

Table 3.23 describes proposed management measures (or design principles).

Table 3.23 Proposed management measures: WM 3.2 – permanent surface infrastructure

Measure[1]	Description
WM 3.2.1	Transformers and any other infrastructure that has potential for leaks or spills will be bunded in accordance with relevant guidelines.
WM 3.2.2	Runoff from permanent surface infrastructure will be managed by a drainage system that has a 1% AEP capacity. Overland flow paths will be provided as required.

Notes: 1. The management measures presented are principles or design objectives, that will be further developed in the detailed design of Main Works. The measures implemented may vary from those presented but will meet the proposed discharge characteristics or other stated objectives.

iv Discharge characteristics

The following sections provide a summary of expected discharge regimes and water quality characteristics.

a Discharge regimes

Table 3.24 describes expected discharge regimes and notes contributing factors. Refer to table notes for assumptions and terminology clarifications.

Table 3.24 Discharge regimes: WM 3.2 – permanent infrastructure

Aspect		Description
Contributing factors	As described in Table 3.1	Constructed surfaces, weather characteristics.
Functionality	Basins	No basins are proposed due to the limited disturbance area.
	Water harvesting	No water harvesting is proposed as no runoff will be captured.
	Discharge mechanism	Discharge via runoff.
Runoff characteristics	Catchment characteristics	Concrete hardstand, buildings and grassed or vegetated areas. The impervious area is expected to be approximately 50% of the total area.
	Hydrologic category	Impervious areas – High runoff potential. Landscaped areas – Type B[2] – Low to moderate runoff potential.
	Runoff volumes[3]	Annualised runoff volumes are expected to be approximately 40% of rainfall.
Water harvesting	Water harvesting volume	nil
	Reduction in discharge volumes	nil
Discharge regime	Discharge frequency[3]	Following any material rainfall[1] – approximately 50 days per year.
	Discharge volumes[3]	As per runoff volumes.

Notes: 1. Material rainfall refers to 5 mm or more in a day.

2. Refers to the Soil Hydrologic Group referenced in Appendix F of *Managing Urban Stormwater: Soils and Construction – Volume 1* (Landcom 2004).

3. Calculated using the stormwater discharge model (described in Attachment D) that was parameterised to achieve event-based runoff coefficients that are similar to the specified hydrologic category (note 2).

b Discharge quality

Table 3.25 describes the expected discharge quality characteristics and notes contributing factors and limitations. Refer to table notes for assumptions and terminology clarifications.

Table 3.25 Discharge quality characteristics: WM 3.2 – permanent surface infrastructure

Analyte	Units	WQO value	Discharge characteristics		Comments
			Likely range[1]	Value applied to RIA[2]	
Contributing factors – Constructed surfaces, weather characteristics, water management system.					
Limitations – no significant limitations have been identified.					
Discharge mechanism – runoff from the water management area.					
pH	-	6.5–8.0	6.5–8.0	6.5–8.0	Hardstand areas will be used for access and occasional maintenance. Hence, runoff is expected to be clean with low levels of suspended sediment and nutrients and other contaminants.
Turbidity	NTU	2–25	2–25	15	
Suspended sediment	mg/L	-	0–10	5	
Hydrocarbons	mg/L	-	No visible oil and grease	No visible oil and grease	
Total nitrogen	mg-N/L	0.25	0.1–0.4	0.25	
Total phosphorus	mg-P/L	0.02	0.01–0.4	0.02	
Other metals and toxicants	mg/L	Note 3	WQO values occasionally exceeded	< WQO values	

Notes: 1. Likely range refers to the estimated range of concentrations that could occur from the project level water management category during typical discharge conditions. The range and values were established based on the estimated runoff quality the effectiveness of the proposed controls.

2. RIA refers to residual impact assessment. RIA values have been established qualitatively considering available data and the spatial variability in soil conditions. The value represents a conservative estimate of typical or median values in discharge from a project level water management category.

3. Default trigger values for 99% level of species protection apply. Refer to the water assessment for WQOs.

3.5.3 Management approach – WM 3.3 permanent access roads

i Overview

As described is Section 0, following construction, access roads will be either sealed, maintained as unsealed roads or rehabilitated. Table 3.16 describes the three access road categories that are referenced in this report and notes roads that apply to each category. The lengths and areas of each road are provided in Attachment A.

This section describes the approach to managing runoff from permanent access roads during the operational phase of the project.

ii Water management risks

Water management risks for permanent access roads are similar to those described in WM 2.4 (Section 0).

iii Mitigation and management

The following mitigation and management measures are proposed:

- primary roads (as described in Table 3.16) will be sealed to reduce water quality risks;
- drainage controls to manage runoff from access roads and transverse or cross drainage;
- for unsealed roads:
  - selective use of materials to maintain road surfaces to reduce water quality risks; and
  - sediment traps or filters will be maintained at all discharge locations to reduce coarse sediment in discharge.

Table 3.26 describes proposed management measures (or design principles).

Table 3.26 Proposed management measures: WM 3.3 – permanent access roads

Measure[1]	Description
WM 3.3.1	Unsealed roads will be maintained with aggregate material to reduce soil loss rates and water quality risks. The use of material that presents elevated water quality risks relative to other material available for road construction and maintenance will be avoided.
WM 3.3.2	Where practical access roads will grade to table drains that are designed and constructed to have non-erosive hydraulic capacity for the 10% AEP event. Transverse (or cross drainage) will be constructed to have the following non-erosive hydraulic capacities: • Primary roads – 1% AEP event; and • Maintenance roads – 2% AEP event.
WM 3.3.3	Sediment traps or filters will be maintained at all discharge locations on unsealed roads to reduce coarse sediment in discharge.

Notes: 1. The management measures presented are principles or design objectives, that will be further developed in the detailed design of Main Works. The measures implemented may vary from those presented but will meet the proposed discharge characteristics or other stated objectives.

iv Discharge characteristics

The following discharge characteristics are expected:

- the discharge characteristics from unsealed roads are expected to be similar to WM 2.4 (as described in Table 3.18 and Table 3.19); and
- the discharge quality from sealed roads is expected to be similar to receiving water quality.

4 Process water

4.1 Overview

The process water system (WM 2.7) will supply water to, and manage water produced by, construction activities. Key water uses (or system demands) include water used for subsurface construction (primarily TBM cooling and dust suppression), concrete production and access road dust suppression. Key inflows into the system include water pumped from subsurface and large surface excavations.

The process water system will comprise separate systems at the Tantangara and Talbingo construction compounds. These systems are referred to as the Tantangara and Talbingo process water systems and will operate independently (ie they will not be connected). Each system will:

- be isolated from the stormwater management system (described in Chapter 3);
- discharge to a reservoir when net inflows into the system exceed net usage; and
- be toped up from the water supply system (described in Section 6.1) when net usage exceeds net inflows.

The water quality of process water will be influenced by the groundwater inflow quality and any changes as a result of construction and water management activities. The water quality is expected to be variable, with potential for poorer water quality to occur in some parts of the process water system. The following water treatment will be provided:

- all process water will be treated to a suitable quality for re-use within the process water system; and
- additional treatment will be provided for all process water that is discharged to the reservoirs.

Groundwater that accumulates in excavations where construction is complete may be suitable for diversion around the process water system provided that:

- the water can be practically separated and reticulated to the reservoirs; and
- water quality changes (contamination) from the broader construction activities can be avoided.

Figure 4.1 shows the conceptual framework of the process water system. The extent of the Tantangara and Talbingo process water systems is described further in Section 4.1.1.

It is expected that the process water system will operate for approximately 5 years during subsurface excavations (see Figure 2.1).

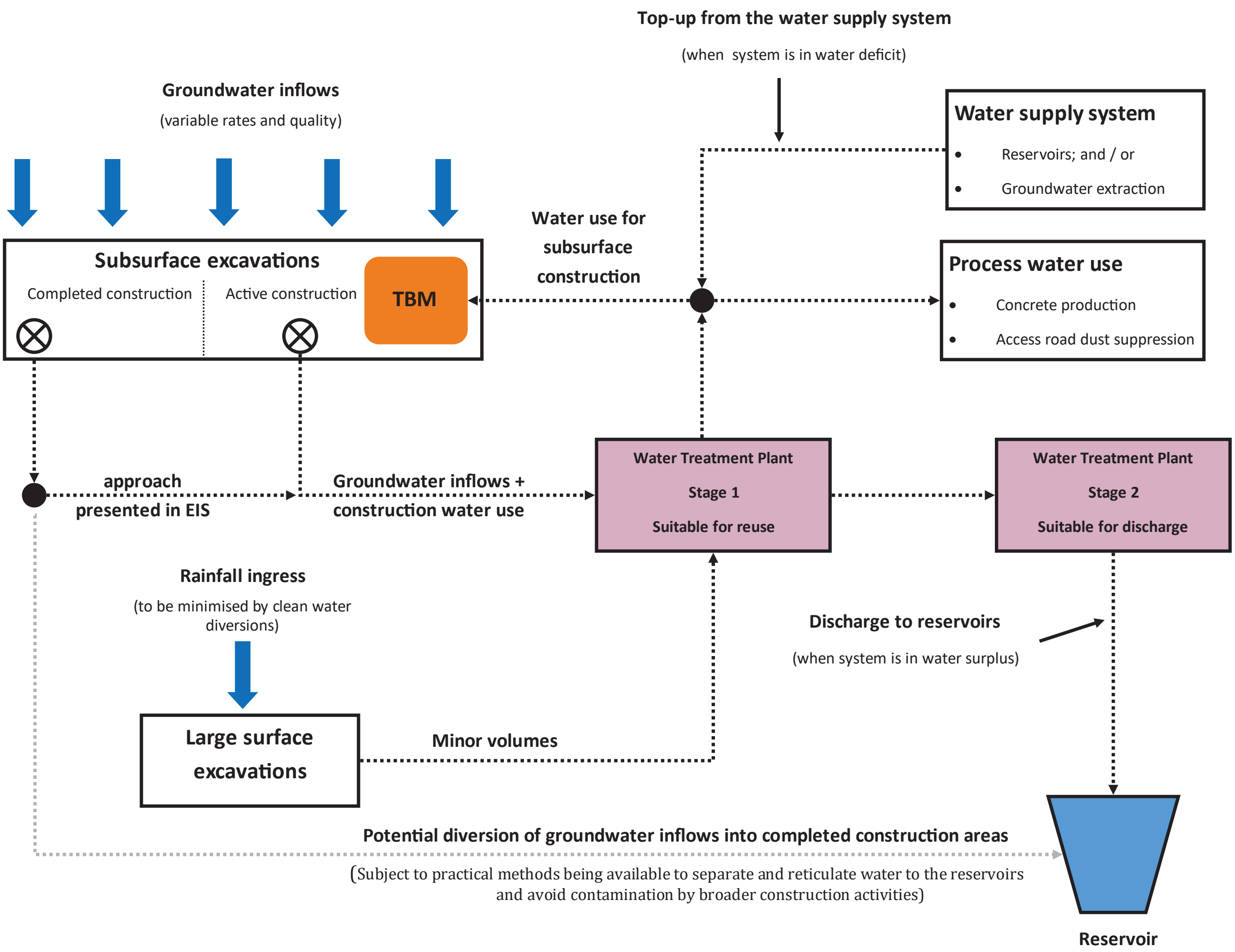

Figure 4.1 Process water system – conceptual framework

4.1.1 Talbingo and Tantangara system extents

The Tantangara and Talbingo process water systems will manage water pumped from connected subsurface excavations. Figure 4.2 shows the extent of subsurface excavations connected to each system. As the volume and water quality of groundwater inflows to underground excavations will be a key contributing factor to the process water system, the following groundwater quality categories have been established to collectively describe inflows from geological units that have similar groundwater quality characteristics:

- Plateau – includes the Boggy Plains Suite, Gooandra Volcanics, Kellys Plain Volcanics, Tantangara Formation and Temperance Formation geological units.
- West ravine – includes the Ravine Beds West geological unit.
- East ravine – includes the Boraig Group and Ravine Beds East geological units.

Figure 4.2 shows the extent of each groundwater quality category. The groundwater quality characteristics of each category are discussed in Section 4.3.1. Refer to the WCR for more information on geological units and associated groundwater quality.

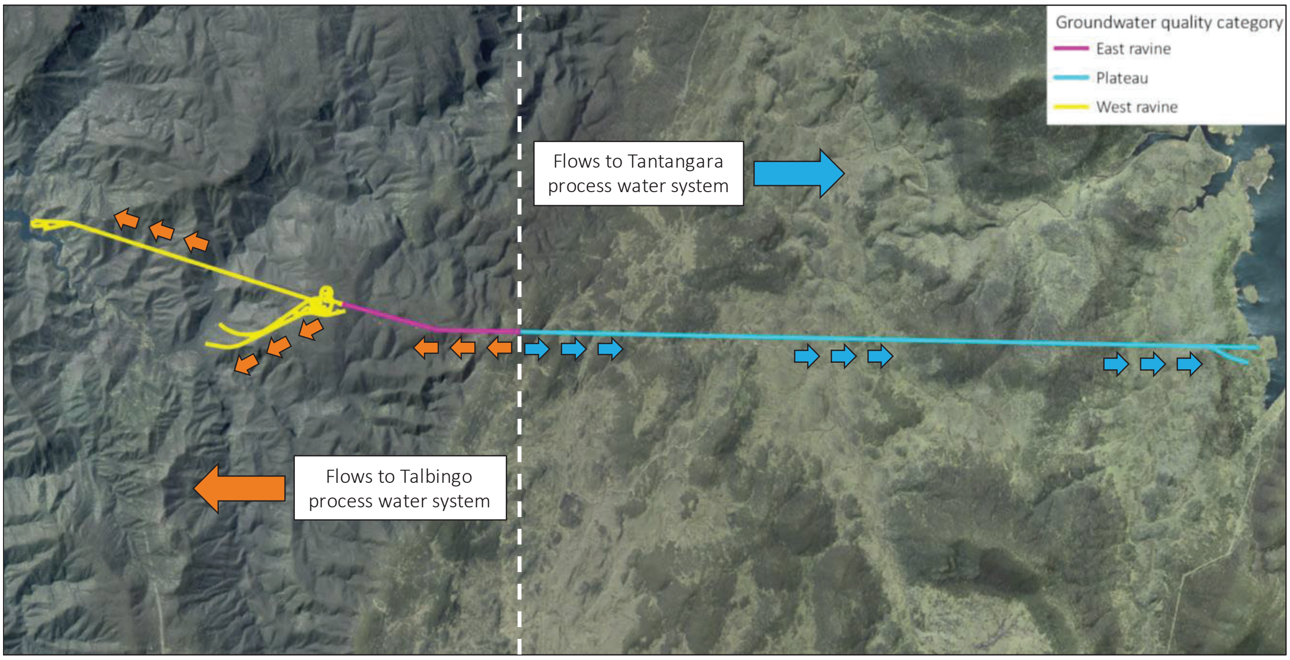

Figure 4.2 Groundwater quality categories and process water system extent

4.1.2 Chapter structure

This chapter describes the process water system and is structured as follows:

- Section 4.2 describes a conceptual water balance and estimated discharge and top-up profiles from the Tantangara and Talbingo process water systems;
- Section 4.3 describes the expected water quality of untreated process water;
- Section 4.4 describes the proposed management approach; and
- Section 4.5 describes discharge characteristics in terms of volume and water quality.

Residual impacts associated with the discharge of process water to reservoirs is described in Chapter 8.

4.2 Conceptual water balance

4.2.1 Overview

A conceptual water balance model has been developed for the Tantangara and Talbingo process water systems. The purpose of the model is to estimate the discharge and top-up profiles from each system over the construction phase of the project.

The water balance is informed by:

- groundwater inflow estimates that were established by the groundwater model developed for Snowy 2.0 Main Works (modelling report, Annexure B to the water assessment); and
- process water usage estimates that were provided by the construction contractor.

The following sections describe key water balance assumptions and results. Model methods, assumptions and results are described in more detail in Attachment C.

For the purposes of water balance modelling it was assumed the process water system would be decommissioned 5.1 years into the project timeframe. This aligned with the timeframes applied to the groundwater model developed for Main Works (modelling report, Annexure B to the water assessment).

4.2.2 System inflows

As indicated in Figure 4.1, the following process water system inflows will occur:

- groundwater inflows into subsurface excavations. Inflows will accumulate in sumps that will be dewatered to the process water system;
- water pumped from sumps of large surface excavations (WM 2.6); and
- top-up water from the water supply system.

This section describes each of these inflows further.

i Groundwater inflows

The groundwater model developed for Snowy 2.0 Main Works (modelling report, Annexure B to the water assessment) provides an estimate of groundwater inflow volumes over the construction phase of the project. Figure 4.3 and Figure 4.4 show the groundwater inflows into the Tantangara and Talbingo process water systems respectively and notes the contribution from each groundwater quality category (as described in Section 4.1.1).

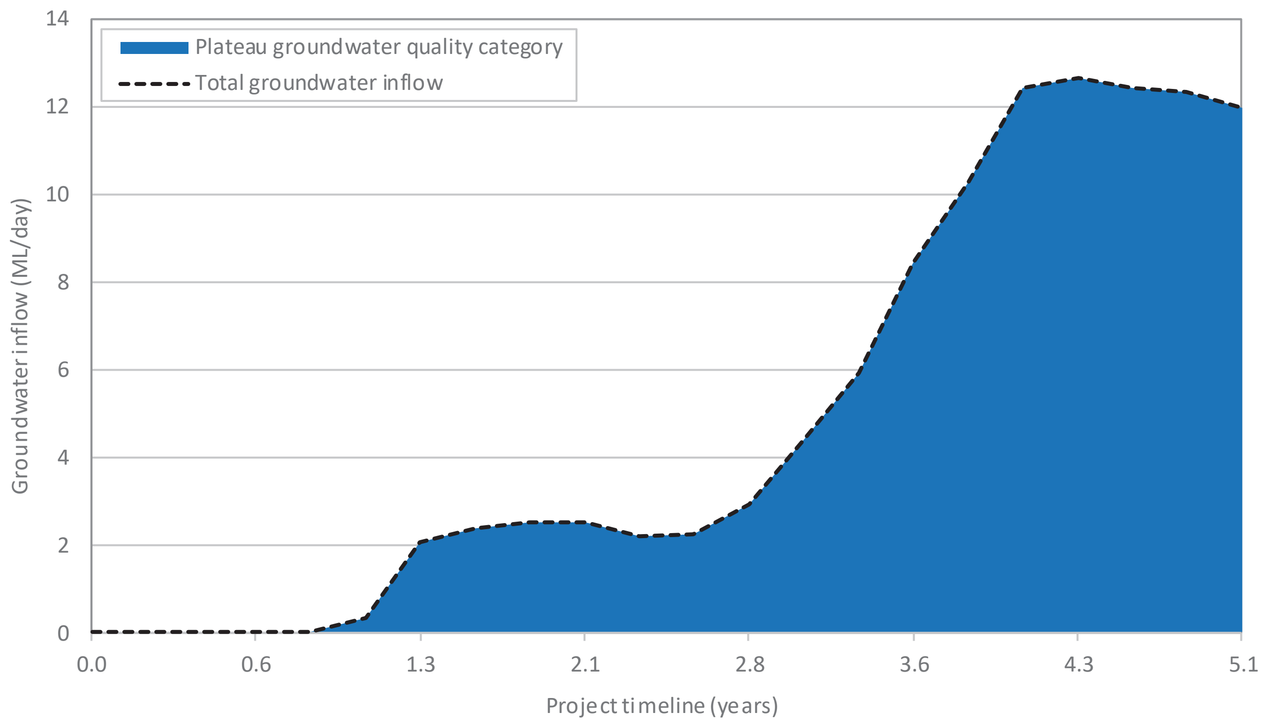

Figure 4.3 Groundwater inflow estimates – Tantangara process water system

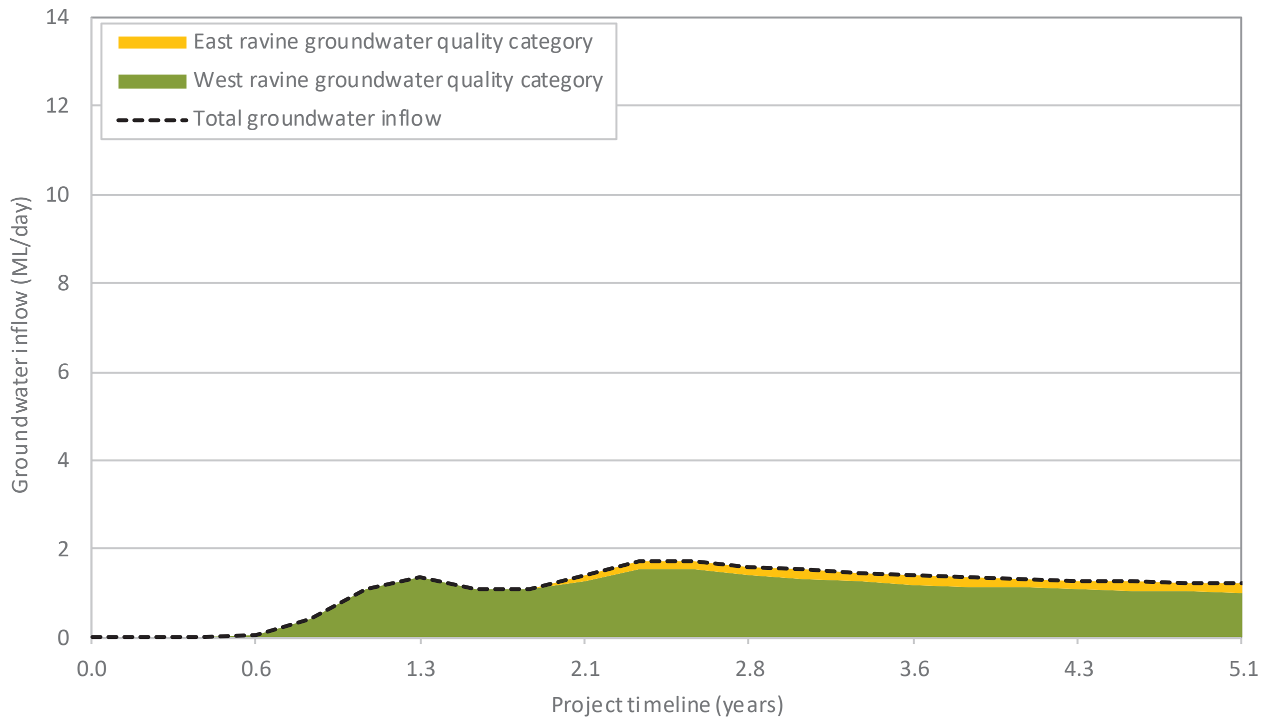

Figure 4.4 Groundwater inflow estimates – Talbingo process water system

ii Dewatering surface excavations

As described in Section 3.4.7 (WM 2.6), water that accumulates in the sumps of large surface excavations such as tunnel intakes may have poorer water quality due to construction activities. Accordingly, water may be dewatered to the process water system if alternatives such as disposal via dust suppression are not practical.

Inflows into surface excavations will occur from direct rainfall and groundwater ingress. Table 4.1 describes large surface excavations that will be connected to the process water system and notes the contributing catchment area and relevant stormwater figure reference (as presented in Chapter 3). It is noted that the inflow contribution from large surface excavations is expected to be minor in comparison to groundwater inflow volumes.

Table 4.1 Large surface excavations (WM 2.6)

Large surface excavation	Contributing catchment area	Stormwater figure reference
Tantangara intake	6 ha	Figure 3.10
Talbingo intake	3 ha	Figure 3.4

iii Top-up from the water supply system

The process water system will be topped up with water from the water supply system (described in Section 6.1). System top-ups will only be required when net usage exceeds net inflows. System top-ups are estimated by the water balance and are provided in Section 4.2.4.

4.2.3 Process water usage

As indicated in Figure 4.1, process water will be used for:

- access road dust suppression;
- concrete production; and
- underground construction – primarily for TBM cooling and dust suppression and drilling and grouting.

Water used for access road dust suppression and concrete production is expected to be lost from the system. Most water used for underground construction is expected to accumulate in tunnel sumps along with groundwater inflows. As the tunnel sumps will be dewatered back to the process water system, water use for underground construction is expected to have a negligible net usage rate. Hence, the net process water usage from each system will be approximately the sum of water used for concrete production and access road dust suppression.

Figure 4.5 shows the net usage profiles for both the Tantangara and Talbingo process water systems. The groundwater inflow profile is also shown for context. Refer to Attachment C for a break-down of net and gross process water uses.

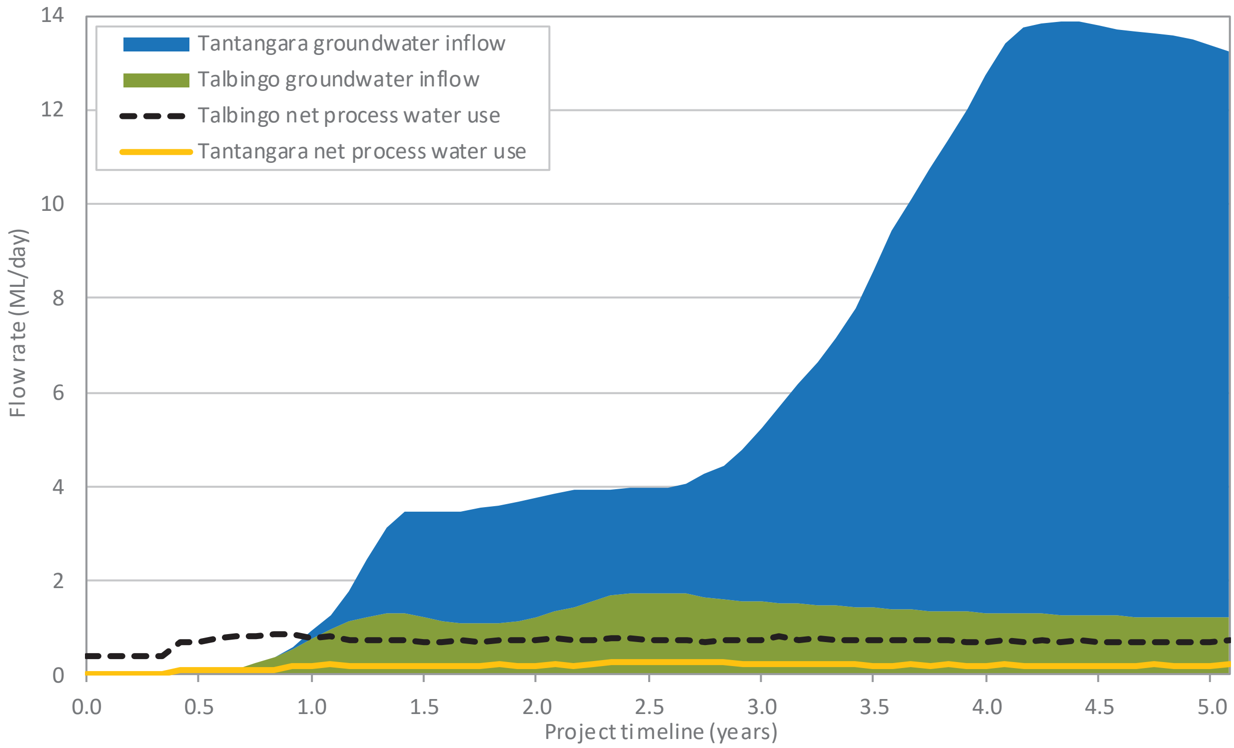

Figure 4.5 Process water usage profile

4.2.4 Water balance results

The water balance model was applied to estimate process water system discharge and top-up profiles over the construction phase of the project. These profiles are shown in Figure 4.6 and Figure 4.7 for the Tantangara and Talbingo process water system respectively. The groundwater inflow and net usage rates are also shown for context. Table 4.2 provides the peak discharge and top-up rates for each system.

Water balance results are also presented in flow chart format in Attachment C.

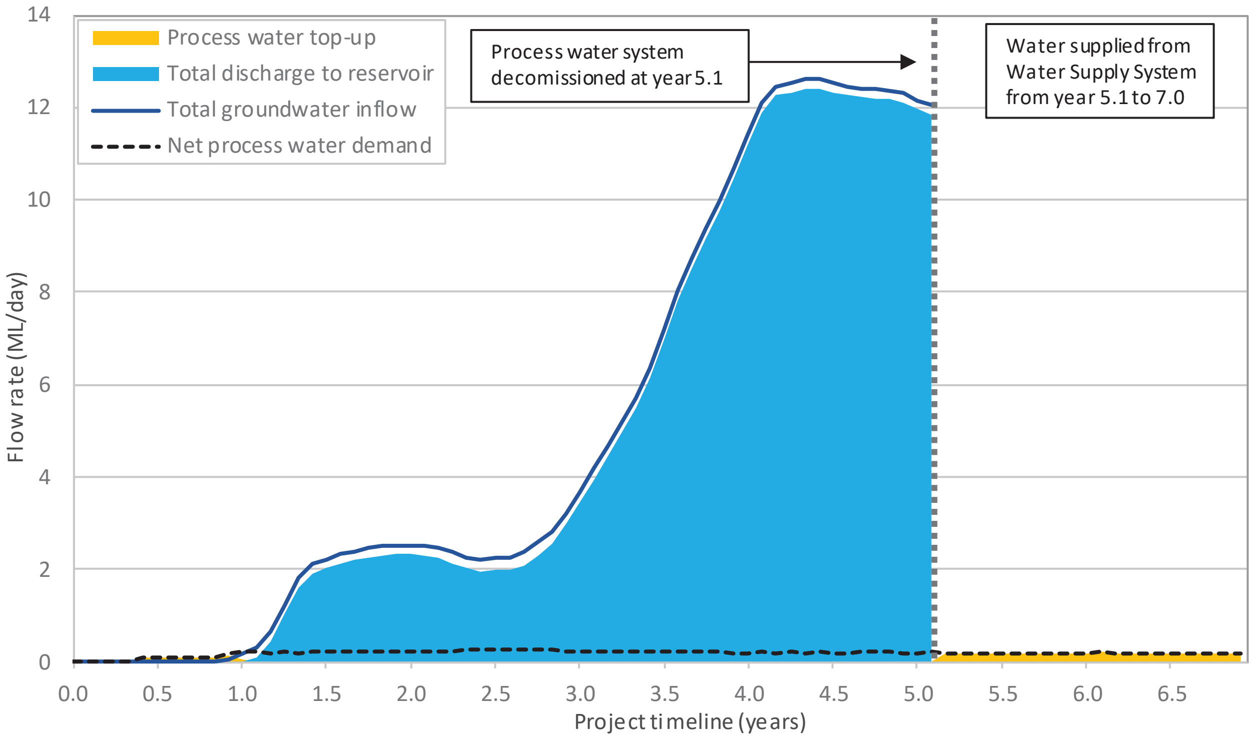

Figure 4.6 Water balance results summary – Tantangara process water system

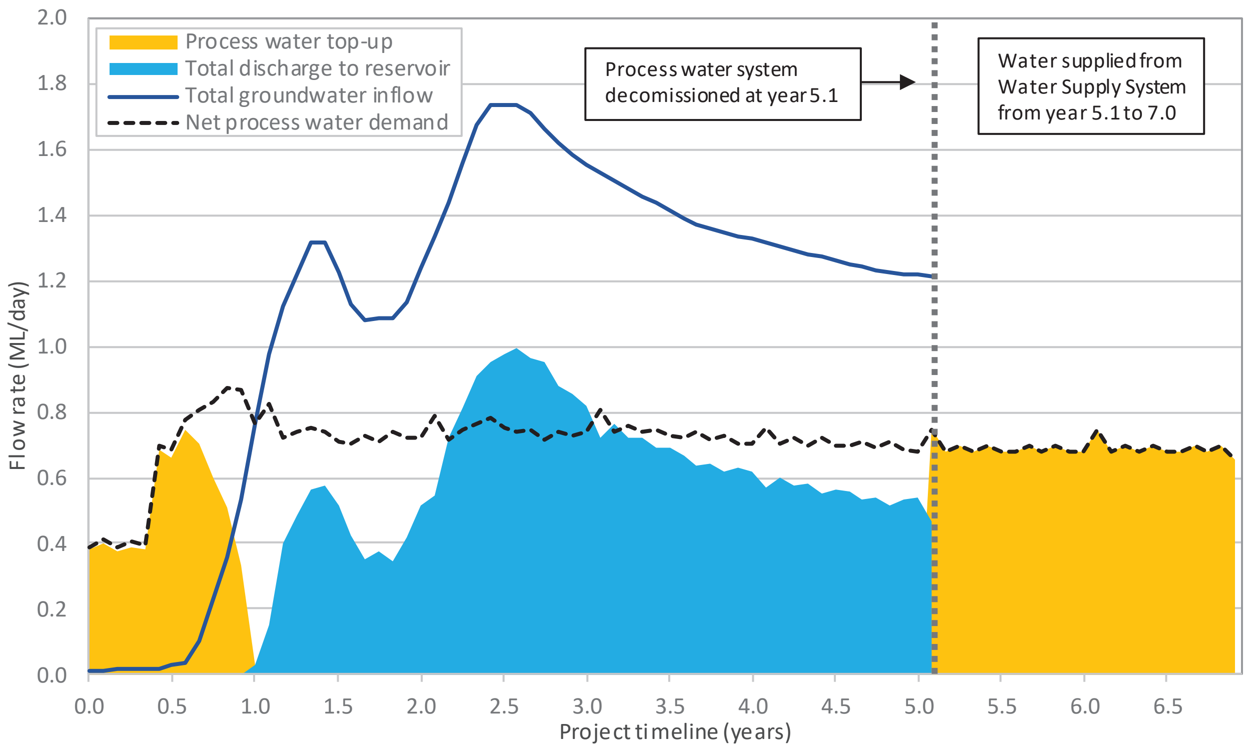

Figure 4.7 Water balance results summary – Talbingo process water system

Table 4.2 Peak discharge and top-up rates

Process water system	Peak top-up rate	Peak discharge rate
Tantangara	6 ML/month or 0.2 ML/day	385 ML/month or 12.4 ML/day
Talbingo	23 ML/month or 0.7 ML/day	31 ML/month or 1.0 ML/day

4.3 Process water quality

As described in Figure 4.1, the process water system will manage water pumped from sumps in subsurface and large surface excavations. The water quality of this water will be a function of:

- the groundwater inflow quality;
- any degradation by construction activities; and
- any degradation due to exposure (via excavation) of material that is PAF.

This section describes each of these factors. This information has been used to inform the management approach (Section 4.4) and discharge characteristics (Section 4.5).

4.3.1 Groundwater inflow characteristics

Section 4.1.1 established groundwater quality categories for geological units that have similar groundwater quality characteristics. Table 4.3 provides the 20^{th}, 50^{th} and 80^{th} percentile values for key analytes. The following information is also provided for context:

- For each category, the receiving process water system is noted along with the maximum groundwater inflow contribution (expressed as a percentage of total inflows) from the category. Groundwater inflows from each category are described in Figure 4.3 and Figure 4.4.
- WQOs for the receiving water (reservoirs) are provided in the water assessment. Refer to the water assessment for further information on the WQOs for reservoirs.

It is noted that Table 4.3 only provides information on metals that have an 80^{th} percentile value greater than the relevant WQO value. Other metals are not expected to be analytes of concern. Refer to the WCR for more information on the groundwater monitoring program, geological units and associated groundwater quality.

Table 4.3 Groundwater inflow quality characteristics

Groundwater quality category and associated geological units			**Plateau** (Boggy Plains Suite, Gooandra Volcanics, Kellys Plain Volcanics, Tantangara Formation, Temperance Formation)			**West ravine** (Ravine Beds West)			**East ravine** (Boraig Group, Ravine Beds East)		
Receiving process water system			**Tantangara** (100% of groundwater inflows)			**Talbingo** (up to 100% of groundwater inflows)			**Talbingo** (up to 16% of groundwater inflows)		
	Unit	**WQO**	**20th Percentile**	**50th Percentile**	**80th Percentile**	**20th Percentile**	**50th Percentile**	**80th Percentile**	**20th Percentile**	**50th Percentile**	**80th Percentile**
Field parameters											
Electrical conductivity	µS/cm	20-30	**74**	**126**	**207**	**433**	**677**	**1,654**	**175**	**320**	**393**
Total dissolved solids	mg/L	-	50	85	134	295	442	1,076	120	228	242
Analytical results – nutrients											
Ammonia as N	mg/L	0.01	<0.01	<0.01	**0.02**	**0.03**	**0.21**	**0.23**	<0.01	0.01	**0.04**
Total nitrogen as N	mg/L	0.35	<0.01	<0.1	0.2	0.1	0.2	**0.44**	<0.1	<0.1	**0.4**
Total phosphorus as P	mg/L	0.01	<0.01	**0.02**	**0.08**	<0.01	**0.03**	**0.07**	**0.02**	**0.06**	**0.28**
Analytical results – inorganics											
Cyanide	mg/L	0.007	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Fluoride	mg/L	2.4	<0.1	0.1	0.3	0.7	1.8	**3.7**	<0.1	0.1	1.4
Analytical results – metals (field filtered)											
Arsenic (As)	mg/L	0.013	<0.001	0.001	0.004	0.001	0.004	**0.024**	<0.001	0.004	0.005
Boron (B)	mg/L	0.37	<0.05	<0.05	<0.05	<0.05	**0.475**	**1.030**	<0.05	<0.05	0.282
Total chromium (Cr)	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.001**	<0.001	<0.001	<0.001
Cobalt (Co)	mg/L	0.0014	<0.001	<0.001	<0.001	<0.001	<0.001	**0.002**	<0.001	<0.001	<0.001
Copper (Cu)	mg/L	0.0014	<0.001	0.001	**0.004**	<0.001	<0.001	0.001	<0.001	<0.001	**0.002**
Iron (Fe)	mg/L	0.3	<0.05	0.100	**0.820**	<0.05	0.120	0.220	<0.05	0.270	**0.736**
Zinc (Zn)	mg/L	0.008	<0.005	0.005	**0.011**	<0.005	<0.005	0.007	<0.005	0.005	**0.015**

The groundwater quality characteristics presented in Table 4.3 indicate that inflows into the Tantangara and Talbingo process water systems will be different, with:

- inflows into the Tantangara system characterised as:
  - having low salinity, with electrical conductivity mostly ranging from 74 to 204 µS/cm; and
  - typical (as indicated by 50th percentile values) nutrient and metal concentrations that are similar to receiving WQO values, with the exception of total phosphorus which exceeds the WQO value.
- inflows into the Talbingo system characterised as:
  - having moderate salinity, with electrical conductivity ranging from 175 to 1,654 µS/cm; and
  - typical (as indicated by 50th percentile values) nutrient and metal concentrations that are similar to receiving WQO values with the exception of ammonia, phosphorus and boron which exceed WQO values.

4.3.2 Construction activities

Table 4.4 describes key construction activities that will occur in subsurface and large surface excavations and associated water quality influences.

Table 4.4 Process water quality – construction activity influences

Construction activity	Associated water quality influences
Use of explosives	Nitrates
TBM operation	Suspended solids
Spoil handling	Suspended solids
Concreting and grouting	Alkaline water, nitrates, metals (including but not limited to aluminium, copper, chromium, zinc)
Plant and equipment washdown	Hydrocarbons, nutrient, metals, surfactants (associated with detergents)
Leaks and spills	Hydrocarbons, metals

4.3.3 Material exposed by excavations

Surface and subsurface excavations will expose material that will remain in place at the shell or boundary of the excavation. Examples include the rock surrounding an excavated tunnel or rock benching in a stabilised surface excavation. Some exposed material may contain PAF material (contamination assessment, Appendix N.1 to the EIS). Exposed PAF material may oxidise resulting in AMD characteristics (low pH, elevated metals and salts). This risk of AMD occurring is a function of minerology, exposed material surface area and groundwater saturation of material that could be potentially oxidised. All these factors are poorly understood but are likely to impact only a small portion of inflows into the process water system and therefore has a low to moderate risk of materially impacting water quality at a system level.

4.3.4 Expected water quality

It is expected that the quality of water pumped from sumps in subsurface and large surface excavations will be highly variable. Generally, the water quality is expected to reflect the quality of groundwater and surface water inflows with varying levels of degradation from construction activities. Table 4.5 describes the expected water quality characteristics of untreated process water and potential risks that have a low to moderate probability of impacting water quality at a system level.

Table 4.5 Expected water quality – untreated process water

Excavation type	Expected water quality characteristics	Potential risks[1]
Subsurface excavations – completed construction	• The water quality is expected to be similar to the quality of groundwater inflows.	• Degradation by broader construction activities (ie vehicle movements, spoil handling). • AMD may occur from some material exposed by excavations. AMD has potential to lower pH and increase metal and salt concentrations.
Subsurface excavations – construction is occurring	• Salinity levels are expected to be similar to levels in groundwater inflows. • Construction activities may result in changes to pH and increases to suspended sediment, hydrocarbons, nutrients and metal concentrations. The magnitude of degradation is expected to be highly variable.	• AMD may occur from some material exposed by excavations. AMD has potential to lower pH and increase metal and salt concentrations.
Large surface excavations – construction is occurring	• Potential for elevated suspended sediment, changes to pH, elevated nutrients and metals to be introduced by construction activities.	• AMD may occur from some material exposed by excavations. AMD has potential to lower pH and increase metal and salt concentrations.

Notes 1. Refers to an impact mechanism that has a low to moderate probability of impacting water quality at a system level.

4.4 Management approach

4.4.1 Water management risks

Risks to the receiving environment associated with process water management include:

- potential for the discharge of untreated process water into the stormwater system or receiving environment due to inadequate system design, equipment failure or stormwater ingress into the process water system; and
- changes to the ambient receiving water quality due to the discharge of treated process water into Tantangara and Talbingo reservoirs.

4.4.2 Mitigation and management

The proposed process water management approach includes:

- source controls to manage the volumes and quality of process water produced;
- re-use of process water to minimise discharge volumes and water take;
- all surplus process water will be discharged to reservoirs. Discharges to watercourses will be avoided; and

- water treatment prior to discharge to the reservoirs.

These measures are described in the following sections.

i Source controls

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

- Stormwater ingress into the process water system will be minimised to reduce the volume of water that requires management.
- Where practical, the storage and handling of chemicals that have potential to contaminate the process water system will be undertaken in bunded areas. Liquid waste streams will be disposed to an appropriate facility.
- Where practical, plant and equipment washdown will be undertaken in designated washdown bays or areas Washdown water will be captured, treated and reused to minimise or avoid discharge into the process water system.

ii Emergency discharge

Where practical, the process water system will be designed to enable emergency discharge to stormwater basins. This will minimise the risk of untreated process water entering a watercourse.

iii Process water treatment

As indicated Figure 4.1, the following stages of treatment are proposed:

- Stage 1 treatment – all process water will be treated to a suitable quality for re-use within the process water system.
- Stage 2 treatment – additional treatment will be provided for all process water that is discharged to the reservoirs.

The location and number of treatment plants will be established at detailed design. Treated (stage 2) process water will be discharged to Tantangara and Talbingo reservoirs via diffuser arrangements. Proposed discharge locations are indicated in Figure 2.2. It is expected that treatment plants will include chemical treatment, filtration, clarification, absorption and potentially ion exchange treatment processes. The most suitable treatment processes and plant configurations will be established at detailed design. Table 4.6 characterises the water quality of treated process water.

Table 4.6 Treated process water quality characteristics

Analyte	Units	WQO value	Discharge characteristics		Comments
			Likely range[1]	Median value	
Electrical conductivity	µS/cm	20–30	No treatment provided		The treatment processes will not remove dissolved solids. Hence, water salinity will not be reduced by the treatment process.
pH	-	6.5–8.0	6.5–8.0	6.5–8.0	Alkalinity and pH will be adjusted as part of the treatment processes.

Table 4.7 Treated process water quality characteristics

Analyte	Units	WQO value	Discharge characteristics		Comments
			Likely range[1]	Median value	
Turbidity	NTU	2–25	0–25	<25	Suspended solids and turbidity will be substantially reduced as part of treatment processes.
Suspended sediment	mg/L	-	0–5	<5	
Oil & grease	mg/L	-	0–5	<5	Oil and grease will be treated as part of the treatment processes.
Ammonia	mg-N/L	0.01	0.02–0.10	0.05	Nutrients will be substantially reduced by the treatment processes.
Total nitrogen	mg-N/L	0.35	0.1–0.35	0.25	
Total phosphorus	mg-P/L	0.01	0.01–0.05	0.02	
Metals and toxicants	mg/L	Note 2	WQO values occasionally exceeded	< WQO values	Metals and toxicants will be managed via source controls and the treatment processes. Notwithstanding, some metals and toxicants are expected to occasionally exceed WQO values. However, median concentrations are expected to be less than WQO values.

Notes: 1. Likely range refers to the estimated range of concentrations that could occur in treated water.
2. Default trigger values for 95% level of species protection apply. Refer to RIR (EMM, 2019) for detailed information on WQO values.

iv Summary of management measures

Table 4.8 provides a summary of proposed process water management measures.

Table 4.8 Proposed management measures: WM 2.7 – process water

Control	Description
WM 2.7.1	A process water management system will be established to: • supply water to construction activities; and • manage water that is pumped from the sumps in subsurface excavations and large surface excavations (WM 2.6). The process water system will be decommissioned once the project enters the commissioning phase and the headrace and tailrace tunnels are flooded.
WM 2.7.2	The process water system will be designed and constructed to minimise stormwater ingress into the system to reduce the volume of water that requires management.
WM 2.7.3	Where practical, the storage and handling of chemicals that have potential to contaminate the process water system will be undertaken in bunded areas. Any liquid waste streams will be disposed to an appropriate facility.
WM 2.7.4	Where practical, plant and equipment washdown will be undertaken in designated washdown bays or areas. Washdown water will be captured, treated and reused to minimise or avoid discharge into the process water system.
WM 2.7.5	Where practical, the process water system will be designed to enable emergency discharge to stormwater basins. This will reduce the risk of untreated process water entering a watercourse.
WM 2.7.6	Groundwater that accumulates in excavations where construction is complete may be diverted around the process water system (ie discharged directly to a reservoir) provided that: • water can be practically separated from the process water system and reticulated to the reservoirs; and • the water quality is similar to the water quality characteristics described in Table 4.9 for treated process water.
WM 2.7.7	All surplus process water will be treated to meet the water quality specifications provided in Table 4.6 Treated process water quality characteristics .
WM 2.7.8	All treated surplus process water will be discharged to Tantangara and Talbingo reservoirs via diffuser arrangements. Indicative discharge locations are provided in Figure 2.2. Discharges to watercourses will be avoided.

4.5 Discharge characteristics

This section describes expected process water discharge regimes and water quality characteristics. This information has been applied to assess residual impacts is Chapter 8.

4.5.1 Discharge regimes

As described in Section 4.2, process water discharges will vary over the construction phase of the project. Figure 4.3 and Figure 4.4 show the estimated discharge profiles to Tantangara and Talbingo reservoirs respectively. Peak discharge rates are provided in Table 4.2. It is noted that no diversion of groundwater from subsurface excavations where construction is completed has been accounted for in the calculation of discharge profiles.

4.5.2 Discharge water quality

Table 5.1 provides the water quality characteristics of process water discharges from the Tantangara and Talbingo process water systems. These values have been established based on the groundwater quality characteristics (as described in Table 4.3) and treated process water characteristics (as described in Table 4.6). The following values are provided:

- Likely ranges – describes the likely range water quality range; and
- Value applied to the RIA – represent a conservative estimate of typical or median discharge water quality.

Table 4.9 Discharge quality characteristics: WM 2.8 – process water

Analyte	Unit	WQO	Tantangara process water system (treated process water)		Talbingo process water system (treated process water)	
			Likely range[1]	Value applied to RIA[2]	Likely range[1]	Value applied to RIA[2]
Electrical conductivity[4]	µS/cm	20–30	70–300[4]	150[4]	400–1,800[4]	700[4]
pH	-	6.5–8.5	6.5–8.5	6.5–8.5	6.5–8.5	6.5–8.5
Turbidity	NTU	2–25	0–25	<25	0–25	<25
Suspended solids	mg/L	-	0–5	<5	0–5	<5
Oil & grease	mg/L	-	0–5	<5	0–5	<5
Ammonia	mg-N/L	0.01	0.02–0.10	0.05	0.02–0.10	0.05
Total nitrogen	mg-N/L	0.35	0.1–0.35	0.25	0.1–0.35	0.25
Total phosphorus	mg-P/L	0.01	0.01–0.05	0.02	0.01–0.05	0.02
Metals and toxicants	mg/L	Note 3	WQO values occasionally exceeded	< WQO values	WQO values occasionally exceeded	< WQO values

Notes: 1. Likely range refers to the estimated range of concentrations or water quality values. The range and values were established based on the groundwater quality characteristics (Table 4.3) and treated process water characteristics (Table 4.6).
2. RIA refers to residual impact assessment. The RIA value represents a conservative estimate of typical or median values in treated process water discharge.
3. Default trigger values for 95% level of species protection apply. Refer to the water assessment for WQO values.
4. The likely range in electrical conductivity values has been established using the 20th and 80th percentile values from Table 4.3. Some adjustments were made to account for the use of metal salt coagulants in the treatment processes and to round the numbers.

5 Water services

5.1 Overview

This chapter describes the approach to supplying potable water and managing wastewater (ie sewage) during the construction and operational phases of the project. The following information is provided:

- Potable water (water management category WM 2.8):
  - a description of supply arrangements; and
  - estimates of usage over the construction phase of the project.
- Wastewater (water management category WM 2.9):
  - estimates of wastewater loads over the construction phase of the project;
  - proposed management measures; and
  - discharge characteristics (including volume, water quality and locations).

The potable water and wastewater management systems will comprise separate systems at the Tantangara and Talbingo construction compounds. These systems are referred to as the Tantangara and Talbingo systems and will operate independently (ie they will not be connected). Residual impacts associated with the discharge of wastewater are described in Chapter 8.

5.2 Potable water – WM 2.8

5.2.1 Construction phase

Potable water will be supplied to all accommodation camps and construction facilities that will have amenities. Water will be sourced from the project's water supply system which is described in Section 6.1. Water will be treated to a potable water standard and will be either reticulated or trucked to use points.

Potable water usage demand will vary over the construction phase of the project in line with the size of the construction workforce. Figure 5.1 shows the estimated usage profile for the Tantangara and Talbingo systems over the construction phase of the project.

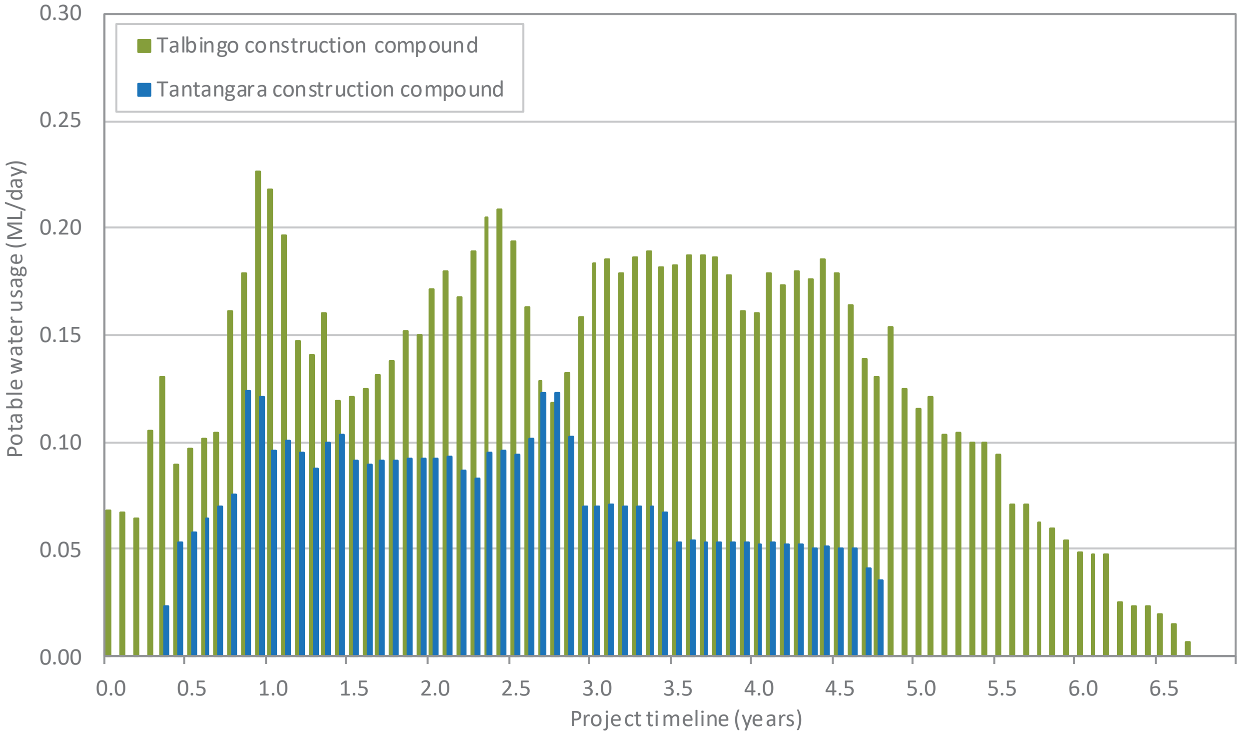

Figure 5.1 Estimated potable water use – construction phase

5.2.2 Operational phase

Small amounts of potable water will be required to supply drinking water and amenities at the power station. Supply arrangements will be established at detailed design.

5.3 Wastewater – WM 2.9

5.3.1 Construction phase

i Overview

Wastewater will be produced at all construction camps and facilities that have amenities. All wastewater will be reticulated or trucked to a wastewater treatment plant. Treated wastewater will be discharged to Tantangara and Talbingo reservoirs via diffuser arrangements.

ii Water management risks

Risks to the receiving environment associated with wastewater management include:

- changes to the ambient receiving water quality due to the discharge of treated wastewater into Tantangara and Talbingo reservoirs; and
- potential for the discharge of untreated wastewater into nearby watercourses due to equipment failure or stormwater ingress into the wastewater management system.

iii Mitigation and management

The proposed wastewater management approach includes measures to:

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

These measures are described in the following sections.

a Source controls

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

- All wastewater produced will be reticulated or trucked to a wastewater treatment plant. All reticulation and storages will be designed to restrict stormwater and groundwater ingress into the wastewater system.
- Water efficient appliances will be used to minimise wastewater 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.
- No trade waste will be discharged to the wastewater system.

b Emergency storage

All wastewater treatment plants will provide emergency storage to minimise the risk of overflows of untreated wastewater due to power outages or equipment failure. The storage volume will be calculated during detailed design based on analysis of response times for emergency trucking and offsite disposal.

c Wastewater treatment

All wastewater will be treated prior to discharge. The location and number of treatment plants will be established at detailed design. Treated wastewater will be discharged to Talbingo and Tantangara reservoirs via diffuser arrangements. Proposed discharge locations are indicated in Figure 2.2. It is expected that wastewater treatment plants will include biological and chemical treatment, filtration, disinfection and either enhanced tertiary treatment or reverse osmosis. The most suitable treatment processes and plant configurations will be established at detailed design. Table 5.1 characterises the water quality of treated wastewater discharges.

Table 5.1 Discharge quality characteristics: WM 2.9 – wastewater

Analyte	Units	WQO value	Discharge characteristics		Comments
			Likely range[1]	Value applied to RIA[2]	
pH	-	6.5–8.5	6.5–8.5	6.5–8.5	Alkalinity and pH will be adjusted as part of the treatment processes.
Turbidity	NTU	2–25	0–10	10	Suspended solids and turbidity will be substantially reduced as part of treatment processes.
Suspended solids	mg/L	-	0–5	5	
Oil & grease	mg/L	-	0–5	5	Oil and grease will be treated as part of the treatment processes.
Biological oxygen demand	mg/L	-	0–5	5	Biological oxygen demand will be substantially reduced by the treatment processes.
Ammonia	mg-N/L	0.01	0.05–0.15	0.1	Nutrients will be managed via source controls such as using low phosphorus detergents and will be substantially reduced by the treatment processes.
Total nitrogen	mg-N/L	0.35	0.2–0.5	0.35	
Total phosphorus	mg-P/L	0.01	0.03–0.09	0.06	
E-coli	cfu/100 mL	150	<1	<1	Microbiological parameters will be effectively managed by the treatment processes.
Enterococci	cfu/100 mL	35	<1	<1	
Protozoans	orgs/100 mL	nil	0	<1	
Metals and toxicants	mg/L	Note 3	WQO values occasionally exceeded	< WQO values	Metals and toxicants will be managed via source controls (such as no trade waste discharges) and the treatment processes. Notwithstanding, some metals and toxicants are expected to occasionally exceed WQO values. However, typical or median concentrations are expected to be less than WQO values.

Notes: 1. Likely range refers to the estimated range of concentrations that could occur in treated wastewater discharge. The range was established based on a review of typical industry values and an assessment of the effectiveness of the proposed controls.

2. RIA refers to residual impact assessment. The RIA value represents a conservative estimate of typical or median values in treated wastewater discharge.

3. Default trigger values for 95% level of species protection apply. Refer to the water assessment for information on WQO values.

iv Summary of controls

Table 5.2 provides a summary of proposed wastewater management measures.

Table 5.2 Proposed management measures: WM 2.9 – wastewater

Control	Description
WM 2.9.1	All wastewater produced will be reticulated or trucked to a wastewater treatment plant. All reticulation and storages will be designed to restrict stormwater and groundwater ingress into the wastewater system.
WM 2.9.2	Water efficient fittings will be used to minimise wastewater loads.
WM 2.9.3	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 2.9.4	No trade waste will be discharged to the wastewater system.

Table 5.2 Proposed management measures: WM 2.9 – wastewater

Control	Description
WM 2.9.5	Each wastewater treatment plant will include emergency storage for untreated wastewater. The storage volume will be calculated during detailed design based on analysis of response times for emergency trucking and offsite disposal.
WM 2.9.6	All wastewater will be treated to meet the water quality specifications provided in Table 5.1.
WM 2.9.7	Treated wastewater will be discharged to Talbingo and Tantangara reservoirs via diffuser arrangements. Indicative discharge locations are provided in Figure 2.2.

v Discharge characteristics

The following sections provide a summary of expected discharge regimes and water quality characteristics. This information has been applied to assess residual impacts in Chapter 8.

a Discharge regimes

Wastewater discharges will vary over the construction phase of the project in line with the size of the construction workforce. Discharge rates are expected to be similar to potable water usage rates (see Figure 5.1). Figure 5.2 shows the estimated discharge profile from the Tantangara and Talbingo systems.

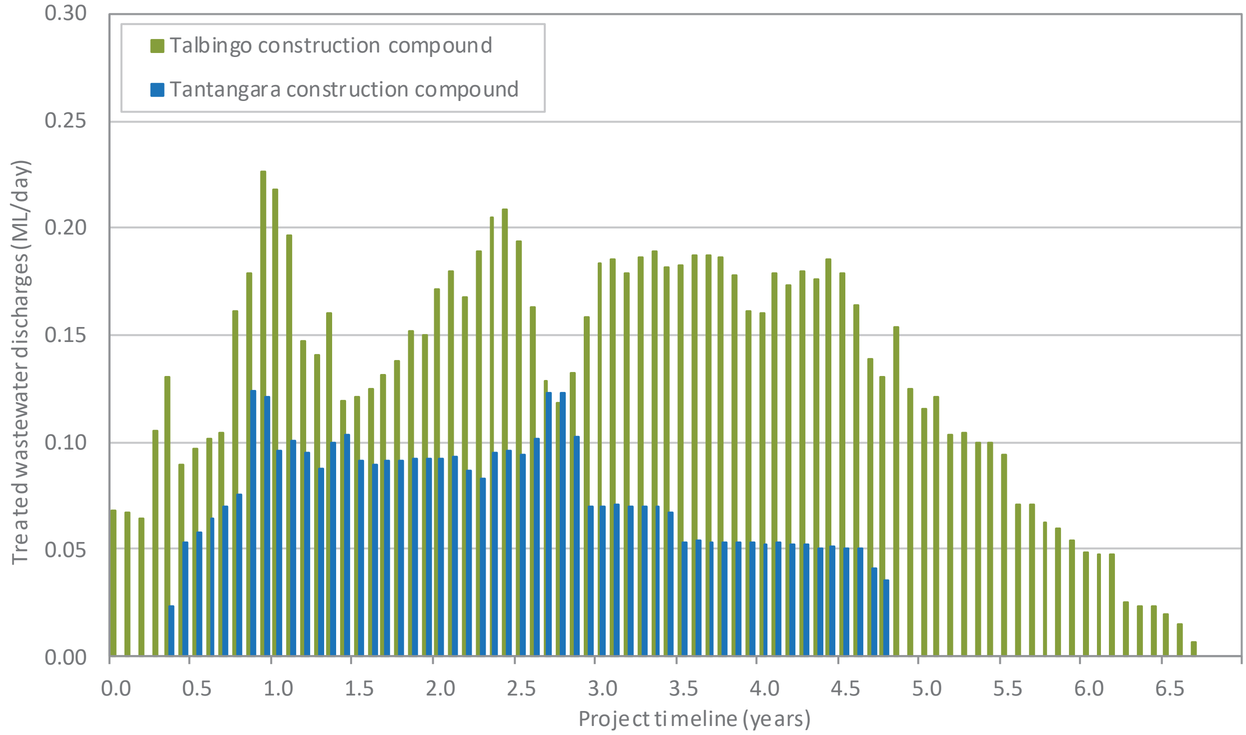

Figure 5.2 Estimated wastewater discharges – construction phase

The median and peak discharge rate have been applied to assess residual impacts associated with wastewater discharges. These values are provided in Table 5.3.

Table 5.3 Wastewater discharge rates applied to residual impacts assessment

Receiving water	Median discharge rate	Peak discharge rate
Talbingo Reservoir	3.9 ML/month or 0.1 ML/day	7.0 ML/month or 0.2 ML/day
Tantangara Reservoir	1.6 ML/month or 0.1 ML/day	3.8 ML/month or 0.1 ML/day

b Discharge water quality

Table 5.1 provides the water quality characteristics of wastewater discharges. These characteristics have been applied to assess residual impacts.

5.3.2 Operational phase

Small amounts of wastewater will be produced by amenities at the power station. All wastewater produced will be trucked to a licenced wastewater treatment plant.

6 Ancillary

6.1 Water supply system – WM 1.4

6.1.1 Management approach

A water supply system is proposed to supply water for potable water use, process water system top-up and ancillary uses such as firefighting. The system will comprise separate systems at the Tantangara and Talbingo construction compounds. These systems are referred to as the Tantangara and Talbingo water supply systems and will operate independently (ie they will not be connected). Each system will most likely source water from regional groundwater resources but will also likely source water from Tantangara and/or Talbingo Reservoirs provided required licences and approvals can be obtained. Extraction from watercourses is not proposed and will be avoided. The most suitable and available extraction locations and water sources will be established at detailed design stage.

6.1.2 Water take

Water take from the water supply system will be approximately the sum of potable water usage (described in Section 5.2.1) and process water system top-up (described in Section 4.2). Figure 6.1 show the water take profile for the Tantangara and Talbingo water supply systems. Figure 6.2 provides a summary of the peak annual water take. The water licencing approach is described in the water assessment.

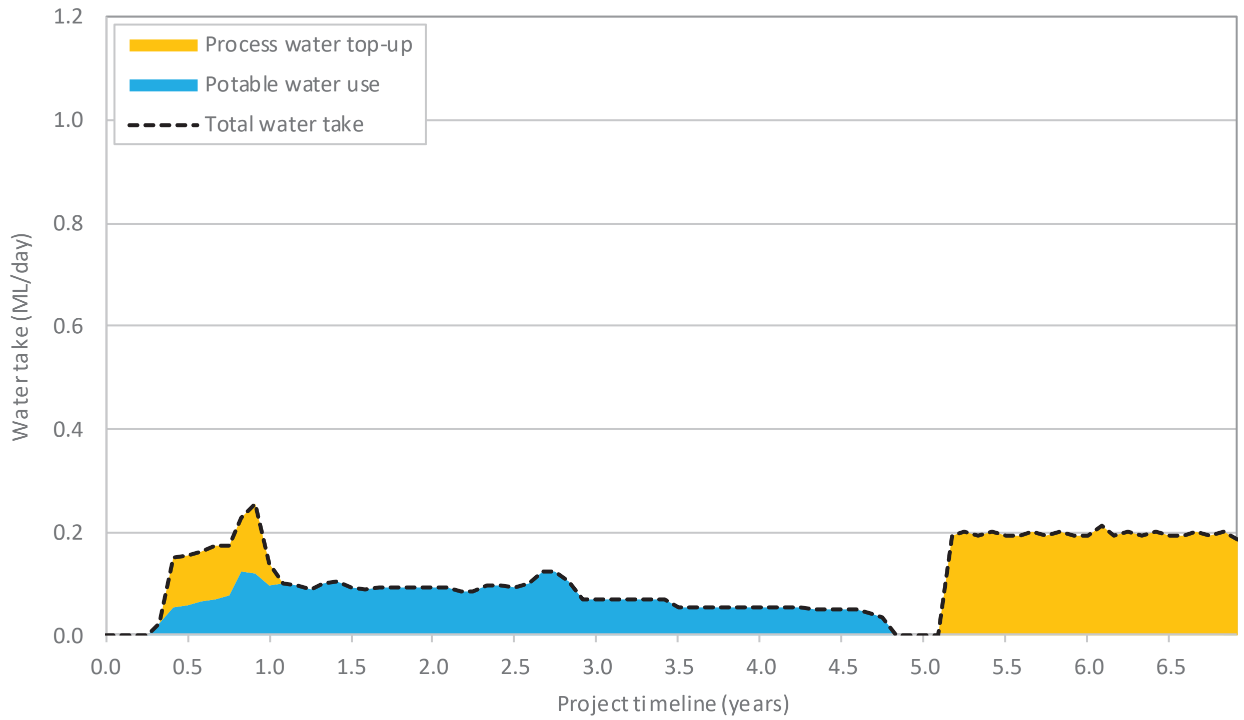

Figure 6.1 Tantangara water supply system – water take

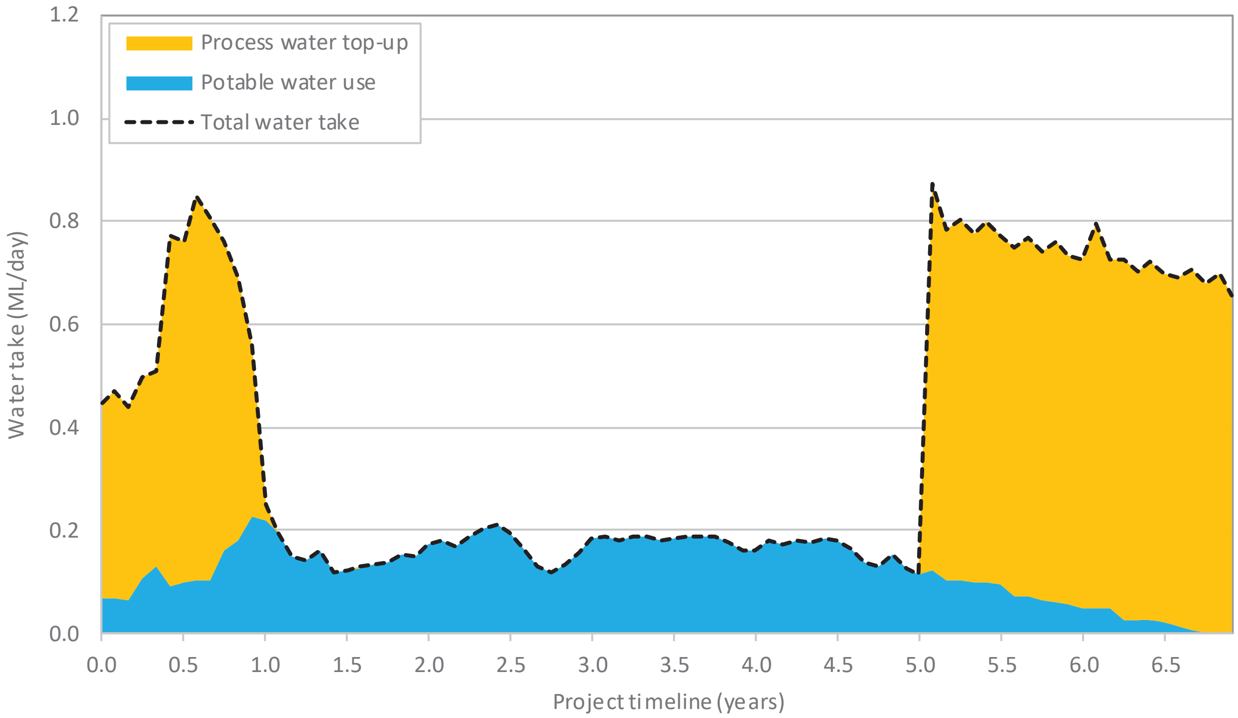

Figure 6.2 Talbingo water supply system – water take

6.2 Tunnel inflows – WM 2.10

6.2.1 Overview

Groundwater inflows are expected during excavation. To stabilise ground conditions and attempt to reduce groundwater inflows, pre and post-grouting methods are proposed:

6.2.2 Management approach

Tunnel boring machines will be equipped with drilling machines to drill drainage holes with pipes to relieve groundwater pressures. If required, pre-excavation grouting will also be used to seal-off groundwater inflow and to improve the stability of the excavation face. Post-excavation grouting, from the segmental lining, may also be used to further consolidate the surrounding rock and/or further reduce water ingress if required.

6.3 Tailrace tunnel dewatering – WM 3.4

6.3.1 Overview

The tailrace tunnel will occasionally need to be dewatered to enable maintenance access. To achieve this, approximately 550 ML of water will need to be pumped from the tunnel.

6.3.2 Management approach

It is proposed to dewater the tunnel at a rate of approximately 2 m^3/s over a period of approximately 3 days. Water will be pumped from the tunnel and reticulated through the MAT to the MAT portal. The water will be discharged into a drainage system that will convey the water to the Yarrangobilly River. The drainage system will be designed and constructed to have non-erosive hydraulic capacity and be structurally sound for the discharge rate and duration.

No impacts to the Yarrangobilly River are expected as:

- the discharge rate is well within the river's natural flow regime; and
- the water discharged will originate from either Tantangara or Talbingo reservoirs, which have similar water quality to the Yarrangobilly River (refer to the WCR for information on water quality).

6.4 Management of groundwater inflows during operational phase – WM 3.5

During operations groundwater inflows will occur into all subsurface excavations. Groundwater inflows into the power station cavern, access tunnels and any other excavation that will not be flooded will be collected and pumped into the collector tunnel or tailrace surge tank.

7 Works on waterfront land

The Water Management Act 2000 defines waterfront land as the bed of any river, lake or estuary and any land within 40 m of a riverbank, lake shore or estuary mean high water mark. Instream works refer to modifications or enhancements to a watercourse. Table 7.1 describes proposed instream works and other works on waterfront land. Proposed management approaches are also described.

Table 7.1 Works on waterfront land

Type	Description	Management approach
Instream works		
Fish weir	A fish weir is proposed in the upper reaches of Tantangara Creek to protect the Tantangara Galaxias from the threat of potential migration of the larger Climbing Galaxia (Aquatic ecology impact assessment – Appendix M.2 to the EIS). The fish weir location is shown in Figure 2.3.	The fish weir will be designed to achieve its purpose of restricting fish passage from downstream watercourses to the upper reaches of Tantangara Creek. The weir design will also seek to minimise scour and erosion of adjoining banks and the downstream watercourse reach.
Watercourse diversions	Any watercourse that traverses the project disturbance area may be temporarily or permanently diverted.	• WM 2.1 describes the management approach for temporary watercourse diversions – refer to Section 3.4.2 for further details. • WM 3.1 describes the management approach for permanent watercourse diversions – refer to Section 3.5.1 for further details.
Culverts and bridges	Culvert and bridge crossings of watercourses are proposed at numerous locations within the project disturbance area.	All culverts and bridges will be designed by a suitably qualified professional in accordance with the relevant Austroads Guidelines.
Service crossings	Service crossings of watercourses are proposed at numerous locations within the project disturbance area.	All service crossings will be designed by a suitably qualified professional in accordance with best practice methods.
Other works		
Works within 40 m of the top of bank of a watercourse or reservoir	Disturbance may occur on any land within the project disturbance area that is within 40 m of a watercourse or reservoir.	• Stormwater will be managed in accordance with the relevant water management category. • Temporary works will be rehabilitated in accordance with the rehabilitation strategy (EIS Appendix F).

8 Residual impacts

8.1 Overview

This chapter describes residual impacts due to stormwater and controlled discharges and is structured as follows:

- Section 8.2 describes impacts to watercourses due to stormwater discharges; and
- Section 8.3 describes impacts to reservoirs due to stormwater discharges to watercourses that flow into reservoirs and the controlled discharge of treated process and wastewater to reservoirs.

8.2 Impacts to watercourses

8.2.1 Overview

This section describes potential impacts to watercourses due to stormwater discharges. Stormwater discharges will occur from areas disturbed by:

- construction of surface infrastructure (WM 1.2 and 1.3) – construction phase 1 only;
- accommodation camps (WM 2.2), construction pads (WM 2.3), access roads (WM 2.4) and large stockpiles (WM 2.5) – construction phases 2 only; and
- permanent surface infrastructure (WM 3.2) and access roads (WM3.3) – operational phase (Phase 3) only.

Potential for receiving water impacts will vary based on:

- discharge characteristics (volume, frequency and water quality);
- the location, area and duration of disturbance; and
- receiving water streamflow and water quality regimes.

This section describes the above-mentioned contributing factors and potential impacts and is structured as follows:

- Section 8.2.2 describes the estimated surface disturbance profiles for the construction and operational phase of the project;
- Section 8.2.3 describes the assessment approach;
- Section 8.2.4 describes changes to streamflow regimes; and
- Section 8.2.5 describes changes to water quality.

8.2.2 Disturbance areas

The potential for stormwater discharges to change receiving water streamflow regimes and water quality is a function of the disturbance area in each catchment. The greatest disturbance will occur during construction phase 1 (initial 15 months of construction) when access roads, services, construction pads, accommodation camps and other surface infrastructure is constructed. Following peak construction phase 1 activity, the disturbance area will reduce as batters and other areas disturbed by the construction of surface infrastructure are rehabilitated. Near the end of construction phase 2, all temporary surface infrastructure will be rehabilitated in accordance with the rehabilitation strategy (Appendix F to the EIS). This will result in a significant reduction in the disturbance area.

The estimated disturbance area associated with each water management category was calculated using the project disturbance area and the conceptual layout. Attachment A describes the applied methods and assumptions and provides a break-down of disturbance in the following areas for each project phase:

- Yarrangobilly River catchment – includes disturbance areas adjacent to the Yarrangobilly River arm of Talbingo Reservoir;
- Upper Eucumbene River catchment – refers to the catchment area upstream of the Snowy Mountains Highway culverts;
- Kellys Plain Creek catchment – includes disturbance areas to the north of Kellys Plain Creek that also drain into the southern portion of Tantangara Reservoir; and
- Other areas – includes all works that will not occur within the above areas.

Table 8.1 provides a summary of the disturbance in each of the above areas. A catchment disturbance ratio (calculated as the disturbance area/the total catchment area) is also provided for each project phase.

Table 8.1 Disturbance area summary

Stormwater management category	**Assumed disturbed area by catchment (ha)**				
	Yarrangobilly River[1]	**Upper Eucumbene River**	**Kellys Plain Creek[2]**	**All other areas**	**Total**
Receiving water catchment area	27,100	564	814		
Construction phase 1 – Applies to the initial 15 months of the overall construction program					
WM 1.2 – Minor works	111	12	98	136	357
WM 1.3 – Major works	95	8	57	16	176
Total	206	20	155	152	533
Catchment disturbance percentage	0.8%	3.5%	19.0%		
Construction phase 2 – Applies for the majority of the 6 year construction program					
WM 2.2 – Accommodation camps	11	-	7	0	19
WM 2.3 – Construction pads	25	-	11	16	52
WM 2.4 – Access roads[3]	16	1	12	13	42
WM 2.5 – Large temporary stockpiles	18	12	5	-	35
Total	70	13	35	19	148
Catchment disturbance percentage	0.3%	2.3%	4.3%		

Table 8.1 Disturbance area summary

Stormwater management category	Assumed disturbed area by catchment (ha)				
	Yarrangobilly River[1]	Upper Eucumbene River	Kellys Plain Creek[2]	All other areas	Total
Operational phase (Phase 3) – Applies for perpetuity following construction					
WM 3.2 – Permanent surface infrastructure	13	-	7	-	20
WM 3.3 – Permanent access roads					
– Unsealed[3]	10	1	8	10	29
– Sealed	5	-	-	-	5
WM 3.3 Total	15	1	8	10	35
Total	28	1	15	10	55
Catchment disturbance percentage	0.1%	0.2%	1.8%		

Notes: 1. Includes disturbance areas adjacent to the Yarrangobilly River arm of Talbingo Reservoir.
2. Includes disturbance areas to the north of Kellys Plain Creek that also drain into the southern portion of Tantangara Reservoir.
3. Refers to the surface area of access roads that will be constructed or substantially modified. The use of existing access tracks that will only be slightly modified (ie by construction of overtaking bays) is not considered to result in material additional disturbance. Refer to Attachment A for further details on the assumptions applied to calculating access road disturbance areas.

8.2.3 Assessment approach

Changes to streamflow regimes and water quality have been estimated using a conceptual stormwater discharge model. The model applies simulated discharge volumes and water quality from each stormwater management category by applying:

- the discharge characteristics established in Chapter 3; and
- the relevant disturbance area (as described in Table 8.1).

The simulated discharge from all stormwater categories is combined and compared to receiving water streamflow regimes and assumed water quality to establish the potential magnitude of change. The approach to accounting for ambient receiving water conditions and describing potential change is discussed further in Section 8.2.4 (changes to streamflow) and Section 8.2.5 (changes to water quality).

Changes to streamflow and water quality are calculated at the following locations:

- Yarrangobilly River – at the Talbingo Reservoir inflow location; and
- Upper Eucumbene River – at the Snowy Mountains Highway culverts.

Changes to water quality are also calculated at:

- Kellys Plain Creek – at the Tantangara Reservoir inflow location.

Changes to streamflow were not assessed at this location as the majority of infrastructure (and disturbance) is located adjacent to the Tantangara Reservoir inundation extent (at full supply level), hence any changes to streamflow regimes will occur within the reservoirs operating range.

i Conceptual stormwater discharge model

The conceptual stormwater discharge model simulates stormwater discharges and mixing within receiving waters. The model is a daily time step model and has a 40-year simulation period (1978 to 2018).

Attachment D describes the model methods and assumptions.

8.2.4 Changes to streamflow regimes

i Streamflow regimes

The WCR describes streamflow regimes as being strongly influenced by seasonal changes to climate. Most watercourses in plateau and regional rivers such as the Yarrangobilly River have perennial streamflow regimes that have strong seasonal trends. During winter and spring months, streamflow is generally high due to persistent rainfall, low evapotranspiration rates and snowmelt influences. During summer and autumn, evapotranspiration rates are high which results in generally dry conditions. Streamflow is maintained by discharges from the shallow groundwater system and quickflow will only occur following significant rainfall events.

There are also many third order and smaller watercourses in proximity to proposed surface works that have either intermittent or ephemeral flow regimes.

Refer to the WCR for further information on watercourses and flow regimes in ravine and plateau.

ii Impact mechanisms

Runoff regimes from disturbed areas or surface infrastructure is expected to be materially different from undisturbed areas due to the removal of vegetation and establishment of engineered surfaces such as roads, hardstand and roof areas. Generally, the frequency and volume of runoff will increase. For some water management categories, these changes will be partially mitigated by stormwater controls such as sedimentation basins and rainwater tanks that capture and harvest stormwater and source controls that promote infiltration. The expected discharge regime from each water management category is described in Chapter 3.

The potential for changes to receiving water streamflow regimes is expected to be mitigated in receiving waters where the total disturbance area is small compared to the catchment area.

iii Assessment approach

Potential changes to streamflow regimes at the Yarrangobilly River and upper Eucumbene River calculation points have been estimated using the conceptual stormwater discharge model. The model compares simulated stormwater discharges to available stream gauge data. For the Yarrangobilly River calculation point, stream gauge data from the Yarrangobilly River (410574) was used. As there is no stream gauge near the upper Eucumbene River calculation point, a streamflow profile was calculated using the Eucumbene (222522) gauge record, adjusted for catchment area.

Potential changes to streamflow regimes in smaller watercourses are described qualitatively.

iv Potential changes

Potential changes to streamflow regimes are shown using flow duration curves that compare receiving water flow regimes, with and without stormwater discharges. Flow duration curves are presented for the Yarrangobilly River and upper Eucumbene River calculation points in Figure 8.1 to Figure 8.2 respectively.

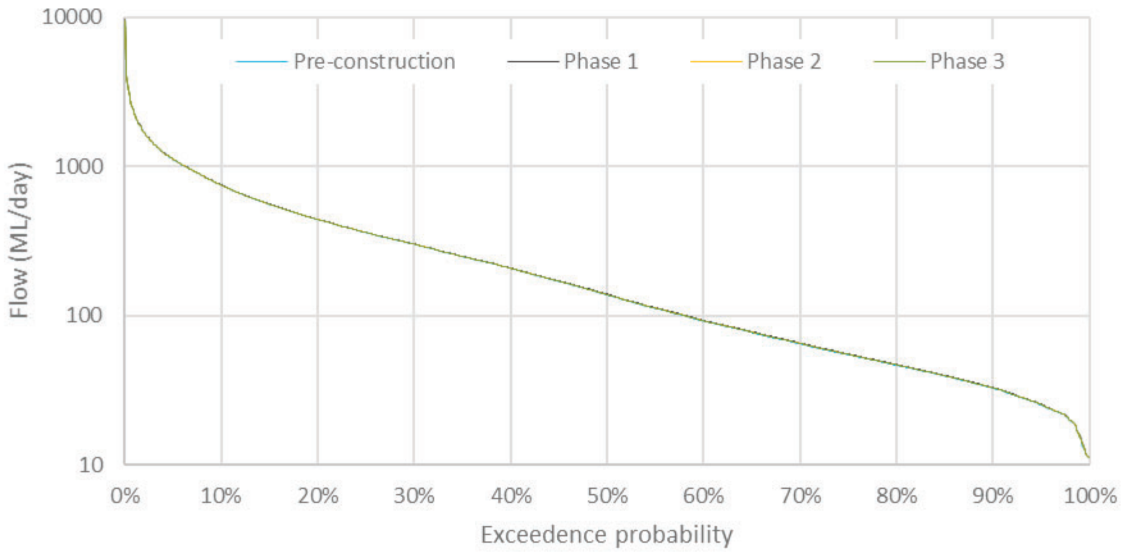

Figure 8.1 Flow duration curve – Yarrangobilly River calculation point

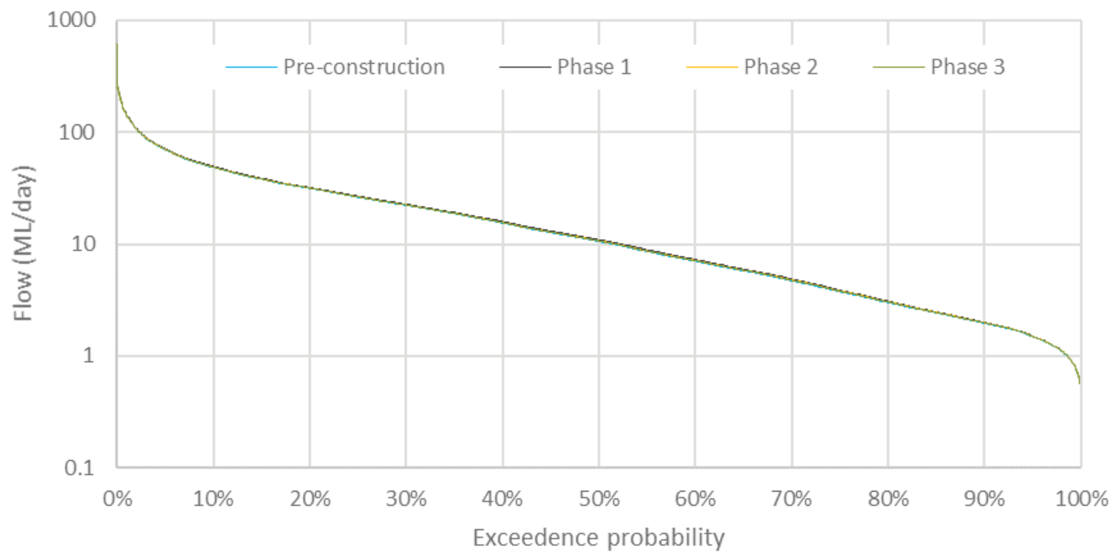

Figure 8.2 Flow duration curve – Upper Eucumbene River calculation point

Model results indicate that there will be no material changes to streamflow regimes of the Yarrangobilly River (Figure 8.1) and upper Eucumbene River (Figure 8.2). This is expected given the disturbance area is less than 5% of the total catchment area (as described in Table 8.1).

v Conclusion

Model results indicate that there will be no material changes to the streamflow regimes of the Yarrangobilly River and upper Eucumbene River due to stormwater discharges.

Some small watercourses that are immediately downstream of disturbance areas may experience increases to the frequency and magnitude of streamflow due to stormwater discharges. Impacted watercourses will primarily be 1st and 2nd order watercourses that are located within or immediately downstream of the project disturbance area. The magnitude of any change is expected to be significantly reduced following the rehabilitation of all temporary surface infrastructure that will occur near the end of construction phase 2.

8.2.5 Changes to water quality

i Baseline water quality data

Baseline surface water monitoring was undertaken between February 2018 and May 2019 in most regional (or major) watercourses within the project area and minor watercourses in vicinity to proposed surface works. Generally, monitoring was undertaken at a monthly frequency, predominantly during dry conditions. However, limited monitoring during wet weather conditions was undertaken in ravine. A review of baseline data identified:

- seasonal trends in water quality during dry weather conditions; and
- water quality during wet weather conditions is materially different to the water quality during dry weather conditions.

Table 8.2 provides a summary of relevant baseline water quality data from watercourses in plateau and ravine. Refer to table notes for terminology clarifications.

Refer to the WCR for further information on the surface water monitoring program and water quality characteristics.

Table 8.2 Summary of baseline water quality data

	Plateau	Ravine
Major watercourses[1] (Dry weather)	• pH generally ranges between 6.2 and 8.5, with occasional lower and upper bound exceedances. • Carbonate and salinity vary seasonally, with higher levels occurring in summer/autumn than winter/spring. • Low concentrations of suspended solids and low turbidity. • Total nitrogen and phosphorus concentrations exceeded WQO values occasionally. • Aluminium concentrations exceeded the WQO value on a frequent basis. Some exceedances were more than 4 x WQO values. • Copper, iron, lead and zinc concentrations exceeded WQO values on an occasional basis. Other metals are generally below WQO values.	• pH ranges between 6.2 to 8.5, with occasional lower and upper bound exceedances. • Low concentrations of suspended solids and low turbidity. • Carbonate and salinity vary seasonally, with higher levels occurring in summer/autumn than winter/spring. • Total nitrogen and phosphorus concentrations exceeded WQO values occasionally. • Aluminium concentrations in the Yarrangobilly River exceeded WQO values frequently in winter/spring and occasionally in summer/autumn. Some exceedances were more than 4 x WQO values. • Copper, chromium and zinc concentrations exceeded WQO values occasionally. Other metals are generally below WQO values.

Table 8.2 Summary of baseline water quality data

	Plateau	Ravine
Major watercourses[1] (Wet weather)	The water quality during wet weather conditions is poorly understood. It is expected that concentrations of suspended sediment, nutrients, and some metals would be higher than dry weather concentrations.	The understanding of water quality during wet weather conditions is informed by data from monitoring undertaken in March and May 2019 following moderate rainfall. Available data indicates that receiving water quality during wet weather conditions is generally poorer relative to dry weather conditions with higher turbidity, lower pH, higher nutrients and metals such as copper and zinc. The median (from five samples) copper concentration was 6 x the WQO value.
Minor watercourses (near proposed surface infrastructure)	The water quality of minor watercourses near the Tantangara construction compound is generally poorer than major watercourses, with total phosphorus, total nitrogen and aluminium all exceeding WQO values on a frequent basis. Turbidity, copper and iron exceeded WQO values on an occasional basis.	The water quality of minor watercourses in Lobs Hole is generally poorer than major watercourses, with turbidity, total phosphorus, copper and zinc exceeding WQO values on a frequent basis. Total nitrogen, arsenic and aluminium exceeded WQO values on an occasional basis.
Runoff from existing disturbed areas	No sampling from existing disturbed areas has been undertaken at plateau.	Runoff samples were collected from existing disturbed areas in Lobs Hole such as access tracks and remnant copper mining areas in May and March 2019. Disturbed area runoff is characterised as being mildly acidic, having very high suspended sediment and turbidity levels, high total nitrogen and total phosphorous, and very high aluminium and copper concentrations. During wet weather conditions (when runoff is occurring to local watercourses in Lobs Hole), the water quality in the Yarrangobilly River is expected to be degraded as it passes through Lobs Hole.

Notes: 1. Major watercourses in plateau refer to the Murrumbidgee and Eucumbene rivers, Tantangara, Gooandra, Nungar and Kellys Plain creeks. Major watercourses in ravine refers to the Yarrangobilly River and Wallaces Creek.
2. General note: exceedances are described in the WCR as:
- frequent if the WQO value was exceeded in 20% or more of samples; and
- occasional if the WQO value was exceeded in at least one sample, but in less than 20% of samples.

ii Impact mechanisms

As described in Section 3.2.2, the water quality of stormwater discharges will be a function of many factors including soil characteristics, constructed surfaces, construction activities, weather and the water management system. The expected discharge characteristics from each water management category are described in Chapter 3. Broadly, discharges from construction phase 1 (WM 1.2 and 1.3) and unsealed access roads (WM 2.4 and 3.3) are expected to have elevated (relative to WQO values) turbidity, nutrients and aluminium and copper, primarily due to stormwater contact with disturbed soils. Discharges from accommodation camps (WM 2.2), construction pads (WM 2.3) and permanent infrastructure (WM 3.2) are expected to have significantly lower turbidity, nutrients and metals. This is primarily due to runoff occurring from constructed surfaces.

The potential for changes to receiving water quality are a function of:

- discharge water quality;
- disturbance area within each catchment;
- ambient water quality; and

- the fate of pollutants post discharge including mixing, decay and assimilation.

iii Assessment approach

Potential changes to water quality at the Yarrangobilly River, upper Eucumbene River and Kellys Plain Creek calculation points has been assessed using the conceptual stormwater discharge model. Stormwater discharges were simulated using a runoff model that was parametrised to achieve the runoff characteristics described for each water management category. The model accounts for the capture and harvesting of stormwater in sedimentation basins. The water quality of discharges was applied using conservative tracers (ie no decay or assimilation is applied) using the 'RIA values' established for each category. The 'RIA values' represent a conservative estimate of typical or median discharge water quality from each water management category. The following analytes were assessed:

- physico-chemical – turbidity and suspended solids;
- nutrients – total phosphorus and nitrogen; and
- metals – aluminium and copper.

The potential magnitude of change is assessed relative to the WQO values that are established in the water assessment applying a mass balance approach. Figure 8.3 shows the model framework.

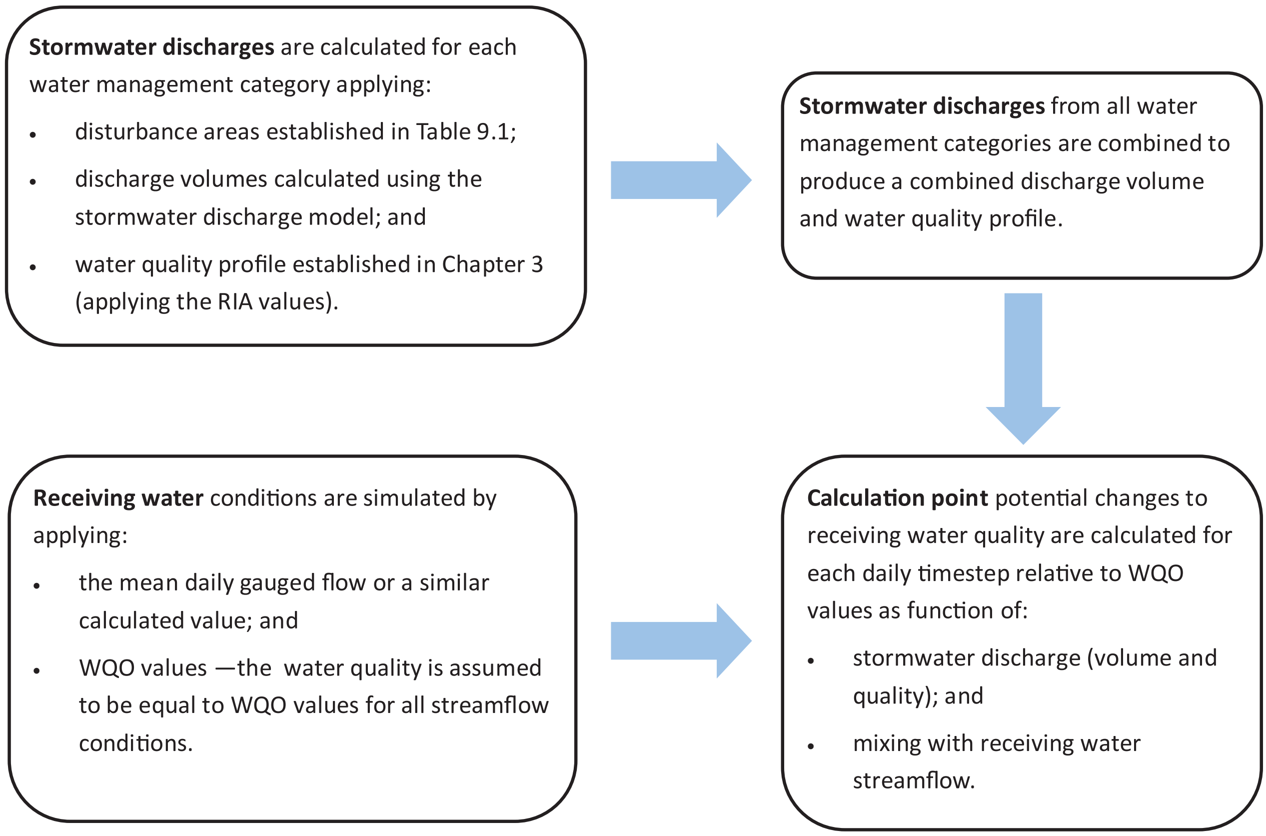

Figure 8.3 Assessment framework

Water quality changes have been assessed adequately for the purpose of this EIS and the assessment approach is deemed fit for purpose. It is noted that the assessment of absolute changes to water quality has not been undertaken because:

- Assessment of absolute changes requires a detailed understanding of receiving water quality during a range of streamflow conditions. Therefore it cannot be reliably undertaken due to the limited information on water quality during wet weather conditions (as described in Table 8.2) when changes due to stormwater discharges are most likely to occur.
- A detailed understanding of the fate of pollutants in the receiving environment is required to undertake an assessment of absolute change. This was not investigated as part of this EIS.

It is noted that:

- A mass balance approach has been applied to estimate changes in turbidity. This approach notes that turbidity is a measure of the water transparency or clarity (instead of the mass of an analyte). However, the results do provide an indication of the degree of mixing of stormwater discharges with receiving water streamflow.
- There is no official WQO value for suspended solids. A value of 10 mg/L has been applied to enable potential changes in suspended solids concentrations to be assessed.

iv Changes to water quality

Changes to water quality are described using the following categories that represent varying magnitudes of change relative to the relevant WQO value:

- no change;
- 0 to 10% increase;
- 10 to 50% increase;
- 50 to 100% increase; and
- greater than 100% increase.

Results are presented for each analyte on a seasonal and wet and dry weather basis, using the following approach:

- Results are presented for summer/autumn and winter/spring periods. This is consistent with the approach applied to characterising baseline water quality in the WCR.
- Wet weather is assumed to be any day where rainfall exceeds 5 mm.

Results are presented in chart form for each project phase at the Yarrangobilly River, upper Eucumbene River and Kellys Plain Creek calculation points. The following nomenclature is used in the chart legends:

- Summer wet – refers to wet weather conditions that occur in summer/autumn.
- Summer dry – refers to dry weather conditions that occur in summer/autumn.
- Winter wet – refers to wet weather conditions that occur in winter/spring.
- Winter dry – refers to dry weather conditions that occur in summer/autumn.

The following sections present and discuss results for each project phase.

a Phase 1 – Construction of surface infrastructure

Construction phase 1 will occur for approximately the initial 15 months of the overall construction phase of the project. The total disturbance area is estimated to be 533 ha (refer to Table 8.1 for a break-down of disturbance areas). Changes to water quality will be associated with discharges from the following water management categories:

- WM 1.2 (minor works) – discharges will occur as runoff from the water management area following any material rainfall (approximately >5 mm/day); and
- WM 1.3 (major works) – discharges will occur as overflow from sedimentation basins that may occur when the 5-day rainfall total exceeds the 85th percentile value.

Potential changes to receiving water quality are shown in:

- Figure 8.4 – Yarrangobilly River calculation point;
- Figure 8.5 – upper Eucumbene River calculation point; and
- Figure 8.6 – Kellys Plain Creek calculation point.

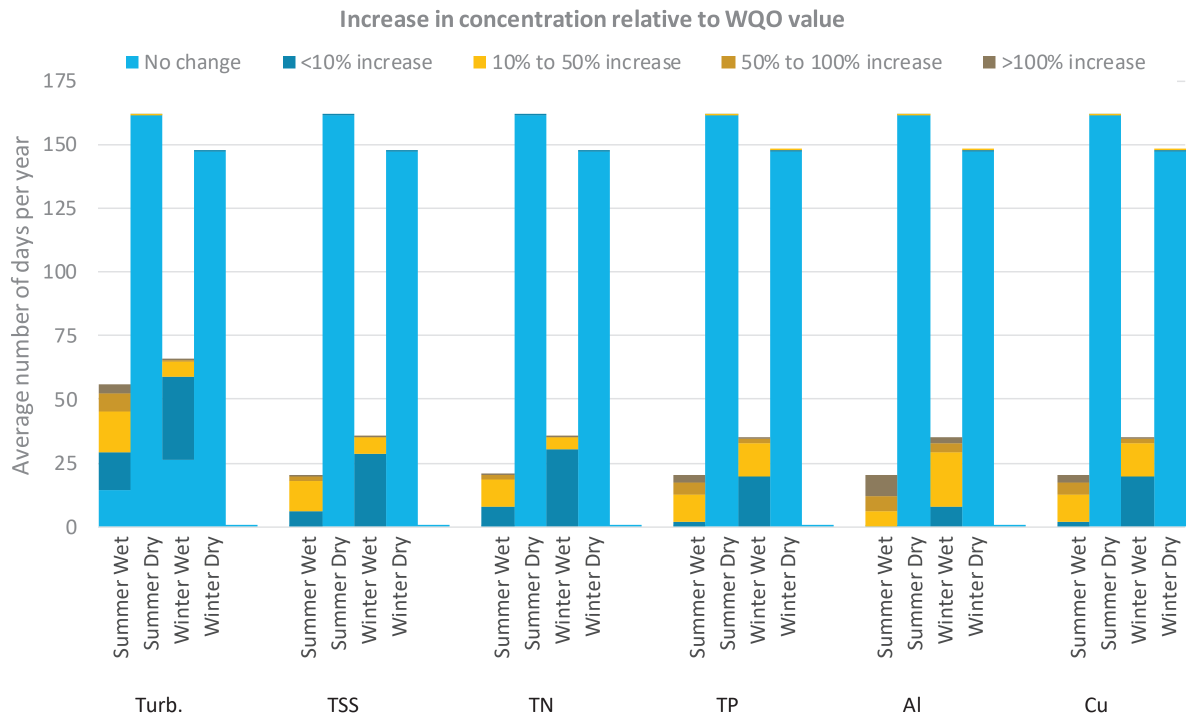

Figure 8.4 Changes to water quality – construction phase 1 – Yarrangobilly River

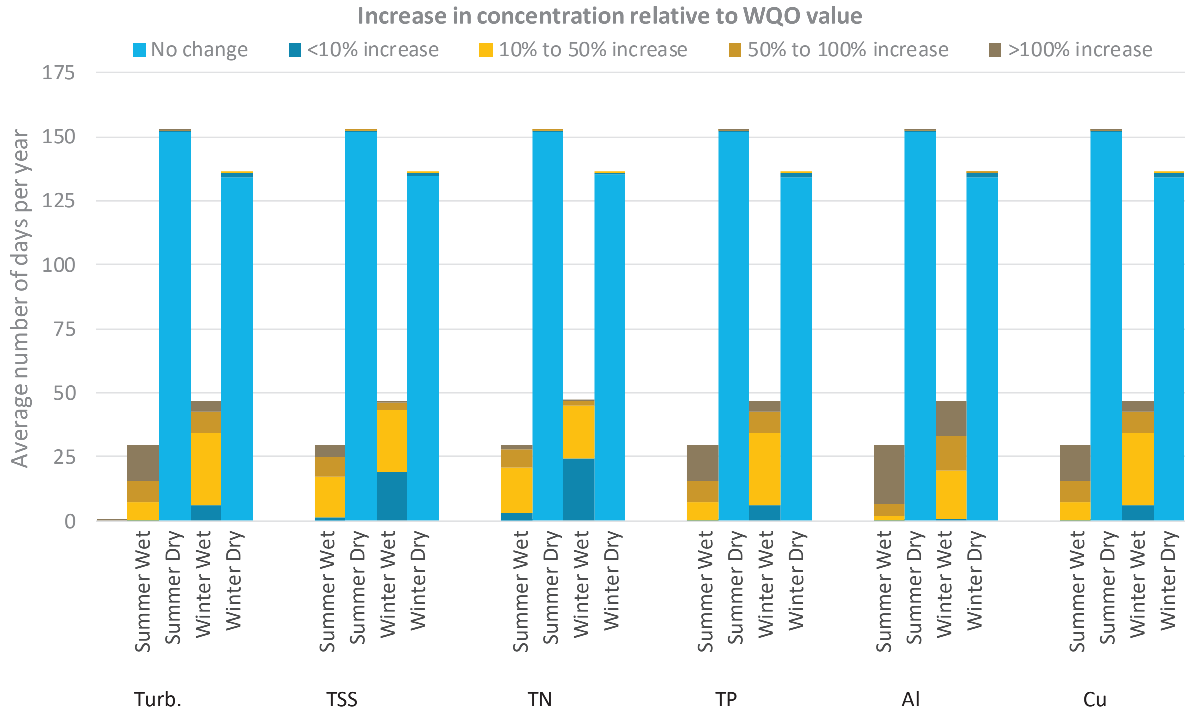

Figure 8.5 Changes to water quality – construction phase 1 – Eucumbene River

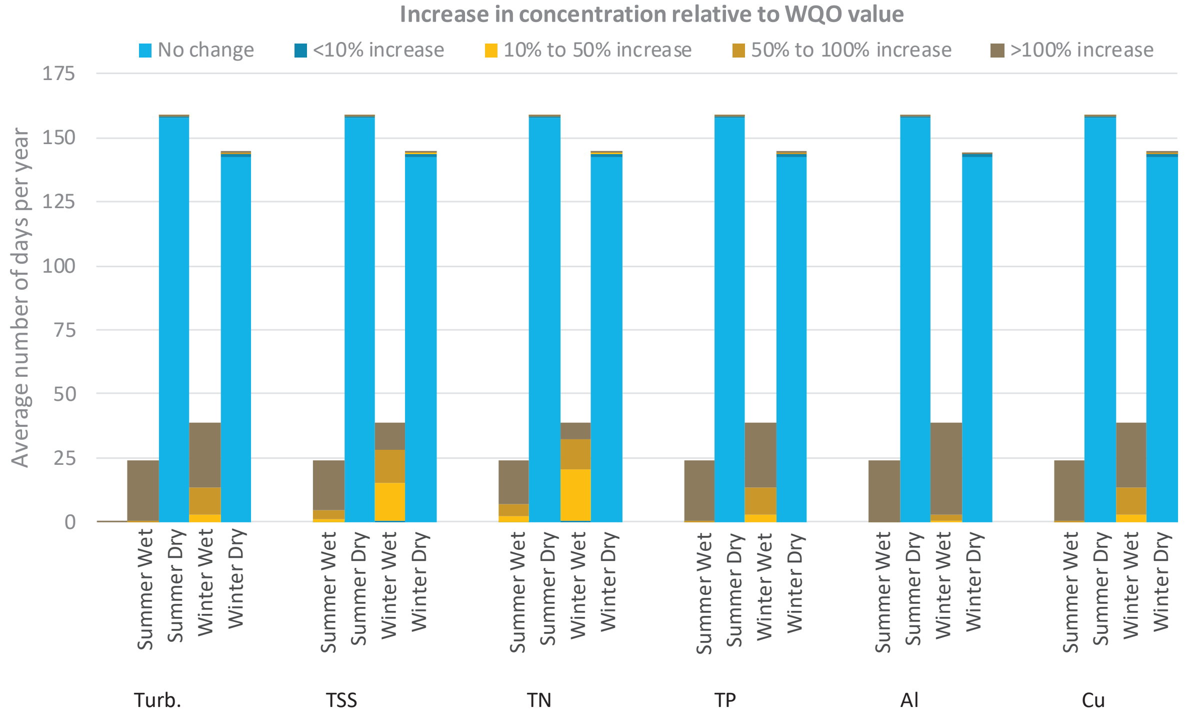

Figure 8.6 Changes to water quality – Phase 1 – Kellys Plain Creek

Model results indicate that:

- Potential changes will only occur during and shortly after wet weather conditions. No changes are expected during dry conditions due to no discharges occurring.
- The magnitude of potential change will vary based on the catchment disturbance ratio (calculated as the disturbance area/the total catchment area), with the lowest potential magnitude of change predicted at the Yarrangobilly River calculation point and the highest potential magnitude of change predicted at the Kellys Plain Creek calculation point.
- There is potential for greater magnitude changes in summer/autumn than winter/spring. This is due to lower streamflow in receiving waters during summer/autumn resulting in less mixing or dilution.

b Phase 2 – Construction of surface infrastructure

Construction phase 2 (all other construction activities) will occur for approximately 5 years following the initial construction phase 1. The total disturbance area is estimated to be 148 ha, 385 ha less than construction phase 1 due to rehabilitation of batters and other areas disturbed during construction phase 1 (refer to Table 8.1 for a break-down of disturbance areas). Changes to water quality during construction phase 2 are associated with discharges from the following water management categories:

- WM 2.4 (access roads) – discharges will occur as runoff from access roads following any material rainfall (approximately >5 mm/day); and
- WM 2.2 (accommodation camps), WM 2.3 (accommodation camps) and WM 2.5 (large stockpiles) – discharges will occur as overflow from sedimentation basins that may occur when the 5-day rainfall total exceeds the 85th percentile value.

Potential changes to receiving water quality are shown in:

- Figure 8.7 – Yarrangobilly River calculation point;
- Figure 8.8 – upper Eucumbene River calculation point; and
- Figure 8.9 – Kellys Plain Creek calculation point.

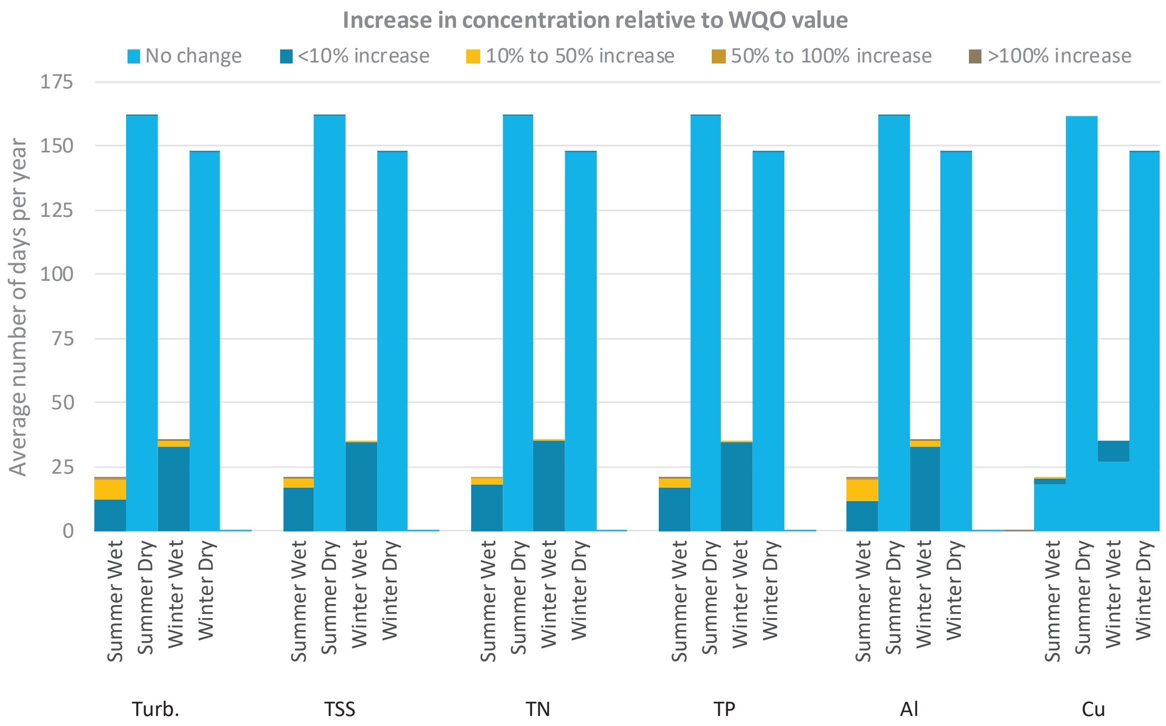

Figure 8.7 Changes to water quality – construction phase 2 – Yarrangobilly River

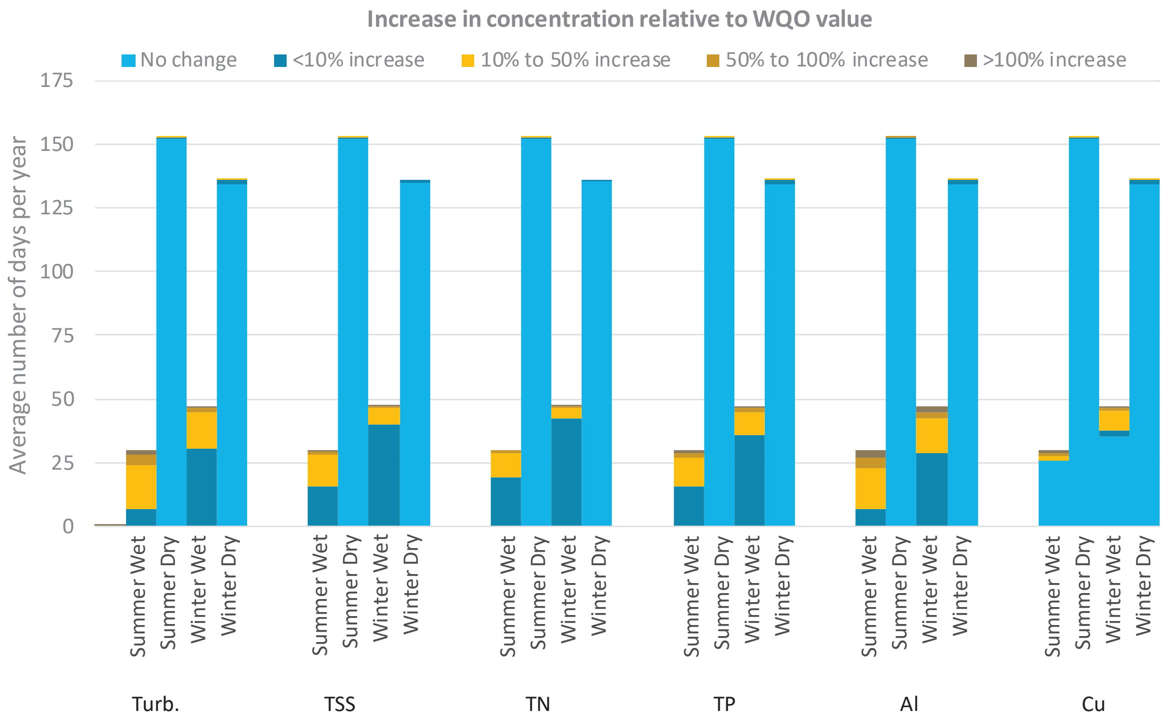

Figure 8.8 Changes to water quality – construction phase 2 – Eucumbene River

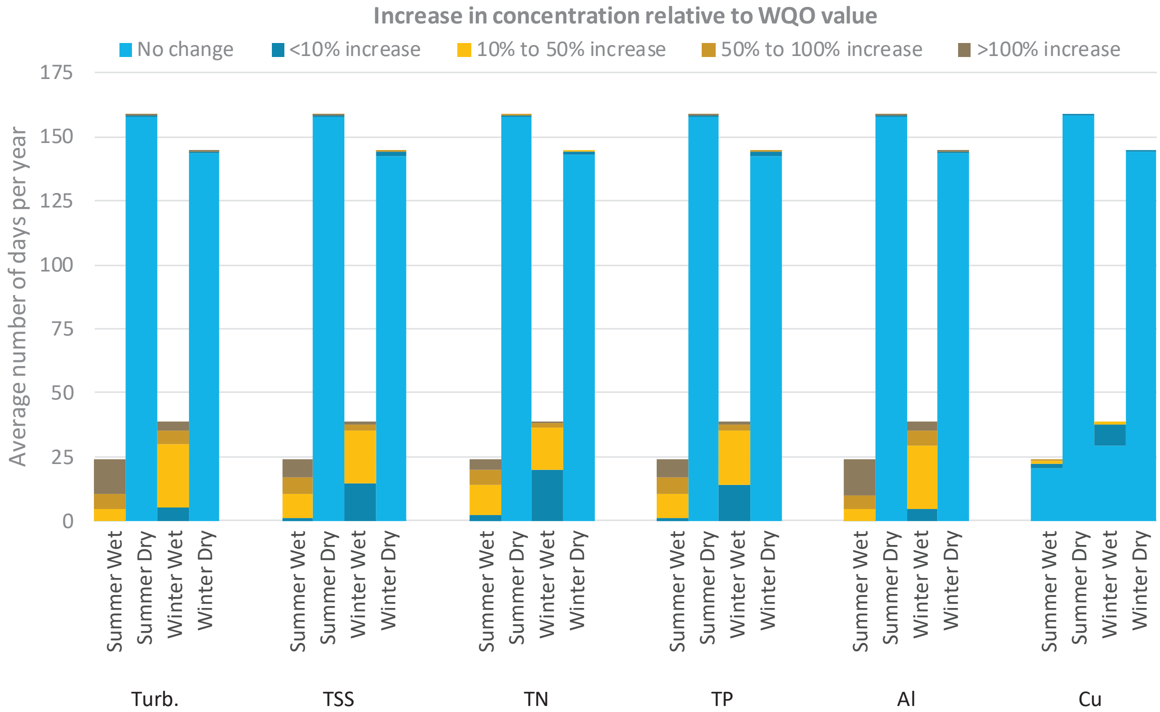

Figure 8.9 Changes to water quality – construction phase 2 – Kellys Plain Creek

Model results indicate that:

- Potential changes will only occur during and shortly after wet weather conditions. No changes are expected during dry conditions due to no discharges occurring.
- The magnitude of change is significantly lower than construction phase 1 due to a reduced disturbance and improved runoff quality.
- The magnitude of potential change will vary based on the catchment disturbance ratio (calculated as the disturbance area/the total catchment area), with the lowest potential magnitude of change predicted at the Yarrangobilly River calculation point and the highest potential magnitude of change predicted at the Kellys Plain Creek calculation point.
- There is potential for greater magnitude changes in summer/autumn than winter/spring. This is due to lower streamflow in receiving waters during summer/autumn resulting in less mixing or dilution.

c Phase 3 – Operations

The operational phase (Phase 3) will occur for perpetuity following the completion of construction. The total disturbance area is estimated to be 55 ha (refer to Table 8.1 for a break-down of disturbance areas). Changes to water quality during the operational phase are associated with discharges from the following water management categories:

- WM 3.2 (permanent infrastructure) – discharges will occur as runoff from the water management area following any material rainfall (approximately > 5 mm/day); and

- WM 3.3 (permanent access roads) – discharges will occur as runoff from access roads following any material rainfall (approximately > 5 mm/day).

Potential changes to receiving water quality are shown in:

- Figure 8.10 – Yarrangobilly River calculation point;
- Figure 8.11 – Upper Eucumbene River calculation point; and
- Figure 8.12 – Kellys Plain Creek calculation point.

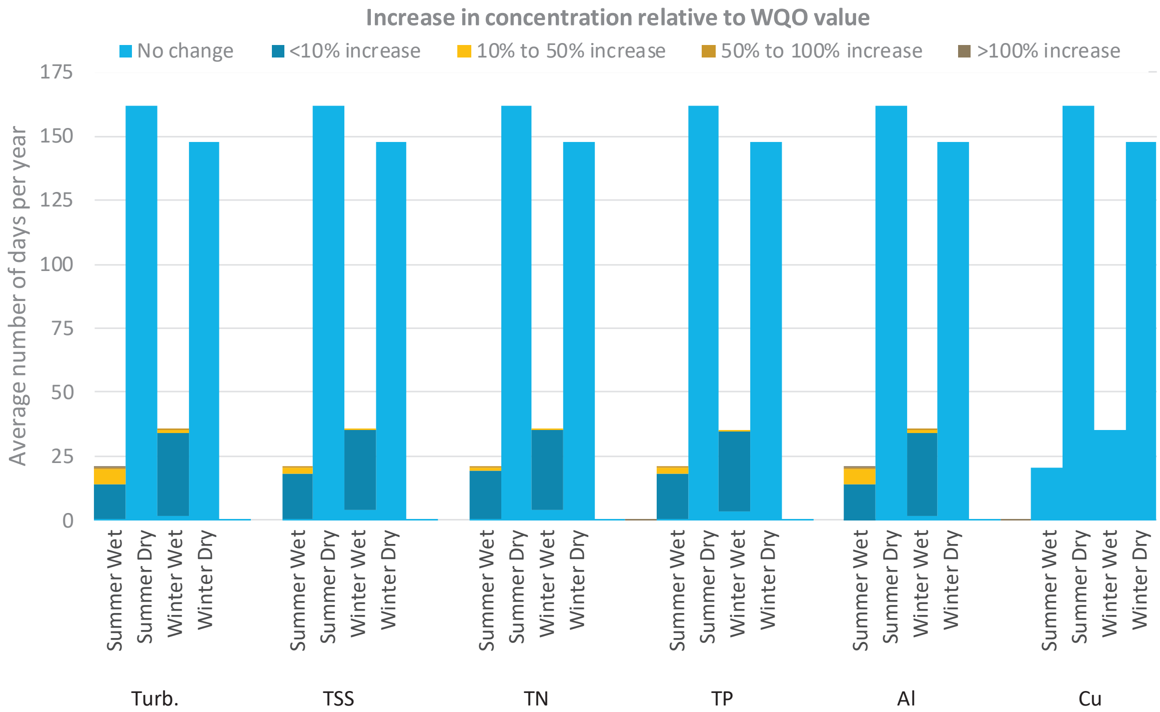

Figure 8.10 Changes to water quality – operational phase – Yarrangobilly River

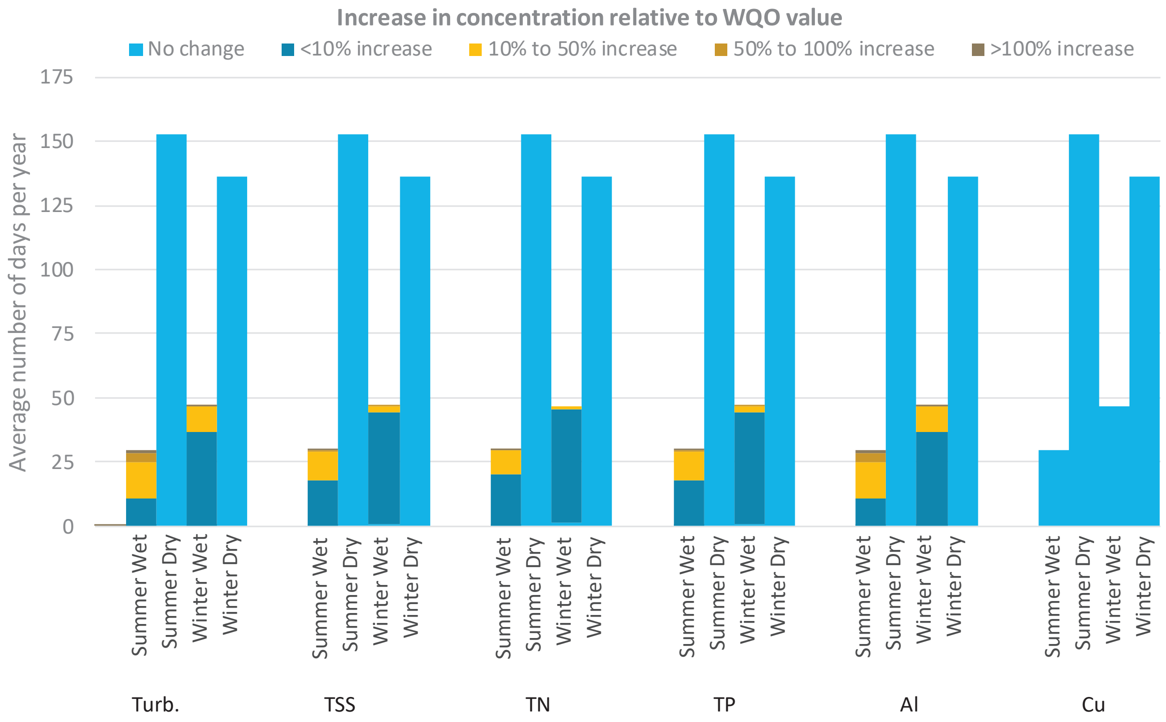

Figure 8.11 Changes to water quality – operational phase – Eucumbene River

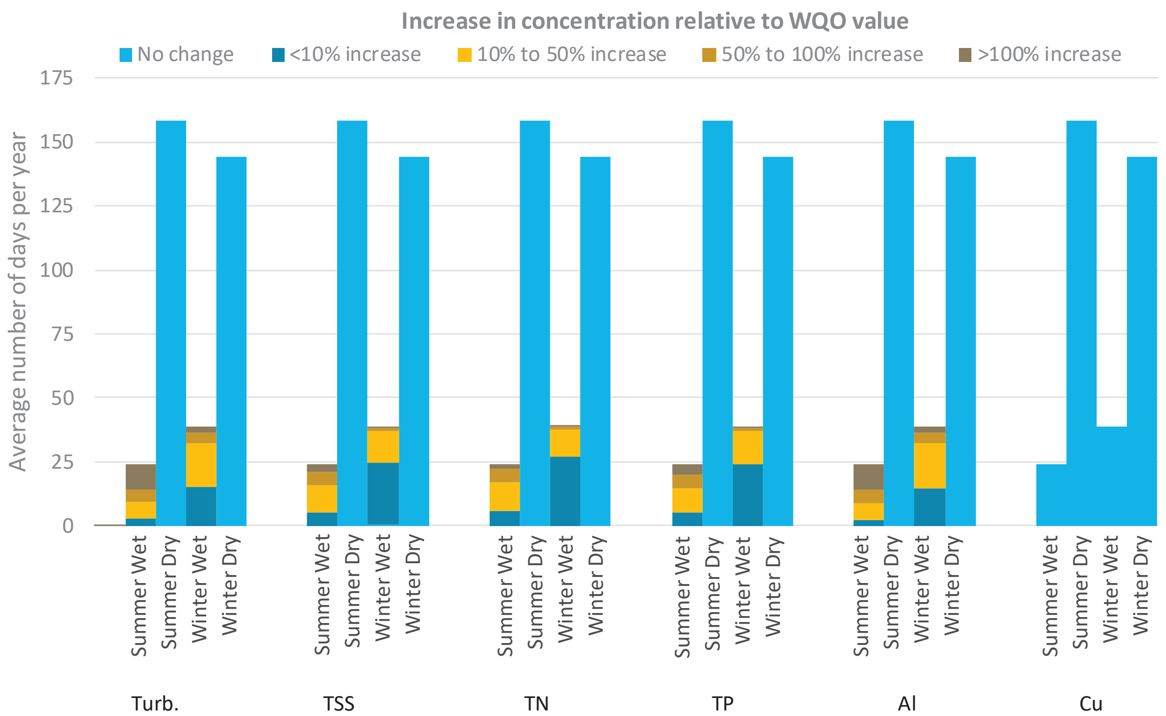

Figure 8.12 Changes to water quality – operational phase – Kellys Plain Creek

Model results indicate that:

- Potential changes will only occur during and shortly after wet weather conditions. No changes are expected during dry conditions due to no discharges occurring.
- The magnitude of change is significantly lower than construction phase 1 and 2 due to a reduced disturbance and improved runoff quality.
- The magnitude of potential change will vary based on the catchment disturbance ratio (calculated as the disturbance area/the total catchment area), with the lowest potential magnitude of change predicted at the Yarrangobilly River calculation point and the highest potential magnitude of change predicted at the Kellys Plain Creek calculation point.
- There is potential for greater magnitude changes in summer/autumn than winter/spring. This is due to lower streamflow in receiving waters during summer/autumn resulting in less mixing or dilution.

v Model sensitivity

The stormwater discharge model has been applied to estimate the potential frequency and magnitude of changes to receiving water quality. Results are presented on a seasonal and wet and dry conditions basis. Table 8.3 describes the key aspects of the model, applied approach and assumptions and the sensitivity of model results to changes in the approach and assumptions.

Table 8.3 Sensitivity to applied approach and assumptions

Aspect	Model approach/assumptions	Model sensitivity to changes to approach/assumptions
Disturbance area	The disturbance area for each water management category was estimated for each project phase using the conceptual layout and assumptions regarding the extent of actual disturbance. Attachment A describes the methods and assumptions applied to establishing disturbance areas.	If the disturbance area is less than estimated the magnitude of potential changes to water quality would decrease. The opposite would apply if the disturbance area is greater than estimated. Changes to disturbance areas are not expected to change the frequency of discharges or resulting frequency of changes to water quality.
Discharge regimes (volume, frequency)	The stormwater discharge model includes runoff models that were parametrised to achieve the runoff characteristics described in Chapter 3 for each water management category. The models account for the capture and harvesting of stormwater in sedimentation basins.	If the stormwater discharge model overestimates discharge volume and frequency: • the magnitude of potential changes to water quality would be lower as there would be a lower analyte load in discharge; and • the frequency of changes to water quality may reduce. The opposite would apply if the stormwater discharge model underestimates discharge volume and frequency.

Table 8.3 Sensitivity to applied approach and assumptions

Aspect	Model approach/assumptions	Model sensitivity to changes to approach/assumptions
Assumed water quality of discharges	The water quality of discharges was applied using conservative tracers (ie no decay or assimilation is applied) using the 'RIA values' established for each category. The 'RIA values' represent a conservative estimate of typical or median discharge water quality from each water management category.	If the stormwater discharge model overestimates the concentration of an analyte in discharge, the magnitude of potential changes to water quality would decrease. The opposite would apply if the stormwater discharge model underestimates the concentration of an analyte in discharge. There is potential for the frequency of changes to water quality to increase if an analyte that is assumed to occur at below WQO levels occurs above WQO levels. The opposite would apply if an analyte that is assumed to occur at above WQO levels occurs below WQO levels.
Ambient water quality	Ambient water quality is assumed to be equal to WQO values for all streamflow conditions. As described in Table 8.2, during wet weather conditions, some analytes are known to exceed WQO values on a frequent or occasional basis.	If the concentration of an analyte in the receiving water is greater than the WQO value the same increase in concentration would occur. However, the relative (or percentage) increase and receiving water risks are likely to be lower. The opposite would apply if an analyte in the receiving water is less than the WQO value.
Fate of analytes post discharge	The stormwater discharge model assumes there is no decay or assimilation of analytes between discharge locations and receiving water calculation points.	Any decay or assimilation would reduce or even eliminate the change in water quality and associated receiving water risks.

In summary, the modelling approach is considered to reliably identify the frequency of when potential changes to receiving water quality may occur. There is greater uncertainty in the predictions of the magnitude of change as this is a function of:

- discharge water quality;
- disturbance area within each catchment;
- ambient water quality; and
- the fate of pollutants post discharge including mixing, decay and assimilation.

vi Conclusion

The potential for stormwater discharges to change receiving water streamflow regimes and water quality will vary based on discharge characteristics and the location, area and duration of disturbance. The potential for changes is proportionally greater:

- during the initial 15 months of the project when the greatest area of disturbance and poorest water quality will occur due to surface construction activities;
- in watercourses that have small catchment areas relative to the disturbance within the catchment; and
- in summer and autumn during moderate rainfall conditions when discharges from the stormwater system may occur but there is insufficient rainfall to generate runoff from the broader catchment.

The potential for changes is proportionally lower:

- following the initial 15 months of the project when disturbance due to construction of surface infrastructure is complete;
- in watercourses that have large catchment areas relative to disturbance within the catchment;
- in winter and spring when streamflow is seasonally high; and
- in summer and autumn during significant rainfall events that result in high streamflow.

Potential changes to water quality in the Yarrangobilly River, the upper Eucumbene River and Kellys Plain Creek have been assessed using the conceptual stormwater discharge model. Table 8.4 provides a summary of the estimated disturbance durations and profiles and potential magnitude of changes to receiving water quality.

Table 8.4 Summary of potential changes to water quality

	Construction phase		Operational phase
	Phase 1 (Construction of surface infrastructure)	**Phase 2** (All other construction activities)	
Disturbance duration	For the Initial 15 months of the 6 year construction program	For the majority of the 6 year construction program	For perpetuity following construction
Disturbance footprint[1]	533 ha	148 ha	55 ha
Percentage of time no change to receiving water quality is expected			
Yarrangobilly River[2]	85%	85%	85%
Upper Eucumbene River	73%	80%	85%
Kellys Plain Creek[3]	83%	76%	81%
Percentage of time concentrations of suspended solids, nutrients or metals in receiving waters may increase by between 0 to 10% of WQO values[4]			
Yarrangobilly River[2]	2%	12%	13%
Upper Eucumbene River	6%	8%	7%
Kellys Plain Creek[3]	0%	8%	7%
Percentage of time concentrations of suspended solids, nutrients or metals in receiving waters may increase by between 10 to 50% of WQO values[4]			
Yarrangobilly River[2]	7%	3%	2%
Upper Eucumbene River	6%	8%	7%
Kellys Plain Creek[3]	0%	8%	7%
Percentage of time concentrations of suspended solids, nutrients or metals in receiving waters may increase by between 50 to 100% of WQO values[4]			
Yarrangobilly River[2]	3%	0%	0%
Upper Eucumbene River	5%	2%	1%
Kellys Plain Creek[3]	1%	3%	3%
Percentage of time concentrations of suspended solids, nutrients or metals in receiving waters may increase by more than 100% of WQO values[4]			

Table 8.4 Summary of potential changes to water quality

	Construction phase		Operational phase
	Phase 1 (Construction of surface infrastructure)	**Phase 2** (All other construction activities)	
Yarrangobilly River[2]	3%	0%	0%
Upper Eucumbene River	10%	1%	0%
Kellys Plain Creek[3]	17%	5%	3%

Notes: 1. Refers the estimated actual disturbance footprint for each project phase.

2. Results for Yarrangobilly River include discharge from disturbance areas adjacent to the Yarrangobilly River arm of Talbingo Reservoir.

3. Results for Kellys Plain Creek include discharge from disturbance areas to the north of Kellys Plain Creek that also drain into the southern portion of Tantangara Reservoir.

4. WQO values refer to the Water Quality Objective values established in the water assessment.

8.3 Reservoirs

8.3.1 Overview

This section describes the potential impacts to the water quality of Talbingo and Tantangara reservoirs due to the discharge of treated wastewater, treated process water and stormwater. The potential for changes to reservoir water quality will be a function of the disturbance area (in the case of stormwater discharges), discharge characteristics (volume, frequency and quality) and receiving water characteristics.

This section is structured as follows:

- Section 0 describes the various discharge mechanisms;
- Section 8.3.3 describes the assessment approach;
- Section 8.3.4 describes potential changes to the water quality of Tantangara Reservoir; and
- Section 8.3.5 describes potential changes to the water quality of Talbingo Reservoir.

8.3.2 Impact mechanisms

Table 8.5 provides a summary of discharge mechanisms that will occur during the construction and operational phases of the project.

Table 8.5 Water management system discharges to reservoirs

Interface	Mechanisms	Relevant water management categories
Construction phase		
Stormwater discharges	• Stormwater discharges during construction phase 1	• WM 1.2 – Minor works • WM 1.3 – Major works
	• Stormwater discharges during construction phase 2	• WM 2.2 – Accommodation camps • WM 2.3 – Construction pads • WM 2.4 – Access roads • WM 2.5 – Large temporary stockpiles
Controlled discharges to reservoirs	• Discharges of treated process water (construction phase 2 only) • Discharges of treated wastewater (construction phase 2 only)	• WM 2.7 – Process water • WM 2.9 – Wastewater
Operational phase		
Stormwater discharges	• Stormwater discharges during the operational phase (ie phase 3)	• WM 3.2 – Permanent surface infrastructure • WM 3.3 – Permanent access roads

8.3.3 Assessment approach

i Approach

The following approach has been applied to assess potential changes to reservoir water quality due to discharges:

- Changes to seasonal loads of salt, total nitrogen and total phosphorus entering the reservoirs was assessed by:
  - calculating the average load of each analyte that enters the reservoirs from streamflow each season; and
  - applying additional loads associated with stormwater, treated wastewater and treated process water discharges.
- Changes to ambient reservoir water quality have been estimated by applying the change in load of each analyte (as a percentage increase) in reservoir inflows to the median seasonal concentration of each analyte.

ii Scenarios

Results are presented for the following seasonal and climate scenarios:

- a typical (or average) summer/autumn period;
- a typical (or average) winter/spring period; and

- a summer/autumn period during drought conditions (ie the 2006–2007 summer/autumn period).

iii Assessment areas

Calculations have been undertaken for:

- Tantangara Reservoir; and
- the Yarrangobilly River arm of Talbingo Reservoir.

Impacts to the greater Talbingo Reservoir are not assessed as they will be significantly lower than changes in the Yarrangobilly River arm of the reservoir, due to mixing with the significant year-round discharge from Tumut 2 power station that enters Talbingo Reservoir via the Tumut River.

8.3.4 Tantangara Reservoir

i Reservoir description

Tantangara Reservoir is operated to divert runoff from the headwaters of the Murrumbidgee River to Lake Eucumbene, whilst meeting environmental release obligations to the Murrumbidgee River. In most years, most inflows occur during winter and spring. Generally, inflows are allowed to accumulate and transfers to Lake Eucumbene are made in early summer. This results in low storage levels over late summer and autumn months.

The WCR describes the reservoir operating regime. Table 8.6 reproduces Table 8.2 from the WCR which provides a summary of the mean annual inflow and outflows.

Table 8.6 Tantangara Reservoir inflow and discharge statistics

	Average annual flow volume[1] (GL/year)	Percentage of inflows/outflows
Inflows		
– Murrumbidgee River	131[3]	58%
– Goodradigbee River Aqueduct	5	2%
– Other (ungagged catchments less evaporation losses)[2]	89	39%
Total inflows	224	-
Outflows		
– Tantangara Dam releases to lower Murrumbidgee River	18	8%
– Tantangara to Eucumbene	207	92%
Total outflows	224	-

Source: WCR table 8.2

Table 8.7 provides the median seasonal electrical conductivity, total nitrogen and total phosphorus concentrations that are used in this assessment.

Table 8.7 Ambient water quality – Tantangara Reservoir

Analytes	Units	Sumer/autumn	Winter/spring
Salinity (as indicated by electrical conductivity)	µS/cm	22	14
Total nitrogen	mg/L	0.20	0.11
Total phosphorus	mg/L	0.03	0.01

Source: Ambient water quality values obtained from WCR.

ii Summary of discharges

The following approach has been applied to calculate analyte loads in reservoir inflows and discharges:

- Seasonal analyte loads in reservoir inflows have been calculated by applying:
  - an estimated reservoir inflow volume for each scenario; and
  - the median seasonal concentration for each analyte that is established in the WCR.
- Combined seasonal analyte loads in stormwater discharges that enter each reservoir have been calculated using the stormwater discharge model that is described in Section 8.2.
- Analyte loads in treated process water have been calculated by applying:
  - the peak discharge rate of 12.4 ML/day (as described in Table 4.2); and
  - the discharge quality characteristics described in Table 4.9.
- Analyte loads in treated wastewater have been calculated by applying:
  - the peak discharge rate of 0.1 ML/day (as described in Table 5.3); and
  - the discharge quality characteristics described in Table 5.1.

Attachment D provides a detailed break-down of all assumptions and calculated loads for the construction and operational phases of the project.

iii Changes to water quality

Predicted changes to ambient reservoir water quality are summarised in:

- Table 8.8 for construction phase 1;
- Table 8.9 for construction phase 2; and
- Table 8.10 for the operational phase (phase 3).

Results are discussed and a summary table is provided below the three tables.

Table 8.8 Potential changes to water quality: Tantangara Reservoir – construction phase 1

	Units	Scenario		
		Summer/autumn (drought)[3]	summer/autumn (typical)	winter/spring (typical)
Summary of inflows and discharges				
Combined stormwater discharges	ML/season	163	207	331
Combined controlled discharges[4]	ML/season	-	-	-
Reservoir inflows	ML/season	13,105	45,222	198,727
Salinity (as indicated by electrical conductivity (EC)				
Salt in combined stormwater discharges[2]	kg/season	2,690	3,416	5,462
Salt in combined controlled discharges[2, 4]	kg/season	-	-	-
Salt in reservoir inflows[2]	kg/season	230,648	795,907	2,841,796
Increase in salinity of inflows	%	1.2%	0.4%	0.2%
Ambient value[5]	µS/cm	22	22	14
Predicted value[5]	µS/cm	22	22	14
Total nitrogen (TN)				
TN in combined stormwater discharges	kg/season	163	207	331
TN in combined controlled discharges[4]	kg/season	-	-	-
TN in reservoir inflows	kg/season	1,311	4,522	19,873
Increase in TN in inflows	%	12.4%	4.6%	1.7%
Ambient value[5]	mg/L	0.20	0.20	0.11
Predicted value[1,5]	mg/L	0.22	0.21	0.11
Total phosphorus (TP)				
TP in combined stormwater discharges	kg/season	33	41	66
TP in combined controlled discharges[4]	kg/season	-	-	-
TP in reservoir inflows	kg/season	131	452	1,987
Increase in TP in inflows	%	25.2%	9.1%	3.3%
Ambient value[5]	mg/L	0.03	0.03	0.01
Predicted value[1,5]	mg/L	0.04	0.03	0.01

Notes: Season refers to the 6 month period applicable to each scenario.
1. The predicted value makes no allowance for decay and assimilation and is therefore conservative.
2. Salt loads are calculated as a function of electrical conductivity. Actual salt loads are likely to be lower.
3. Calculations based on reservoir inflows and calculated stormwater discharges for the 2006/2007 summer/autumn period.
4. Combined controlled discharges refers to the combined discharges of treated process water and treated wastewater.
5. Ambient and predicted values refer to typical or median values.

Table 8.9 Potential changes to water quality: Tantangara Reservoir – construction phase 2

	Units	Scenario		
		Summer/autumn (drought)[3]	summer/autumn (typical)	winter/spring (typical)
Summary of inflows and discharges				
Combined stormwater discharges	ML/season	33	44	77
Combined controlled discharges[4]	ML/season	2,275	2,275	2,275
Reservoir inflows	ML/season	13,105	45,222	198,727
Salinity (as indicated by electrical conductivity (EC)				
Salt in combined stormwater discharges[2]	kg/season	545	726	1,271
Salt in combined controlled discharges[2, 4]	kg/season	193,133	193,133	193,133
Salt in reservoir inflows[2]	kg/season	230,648	795,907	2,841,796
Increase in salinity of inflows	%	84.0%	24.4%	6.8%
Ambient value[5]	µS/cm	22	22	14
Predicted value[5]	µS/cm	40	27	15
Total nitrogen (TN)				
TN in combined stormwater discharges	kg/season	31	41	71
TN in combined controlled discharges[4]	kg/season	570	570	570
TN in reservoir inflows	kg/season	1,311	4,522	19,873
Increase in TN in inflows	%	45.9%	13.5%	3.2%
Ambient value[5]	mg/L	0.20	0.20	0.11
Predicted value[1,5]	mg/L	0.29	0.23	0.11
Total phosphorus (TP)				
TP in combined stormwater discharges	kg/season	3	4	8
TP in combined controlled discharges[4]	kg/season	46	46	46
TP in reservoir inflows	kg/season	131	452	1,987
Increase in TP in inflows	%	37.4%	11.1%	2.7%
Ambient value[5]	mg/L	0.03	0.03	0.01
Predicted value[1,5]	mg/L	0.04	0.03	0.01

Notes: Season refers to the 6 month period applicable to each scenario.

1. The predicted value makes no allowance for decay and assimilation and is therefore conservative.
2. Salt loads are calculated as a function of electrical conductivity. Actual salt loads are likely to be lower.
3. Calculations based on reservoir inflows and calculated stormwater discharges for the 2006/2007 summer/autumn period.
4. Combined controlled discharges refers to the combined discharges of treated process water and treated wastewater.
5. Ambient and predicted values refer to typical or median values.

Table 8.10 Potential changes to water quality: Tantangara Reservoir – construction phase 3

	Units	Scenario		
		Summer/autumn (drought)[3]	summer/autumn (typical)	winter/spring (typical)
Summary of inflows and discharges				
Combined stormwater discharges	ML/season	28	33	47
Combined controlled discharges[4]	ML/season	-	-	-
Reservoir inflows	ML/season	13,105	45,222	198,727
Salinity (as indicated by electrical conductivity (EC)				
Salt in combined stormwater discharges[2]	kg/season	462	545	776
Salt in combined controlled discharges[2, 4]	kg/season	-	-	-
Salt in reservoir inflows[2]	kg/season	230,648	795,907	2,841,796
Increase in salinity of inflows	%	0.2%	0.1%	0.0%
Ambient value[5]	µS/cm	22	22	14
Predicted value[5]	µS/cm	22	22	14
Total nitrogen (TN)				
TN in combined stormwater discharges	kg/season	20	23	71
TN in combined controlled discharges[4]	kg/season	-	-	-
TN in reservoir inflows	kg/season	1,311	4,522	19,873
Increase in TN in inflows	%	1.5%	0.5%	0.4%
Ambient value[5]	mg/L	0.20	0.20	0.11
Predicted value[1,5]	mg/L	0.20	0.20	0.11
Total phosphorus (TP)				
TP in combined stormwater discharges	kg/season	2	2	3
TP in combined controlled discharges[4]	kg/season	-	-	-
TP in reservoir inflows	kg/season	131	452	1,987
Increase in TP in inflows	%	1.5%	0.4%	0.2%
Ambient value[5]	mg/L	0.03	0.03	0.01
Predicted value[1,5]	mg/L	0.03	0.03	0.01

Notes: Season refers to the 6 month period applicable to each scenario.

1. The predicted value makes no allowance for decay and assimilation and is therefore conservative.
2. Salt loads are calculated as a function of electrical conductivity. Actual salt loads are likely to be lower.
3. Calculations based on reservoir inflows and calculated stormwater discharges for the 2006/2007 summer/autumn period.
4. Combined controlled discharges refers to the combined discharges of treated process water and treated wastewater.
5. Ambient and predicted values refer to typical or median values.

iv Conclusion

The following water management system discharges have potential to change reservoir water quality:

- stormwater discharges into watercourses that flow into reservoirs; and
- controlled discharges of treated wastewater and process water directly to reservoirs.

Table 8.11 provides estimates of the change in median ambient salinity levels (as indicated by electrical conductivity) and total nitrogen and phosphorus concentrations. It is noted that:

- The change in nutrient concentrations is likely to be less due to decay and assimilation.
- Higher concentration increases may occur near treated wastewater and process water discharge locations. However, the spatial extent of higher concentrations (also referred to as a mixing zone) is expected to be within tens of metres of discharge locations.
- Additional changes to reservoir water quality may occur due to spoil management activities.

Table 8.11 Summary of potential changes to ambient water quality: Tantangara Reservoir

	Units	Summer/autumn (drought)[1]	summer/autumn (typical)	winter/spring (typical)
Construction phase 1 – Applies to the initial 15 months of the 6 year construction program				
Salinity (as indicated by EC)	µS/cm	22 to 22	22 to 22	14 to 14
Total nitrogen	mg/L	0.20 to 0.22	0.20 to 0.21	0.11 to 0.11
Total Phosphorus	mg/L	0.03 to 0.04	0.03 to 0.03	0.01 to 0.01
Construction phase 2 – Applies for the majority of the 6 year construction program				
Salinity (as indicated by EC)	µS/cm	22 to 40	22 to 27	14 to 15
Total nitrogen	mg/L	0.20 to 0.29	0.20 to 0.23	0.11 to 0.11
Total Phosphorus	mg/L	0.03 to 0.04	0.03 to 0.03	0.01 to 0.01
Operational phase (Phase 3) – Applies for perpetuity following construction				
Salinity (as indicated by EC)	µS/cm	22 to 22	22 to 22	14 to 14
Total nitrogen	mg/L	0.20 to 0.20	0.20 to 0.20	0.11 to 0.11
Total Phosphorus	mg/L	0.03 to 0.03	0.03 to 0.03	0.01 to 0.01

Notes: The predicted values for total nitrogen and total phosphorus make no allowance for decay and assimilation and are therefore conservative.
Ambient values refer to typical or median values.

1. Calculations based on reservoir inflows and calculated stormwater discharges for the 2006/2007 summer/autumn period.

In conclusion, the combination of stormwater discharges and controlled discharges of treated wastewater and process water during the construction phase of the project have potential to increase the ambient salinity levels and nutrients concentrations may occur. The magnitude of change is expected to be greater:

- in summer/autumn due to lower seasonal streamflow into the reservoir than winter /spring; and
- during drought conditions due to lower streamflow into the reservoir.

No material changes to reservoir water quality are expected due to stormwater discharges during the operational phase of the project.

8.3.5 Talbingo Reservoir

i Overview

As discussed in Section 8.3.3, potential changes to the ambient water quality of the Yarrangobilly River arm of Talbingo Reservoir is assessed. Changes to the greater Talbingo Reservoir are not assessed as they will be significantly lower than changes in the Yarrangobilly River arm of the reservoir, due to mixing with the significant year-round discharge from Tumut 2 power station that enters Talbingo Reservoir via the Tumut River.

ii Reservoir description

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. The water level is maintained within an 8.8 m operating range.

The reservoir receives inflows from:

- the Tumut River (primarily from discharges from Tumut 2 power station);
- the Yarrangobilly River;
- pumping from Jounama Pondage; and
- smaller tributaries and direct rainfall.

All outflows occur via discharges from Tumut 3 power station. Water levels can change rapidly due to discharge of water through Tumut 3 power station, inflows due to rainfall, or discharge from Tumut 2 power station.

Table 8.12 reproduces Table 8.4 from the WCR which provides a summary of the mean annual inflow and outflows.

Table 8.12 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	98[4]	8%
– Tumut 2 discharge	1,053	86%
– Tumut 3 pumping	387	-
– Other (ungauged catchments less evaporation losses)[3]	77	6%
Total inflows	1,616	-
Outflows		
– Tumut 3 discharge	1,616	-
Net discharge[2]	1,229	

Source: WCR Table 8.4

Table 8.13 provides the median seasonal electrical conductivity levels and total nitrogen and total phosphorus concentrations that are used in this assessment.

Table 8.13 Ambient water quality – Talbingo Reservoir

Analytes	Units	Sumer/autumn	Winter/spring
Salinity (as indicated by electrical conductivity)	µS/cm	27	22
Total nitrogen	mg/L	0.22	0.12
Total phosphorus	mg/L	0.04	0.01

Source: Ambient water quality values obtained from WCR.

iii Summary of discharges

The following approach has been applied to calculate analyte loads in inflows and discharges to the Yarrangobilly River arm of Talbingo Reservoir:

- Seasonal analyte loads in reservoir inflows have been calculated by applying:
  - an estimated reservoir inflow volume (from Yarrangobilly River) for each scenario; and
  - the median seasonal concentration for each analyte that is established in the WCR.
- Combined seasonal analyte loads in stormwater discharges that enter each reservoir have been calculated using the stormwater discharge model that is described in Section 8.2.
- Analyte loads in treated process water have been calculated by applying:
  - the peak discharge rate of 1.0 ML/day (as described in Table 4.2); and
  - the discharge quality characteristics described in Table 4.9.
- Analyte loads in treated wastewater have been calculated by applying:
  - the peak discharge rate of 0.2 ML/day (as described in Table 5.3); and
  - the discharge quality characteristics described in Table 5.1.

Attachment D provides a detailed break-down of all assumptions and calculated loads for the construction and operational phases of the project.

iv Changes to water quality

Predicted changes to ambient reservoir water quality are summarised in:

- Table 8.14 for construction phase 1;
- Table 8.15 for construction phase 2; and
- Table 8.16 for the operational phase (phase 3).

Results are discussed and a summary table is provided below the three tables.

Table 8.14 Potential changes to water quality: Yarrangobilly River arm of Talbingo Reservoir – construction phase 1

	Units	Scenario		
		Summer/autumn (drought)[3]	summer/autumn (typical)	winter/spring (typical)
Summary of inflows and discharges				
Combined stormwater discharges	ML/season	156	230	356
Combined controlled discharges[4]	ML/season	-	-	-
Reservoir inflows	ML/season	4,600	22,250	89,087
Salinity (as indicated by electrical conductivity (EC)				
Salt in combined stormwater discharges[2]	kg/season	2,574	3,795	5,874
Salt in combined controlled discharges[2,4]	kg/season	-	-	-
Salt in reservoir inflows[2]	kg/season	404,800	1,958,000	3,429,850
Increase in salinity of inflows	%	0.6%	0.2%	0.2%
Ambient value[5]	µS/cm	27	27	22
Predicted value[5]	µS/cm	27	27	22
Total nitrogen (TN)				
TN in combined stormwater discharges	kg/season	156	230	356
TN in combined controlled discharges[4]	kg/season	-	-	-
TN in reservoir inflows	kg/season	460	2,225	8,909
Increase in TN in inflows	%	33.9%	10.3%	4.0%
Ambient value[5]	mg/L	0.20	0.20	0.12
Predicted value[1,5]	mg/L	0.27	0.22	0.12
Total phosphorus (TP)				
TP in combined stormwater discharges	kg/season	31	46	71
TP in combined controlled discharges[4]	kg/season	-	-	-
TP in reservoir inflows	kg/season	46	223	891
Increase in TP in inflows	%	67.4%	20.6%	8.0%
Ambient value[5]	mg/L	0.03	0.03	0.01
Predicted value[1,5]	mg/L	0.05	0.04	0.01

Notes: Season refers to the 6 month period applicable to each scenario.
1. The predicted value makes no allowance for mixing, decay and assimilation and is therefore conservative.
2. Salt loads are calculated as a function of electrical conductivity. Actual salt loads are likely to be lower.
3. Calculations based on reservoir inflows and calculated stormwater discharges for the 2006/2007 summer/autumn period.
4. Combined controlled discharges refers to the combined discharges of treated process water and treated wastewater.
5. Ambient and predicted values refer to typical or median values.

Table 8.15 Potential changes to water quality: Yarrangobilly River arm of Talbingo Reservoir – construction phase 2

	Units	Scenario		
		Summer/autumn (drought)[3]	summer/autumn (typical)	winter/spring (typical)
Summary of inflows and discharges				
Combined stormwater discharges	ML/season	44	70	120
Combined controlled discharges[4]	ML/season	218	218	218
Reservoir inflows	ML/season	4,600	22,250	89,087
Salinity (as indicated by electrical conductivity (EC)				
Salt in combined stormwater discharges[2]	kg/season	726	1,155	1,980
Salt in combined controlled discharges[2, 4]	kg/season	83,930	83,930	83,930
Salt in reservoir inflows[2]	kg/season	404,800	1,958,000	3,429,850
Increase in salinity of inflows	%	20.9%	4.3%	2.5%
Ambient value[5]	µS/cm	27	27	22
Predicted value[5]	µS/cm	33	28	23
Total nitrogen (TN)				
TN in combined stormwater discharges	kg/season	42	66	112
TN in combined controlled discharges[4]	kg/season	59	59	59
TN in reservoir inflows	kg/season	460	2,225	8,909
Increase in TN in inflows	%	22.0%	5.6%	1.9%
Ambient value[5]	mg/L	0.20	0.20	0.12
Predicted value[1,5]	mg/L	0.24	0.21	0.12
Total phosphorus (TP)				
TP in combined stormwater discharges	kg/season	5	8	13
TP in combined controlled discharges[4]	kg/season	6	6	6
TP in reservoir inflows	kg/season	46	223	891
Increase in TP in inflows	%	23.9%	6.3%	2.1%
Ambient value[5]	mg/L	0.03	0.03	0.01
Predicted value[1,5]	mg/L	0.04	0.03	0.01

Notes: Season refers to the 6 month period applicable to each scenario.

1. The predicted value makes no allowance for mixing, decay and assimilation and is therefore conservative.
2. Salt loads are calculated as a function of electrical conductivity. Actual salt loads are likely to be lower.
3. Calculations based on reservoir inflows and calculated stormwater discharges for the 2006/2007 summer/autumn period.
4. Combined controlled discharges refers to the combined discharges of treated process water and treated wastewater.
5. Ambient and predicted values refer to typical or median values.

Table 8.16 Potential changes to water quality: Yarrangobilly River arm of Talbingo Reservoir – construction phase 3

	Units	Scenario		
		Summer/autumn (drought)[3]	summer/autumn (typical)	winter/spring (typical)
Summary of inflows and discharges				
Combined stormwater discharges	ML/season	44	55	75
Combined controlled discharges[4]	ML/season	-	-	-
Reservoir inflows	ML/season	4,600	22,250	89,087
Salinity (as indicated by electrical conductivity (EC)				
Salt in combined stormwater discharges[2]	kg/season	726	908	1,238
Salt in combined controlled discharges[2, 4]	kg/season	-	-	-
Salt in reservoir inflows[2]	kg/season	404,800	1,958,000	3,429,850
Increase in salinity of inflows	%	0.2%	0.0%	0.0%
Ambient value[5]	µS/cm	27	27	22
Predicted value[5]	µS/cm	27	27	22
Total nitrogen (TN)				
TN in combined stormwater discharges	kg/season	25	31	43
TN in combined controlled discharges[4]	kg/season	-	-	-
TN in reservoir inflows	kg/season	460	2,225	8,909
Increase in TN in inflows	%	5.4%	1.4%	0.5%
Ambient value[5]	mg/L	0.20	0.20	0.12
Predicted value[1,5]	mg/L	0.21	0.20	0.12
Total phosphorus (TP)				
TP in combined stormwater discharges	kg/season	2	3	4
TP in combined controlled discharges[4]	kg/season	-	-	-
TP in reservoir inflows	kg/season	46	223	891
Increase in TP in inflows	%	4.3%	1.3%	0.4%
Ambient value[5]	mg/L	0.03	0.03	0.01
Predicted value[1,5]	mg/L	0.03	0.03	0.01

Notes: Season refers to the 6 month period applicable to each scenario.
1. The predicted value makes no allowance for mixing, decay and assimilation and is therefore conservative.
2. Salt loads are calculated as a function of electrical conductivity. Actual salt loads are likely to be lower.
3. Calculations based on reservoir inflows and calculated stormwater discharges for the 2006/2007 summer/autumn period.
4. Combined controlled discharges refers to the combined discharges of treated process water and treated wastewater.
5. Ambient and predicted values refer to typical or median values.

v Conclusion

The following water management system discharges have potential to change reservoir water quality:

- stormwater discharges into watercourses that flow into reservoirs; and
- controlled discharges of treated wastewater and process water directly to reservoirs.

Table 8.17 provides estimates of the change in median ambient salinity levels (as indicated by electrical conductivity) and total nitrogen and phosphorus concentrations. It is noted that:

- The change in salinity levels and nutrient concentrations is likely to be less due to:
  - decay and assimilation (nutrients only); and
  - mixing between the Yarrangobilly River arm and the greater reservoir (all analytes).
- Higher concentration increases may occur near treated wastewater and process water discharge locations. However, the spatial extent of higher concentrations (also referred to as a mixing zone) is expected to be within Tens of metres of discharge locations.
- Additional changes to reservoir water quality may occur due to spoil management activities.

Table 8.17 Summary of potential changes to ambient water quality: Yarrangobilly River arm of Talbingo Reservoir

	Units	Summer/autumn (drought)[1]	summer/autumn (typical)	winter/spring (typical)
Construction phase 1 – Applies to the initial 15 months of the 6 year construction program				
Salinity (as indicated by EC)	µS/cm	27 to 27	27 to 27	22 to 22
Total nitrogen	mg/L	0.20 to 0.27	0.20 to 0.22	0.12 to 0.12
Total Phosphorus	mg/L	0.03 to 0.05	0.03 to 0.04	0.01 to 0.01
Construction phase 2 – Applies for the majority of the 6 year construction program				
Salinity (as indicated by EC)	µS/cm	27 to 33	27 to 28	22 to 23
Total nitrogen	mg/L	0.20 to 0.24	0.20 to 0.21	0.12 to 0.12
Total Phosphorus	mg/L	0.03 to 0.04	0.03 to 0.03	0.01 to 0.01
Operational phase (Phase 3) – Applies for perpetuity following construction				
Salinity (as indicated by EC)	µS/cm	27 to 27	27 to 27	22 to 22
Total nitrogen	mg/L	0.20 to 0.21	0.20 to 0.20	0.12 to 0.12
Total Phosphorus	mg/L	0.03 to 0.03	0.03 to 0.03	0.01 to 0.01

Notes: The predicted values for total nitrogen and total phosphorus make no allowance for decay and assimilation and are therefore conservative.

Ambient values refer to typical or median values

1. Calculations based on reservoir inflows and calculated stormwater discharges for the 2006/2007 summer/autumn period.

In conclusion, the combination of stormwater discharges and controlled discharges of treated wastewater and process water during the construction phase of the project have potential to increase the ambient salinity levels and nutrients concentrations. The magnitude of change is expected to be greater:

- in summer/autumn due to lower seasonal streamflow into the reservoir; and
- during drought conditions due to lower streamflow into the reservoir.

No material changes to reservoir water quality are expected during the operational phase of the project.

No material changes to the greater Talbingo Reservoir are expected due to mixing with the significant year-round discharge from Tumut 2 power station that enters Talbingo Reservoir via the Tumut River.

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Glossary

Term	Definition
Aquifer	A geological formation or group of formations; able to receive, store and transmit significant quantities of water. Means a geological structure or formation, or an artificial landfill, that is permeated with water or is capable of being permeated with water (NSW Water Management Act 2000 definition).
Catchment	The land area draining to a point of interest, such as a water storage or monitoring site on a watercourse.
Controlled discharge	Water management system discharges that occur via a controlled process.
Clean water	Surface water runoff from catchments that are undisturbed or rehabilitated following disturbance
Dewatering	Removal of water from an aquifer as part of the construction phase of a development or part of ongoing activities to maintain access, serviceability and/or safe operating conditions.
Discharge	A general term that refers to all discharge mechanisms.
Discharge via overflow	Water management system discharges that occur via overflow from a water management basin.
Discharge via runoff	Water management system discharges that occur due to stormwater runoff from a water management area.
Electrical conductivity (EC)	Electrical conductivity (EC) measures dissolved salt in water. The standard EC unit is microSiemens per centimetre (µS/cm) at 25 °C.
Ephemeral	Something which only lasts for a short time. Typically used to describe rivers, lakes and wetlands that are intermittently dry.
Existing disturbed areas	refers to areas such as access roads that were constructed/disturbed prior to activities associated with the project.
Evaporation	A process that occurs at a liquid surface, resulting in a change of state from liquid to vapour. In relation to water resource assessment and water accounting, evaporation refers to the movement of water from the land surface (predominantly liquid) to the atmosphere (water vapour). The liquid water at the land surface that may be available for evaporation includes surface water, soil water, shallow groundwater, water within vegetation, and water on vegetation and paved surfaces.
Evapotranspiration	The combined loss of water from a given area during a specified period of time by evaporation from the soil or water surface and by transpiration from plants.
Full supply level	The normal maximum operating water level of a surface water storage when not affected by floods. This water level corresponds to 100% capacity.
Groundwater	Water contained within rocks and sediments below the ground surface in the saturated zone, including perched systems above the regional watertable.
Infiltration	The process by which water on the ground surface enters the soil profile.
Parameter	A measurable characteristic of a physical entity (feature); for example, the temperature of water in a river.
Potable water	Water that has been treated to a potable water standard.
Process water	Water that will be produced by or used by the proposed construction activities.
pH	Value that represents the acidity or alkalinity of an aqueous solution. It is defined as the negative logarithm of the hydrogen ion concentration of the solution.
Precipitation	All forms in which water falls on the land surface and open water bodies as rain, sleet, snow, hail, or drizzle.

Term	Definition
Quickflow	The component of streamflow that has travelled through the catchment as interflow or across the surface as overland flow or is released from bank storage during the recession from a flood peak.
Receiving water	Any watercourse or waterbody that receives discharge from the water management system.
Sensitivity	The degree to which numerical model outputs are affected by changes in selected input parameters.
Stormwater	Surface water runoff from areas disturbed by the Main Works.
Streamflow	The flow of water in streams, rivers and other channels.
Surface runoff	Water from precipitation or other sources that flows over the land surface.
Surface water	Water that flows over or is stored on the surface of the earth that includes: (a) water in a watercourse, lake or wetland and (b) any water flowing over or lying on land: (i) after having precipitated naturally or (ii) after having risen to the surface naturally from underground.
Turbidity	Means the measure of the light scattering properties of water and is an indicator of the presence of suspended solids.
Water balance	The flow of water into and out of, and changes in the storage volume of, a surface water system, groundwater system, catchment or specified area over a defined period of time.
Water quality	The physical, chemical and biological characteristics of water. Water-quality compliance is usually assessed by comparing these characteristics with a set of reference standards. Common standards used are those for drinking water, safety of human contact and the health of ecosystems.
Wastewater	Wastewater (or sewage) generated from the accommodation camp and other amenities.
Water management category	A term used to describe a unique aspect of the water management system.

Abbreviations

Abbreviation	Description
AEP	Annual Exceedance Probability
AMD	Acid metalliferous drainage
DPIE	Department of Planning, Industry and Environment
EC	Electrical conductivity
ECVT	Emergency egress, Communication, and Ventilation tunnel
EIS	Environmental Impact Statement
ESCP	Erosion and Sediment Control Plan
FSL	Full supply level
km	Kilometres
KNP	Kosciuszko National Park
m	metres
MAT	Main access tunnel
MOL	Minimum operating level
MW	Megawatts
MWh	Megawatt hours
NEM	National Electricity Market
NSW	New South Wales
PAF	Potentially acid forming
RIR	Residual impacts report
TBM	Tunnel boring machine
TKN	Total kjeldahl nitrogen
WCR	Water characterisation report
WMR	Water management report

Attachment A

Stormwater management areas

A.1 Introduction and purpose

This attachment to the water management report (WMR) (Annexure D to the water assessment) describes the methods and assumptions applied to calculate disturbance profiles for each stormwater management category established in the WMR. The disturbance profiles are used to calculate stormwater discharge profiles that were applied to assess residual impacts associated with stormwater discharges. Residual impacts are also documented in the WMR.

A.2 Water management categories

The WMR describes stormwater approaches separately for the following project phases:

- Construction – refers to the construction of Snowy 2.0 Main Works, including the following phases:
  - Construction Phase 1 – Construction of surface infrastructure – refers to the construction of access roads, service trenches, accommodation camps, construction pads, tunnel portals and other surface infrastructure.
  - Construction Phase 2 – All other construction activities – refers to the construction of subsurface infrastructure and tunnel intakes and the use of surface infrastructure such as access roads, construction pads and accommodation camps to support construction activities.

  It is noted that at a project level the two construction phases will occur concurrently during the initial years of the project schedule, but at a local level, the phases would occur sequentially.

- Operational phase (Phase 3) – refers to the operational phase of Snowy 2.0.

For each phase, project level stormwater management categories have been established to describe each unique aspect of the proposed stormwater system. Table A.1 describes the stormwater categories that are relevant to each project phase and notes the approximate disturbance duration associated with each phase.

Table A.1 Project phases and water management categories

Project phase	Disturbance period	Stormwater categories
Construction Phase 1 – construction of surface infrastructure	Initial 15 months of construction	• WM 1.2 – Minor works • WM 1.3 – Major works
Construction Phase 2 – all other construction activities	Approximately 5 years	• WM 2.2 – Accommodation camps • WM 2.3 – Construction pads • WM 2.4 – Access roads • WM 2.5 – Large temporary stockpiles
Operational phase (Phase 3)	For perpetuity following construction	• WM 3.2 – Permanent surface infrastructure • WM 3.3 – Permanent access roads

A.3 Data

The following data has been used to establish disturbance profiles:

- the project disturbance area;
- the conceptual layout; and
- minimum operating levels for Tantangara and Talbingo reservoirs.

A.4 Approach

The project disturbance area describes the maximum extent of surface disturbance. The actual disturbance footprint is expected to be substantially less than the project disturbance area. The following approach was applied to calculate estimated actual disturbance areas for each stormwater management category:

- Step 1 – potential disturbance areas relevant to each phase were calculated from the project disturbance area.
- Step 2 – actual disturbance areas were estimated for each stormwater management category based on the potential disturbance areas, the conceptual layout and various actual to potential disturbance ratios.

A.5 Step 1 – Calculation of potential disturbance areas

A.5.1 Assumptions

Table A.2 describes assumptions that were applied to calculate the potential disturbance area from the project disturbance area.

Table A.2 Potential disturbance area calculation assumptions

Assumption	Description/justification
All phases – disturbance areas which are below the minimum operating level of reservoirs, or otherwise associated with on-reservoir activity (such as barging) have been excluded.	No stormwater runoff will occur from reservoir water bodies.
All phases – disturbance area associated with spoil emplacement areas have been excluded	Impacts related to spoil emplacement are not assessed in this WMR.
Phase 2 and 3 – the assumed disturbance is limited to the inside of the cut and fill batters of the conceptual layout.	Following construction, cut and fill batters will be stabilised and rehabilitated in accordance with the rehabilitation strategy (Appendix F to the EIS). Rehabilitated areas are not considered to be disturbed areas.
Phase 3 only – the assumed disturbance is limited to the conceptual layout of the permanent surface infrastructure and access roads.	Near the end of the construction phase of the project, temporary surface infrastructure will be decommissioned, and disturbance areas will be reprofiled and rehabilitated in accordance with the rehabilitation strategy (Appendix F to the EIS). Rehabilitated areas are not considered to be disturbed areas.

A.6 Potential disturbance areas

Table A.3 provides the calculated potential disturbance area for each phase and category.

Table A.3 Potential disturbance area by phase and category

Stormwater management category	Potential disturbance area by project phase (ha)		
	Phase 1	Phase 2	Phase 3
WM 1.2 – Minor works	713	-	-
WM 1.3 – Major works	283	-	-
WM 2.2 – Accommodation camps	-	19	-
WM 2.3 – Construction pads	-	52	-
WM 2.4 – Access roads	-	660	-
WM 2.5 – Large temporary stockpiles	-	35	-
WM 3.2 – Permanent surface infrastructure	-	-	20
WM 3.3 – Permanent access roads	-	-	515
Total potential disturbance area	**996**	**766**	**535**
Areas below reservoir minimum operating levels	684	684	648
Assumed rehabilitated areas	0	230	497
Total disturbance area	**1,680**	**1,680**	**1,680**

A.7 Step 2 – Calculation of actual disturbance areas

A.7.1 Reduction factors

Reduction factors have been established to calculate the actual disturbance area from the potential disturbance areas. Table A.4 presents the applied reduction factors for each water management category with explanatory notes.

Table A.4 Reduction factors

Stormwater management category	Reduction factors	Comments
WM 1.2 – Minor works	0.5	Minor works are primarily associated with the construction of road and service corridors. The potential disturbance boundary includes contingency for design and unforeseen local constraints. Based on the conceptual layout, approximately 50% of the potential disturbance area is expected to be disturbed.
WM 1.3 – Major works	0.6	Major works are primarily associated with the construction of accommodation camps, portals and construction pads. The potential disturbance boundary includes contingency for design and unforeseen local constraints. Based on the conceptual layout, approximately 60% of the potential disturbance area is expected to be disturbed.
WM 2.2 – Accommodation camps	1.0	The potential disturbance area digitised from the concept layout based on the internal batter extent. Hence, no further reduction is required.
WM 2.3 – Construction pads	1.0	The potential disturbance area was digitised from the concept layout based on the internal batter extent. Hence, no further reduction is required.
WM 2.4 – Access roads	-	Actual disturbance area was calculated using an alternative method – see section A.7.2.

Table A.4 Reduction factors

Stormwater management category	Reduction factors	Comments
WM 2.5 – Large temporary stockpiles	1.0	The potential disturbance area was digitised from the concept layout based on the outer batter extent. Hence, no further reduction is required.
WM 3.2 – Permanent surface infrastructure	1.0	The potential disturbance area was digitised from the concept layout based on the internal batter extent. Hence, no further reduction is required.
WM 3.3 – Permanent access roads	-	Actual disturbance area was calculated using an alternative method – see Section A.7.2.

A.7.2 Access roads – construction phase 2 and operational phase

Access roads are included in disturbance area calculations for construction phase 2 (WM 2.4) and the operational phase (WM 3.3). Broadly, all roads have been categorised as follows:

- Existing 4WD tracks that will have minor modifications (ie additional passing bays).
- Existing 4WD tracks that will be substantially modified to be dual lane unsealed roads.
- New dual lane unsealed roads that will be constructed as part of the project.
- Roads that will be sealed near the end of the construction phase.

The following assumptions have been applied to calculating actual disturbance areas:

- Existing 4WD tracks that will only have minor modifications are not considered to materially increase the disturbance area and are therefore not considered to be additional disturbance areas associated with the project.
- Unsealed and sealed roads are expected to have different runoff quality characteristics and are therefore separated.
- The actual disturbance area is limited to the road surface. Road drainage will be designed to have non-erosive capacity (described in Chapter 3 of the WMR) and road batters will be established and rehabilitated.

Table A.5 provides the following information for each road included in the project description:

- relevant phase and stormwater management category;
- construction upgrades;
- final condition;
- catchment location;
- approximate length;
- typical cross section width of road surface (excluded drains and batters); and
- estimated actual disturbance area.

Table A.5 Assumed disturbance areas – access roads

Road	Phase	Stormwater management category	Construction upgrade	Final condition	Catchment	Length (m)	Typical cross-sectional width (m)	Estimated actual disturbed area (ha)
Lobs Hole Ravine Road (south)	2 and 3	WM 2.4, WM 2.3	Significant upgrade	Sealed	Yarrangobilly River	4,064	7	3
					Other areas	10,389	7	7
Lobs Hole Ravine Road (north)	2 and 3	-	Minor modifications	4WD track	Yarrangobilly River	12,164	7	9
Mines Trail Road	2 and 3	WM 2.4, WM 2.3	Significant upgrade	Sealed	Yarrangobilly River	2,528	7	2
Lobs Hole Road	2 and 3	WM 2.4, WM 3.3	Significant upgrade	Gravel	Yarrangobilly River	3,123	7	2
Marica Trail	2 and 3	WM 2.4, WM 3.3	Significant upgrade	Gravel	Upper Eucumbene River	2,103	7	1
					Wallaces Creek	3,249	7	2
Marica West	2 and 3	WM 2.4, WM 3.3	New road	Gravel	Yarrangobilly River	5,486	7	4
					Wallaces Creek	1,685	7	1
Powerline Road	2 only	WM 2.4	New road	Gravel	Yarrangobilly River	1,409	6	1
				Gravel	Talbingo Reservoir	1,339	6	1
Pipeline Road	2 and 3	WM 2.4, WM 3.3	New road	Gravel	Yarrangobilly River	1,422	6	1
Talbingo Excavated Rock Emplacement Access Road	2 only	WM 2.4	New road	Rehabilitated	Talbingo Reservoir	3,183	7	2
Tantangara Road	2 and 3	WM 2.4, WM 3.3	Significant upgrade	Gravel	Kellys Plain Creek	2,001	6	1
					Nungar Creek	8,079	6	5
					Other areas	5,093	6	3
Tantangara Excavated Rock Emplacement Access Road	2 only	WM 2.4	Significant upgrade	Rehabilitated	Tantangara Reservoir	5,386	7	4
Quarry Trail	2 and 3	WM 2.4, WM 3.3	Significant upgrade	Gravel	Tantangara Reservoir	1,551	6	1
				Gravel	Kellys Plain Creek	1,452	6	1
Gooandra Trail/Bullock Hill Trail	2 and 3	-	Minor modifications	4WD track	Tantangara Creek	23,931	6	14
Total WM 2.4								**42**
Total WM 3.3								**35**

A.7.3 Actual disturbance areas

Table A.6 provides the estimated actual disturbance areas for each project phase. The areas are broken-down into regional catchments.

Table A.6 Actual disturbance areas by catchment

Stormwater management category	Reduction factors	Estimated actual disturbance area by catchment (ha)[1]											
		Lower Eucumbene River	Upper Eucumbene River	Tantangara Creek	Wallaces Creek	Yarrangobilly River	Kellys Plain Creek	Nungar Creek	Tantangara Reservoir	Talbingo Reservoir	Rock Forest	Other areas[2]	Total
WM 1.2 – Minor works	0.5	7	12	26	25	85	35	39	24	25	0	79	357
WM 1.3 – Major works	0.6	0	8	-	11	84	28	-	29	-	16	-	176
												Construction phase 1 total:	**533**
WM 2.2 – Accommodation camps	1.0	-	-	-	2	9	7	-	-	-	-	-	19
WM 2.3 – Construction pads	1.0	-	-	-	2	24	5	-	5	-	16	-	52
WM 2.4 – Access roads	-	-	1	-	3	12	2	5	5	3	-	10	42
WM 2.5 – Large temporary stockpiles	1.0	-	12	-	6	12	-	-	5	-	-	-	35
												Construction phase 2 total:	**148**
WM 3.2 – Permanent surface infrastructure	1.0	-	-	-	2	11	-	-	7	-	-	-	20
WM 3.3 – Permanent access roads	-	-	-	-	-	-	-	-	-	-	-	-	-
– Unsealed	-	-	1	-	3	6	2	5	1	-	-	10	29
– Sealed	-	-	-	-	-	5	-	-	-	-	-	-	5
WM 3.3 Total	-	-	1	-	3	11	2	5	1	-	-	-	35
												Operational phase (phase 3) total:	**55**

Notes: 1. Values are presented to the nearest integer.

2. Other areas include: sections of Tantangara Road which flow to the lower sections of the Eucumbene River, and sections of Lobs Hole Ravine Road, Snowy Mountains Highway and the Link Road which are outside of the catchments characterised elsewhere.

A.8 Disturbance areas applied to residual impacts assessment

The area and duration of disturbance for each stormwater management category has been estimated based on the actual disturbance area, conceptual layout and project schedule. These values are applied to discharge modelling (see WMR, Annexure D to the water assessment) to assess changes in receiving water flow regimes and water quality in the following three key catchments:

- Yarrangobilly River (including Wallaces Creek);
- Upper Eucumbene River; and
- Kellys Plain Creek.

Table A.7 provides a break-down of the disturbance areas applied to assess residual impacts.

Table A.7 Disturbance areas applied to discharge modelling

Stormwater management category	Estimated actual disturbed area by catchment (ha)[1]				
	Yarrangobilly River[2]	Upper Eucumbene River	Kellys Plain Creek[3]	All other areas	Total
WM 1.2 – Minor works	111	12	98	136	357
WM 1.3 – Major works	95	8	57	16	176
Construction phase 1 total					**533**
WM 2.2 – Accommodation camps	11	-	7	0	19
WM 2.3 – Construction pads	25	-	11	16	52
WM 2.4 – Access roads[3]	16	1	12	13	42
WM 2.5 – Large temporary stockpiles	18	12	5	-	35
Construction phase 2 total					**148**
WM 3.2 – Permanent surface infrastructure	13	-	7	-	20
WM 3.3 – Permanent access roads					
– Unsealed[4]	10	1	8	10	29
– Sealed	5				5
WM 3.3 Total	15	1	8	10	35
Operational phase (phase 3) total					**55**

Notes: 1. Values are presented to the nearest integer.
2. Includes disturbance areas in Yarrangobilly River and Wallaces Creek catchments.
3. Includes disturbance areas in Kellys Plain Creek, Nungar Creek and Tantangara Reservoir catchments.
4. Refers to the surface area of access roads that will be constructed or substantially modified. The use of existing access tracks that will only be slightly modified (ie by construction of overtaking bays) is not considered to result in material additional disturbance.

Attachment B

Summary of water management measures

Table B.1 Summary of proposed management measures

Measure[1]	Description
Construction phase 1 – construction of surface infrastructure	
WM 1.1 Clean water management	
WM 1.1.1	Where practical, clean water will be diverted around or through construction areas. Runoff from clean water areas that cannot be diverted will be accounted for in the design of water management systems. Temporary clean water drainage will be designed to have non-erosive hydraulic capacity. The design event will be established based on disturbance duration and other relevant factors.
WM 1.1.2	Where practical, clean water diversions will seek to avoid increasing flow rates in adjoining watercourses.
WM 1.2 minor works	
WM 1.2.1	An Erosion and Sediment Control Plan (ESCP) will be prepared for each construction area. Each ESCP will: • apply the methods and principles provided in *Managing Urban Stormwater: Soils and Construction:* – *Volume 1 – Soils and construction* (Landcom 2004); and/or – *Volume 2A – Installation of services* (DECC 2008); and/or – *Volume 2C – Unsealed roads* (DECC 2008); unless stated below; • consider local soil characteristics, topography and environmental constraints and proposed construction methods; • apply clean water management controls as per: – WM 1.1 for clean water management during surface construction disturbance; – WM 2.1 for temporary watercourse diversions around temporary surface infrastructure; and – WM 3.1 for permanent watercourse diversions. • all temporary drainage and sediment control measures will be designed to have non-erosive hydraulic capacity and be structurally sound for a design event. The design event will be established based on the disturbance duration and other relevant factors; • consider all practical erosion control and rehabilitation methods and apply the most appropriate method; • consider all practical methods to stabilise small temporary stockpiles and apply the most appropriate method. Apply management controls as per WM 2.5 for the management of large temporary stockpiles; • apply enhanced erosion controls where significant risks are identified; and • be progressively amended as required during construction.
WM 1.2.2	The following will be implemented: • measures to manage the storage and handling of hydrocarbons and other chemicals that have potential to pollute receiving waters; and • measures to manage accidental leaks and spills.
WM 1.2.3	Suitably qualified erosion and sediment control professional(s) will be commissioned to: • oversee the development of ESCPs; • inspect and audit controls; • train relevant staff; and • progressively improve methods and standards as required.

Table B.1 Summary of proposed management measures

Measure[1]	Description
WM 1.3 major works	
WM 1.3.1	An ESCP will be prepared for each construction area. Each ESCP will: • apply the methods and principles provided in *Managing Urban Stormwater: Soils and Construction:* – *Volume 1 – Soils and construction* (Landcom 2004); and/or – *Volume 2A – Installation of services* (DECC 2008); and/or – *Volume 2C – Unsealed roads* (DECC 2008); unless stated below; • consider local soil characteristics, topography and environmental constraints and proposed construction methods; • apply clean water management controls as per: – WM 1.1 for clean water management during surface construction disturbance; – WM 2.1 for temporary watercourse diversions around temporary surface infrastructure; and – WM 3.1 for permanent watercourse diversions. • consider all practical source control and rehabilitation methods and apply the most appropriate methods; • consider all practical methods to stabilise small temporary stockpiles and apply the most appropriate method. Apply management controls as per WM 2.5 for the management of large temporary stockpiles; • all temporary drainage and sediment control measures will be designed to have non-erosive hydraulic capacity and be structurally sound for a design event. The design event will be established based on the disturbance duration and other relevant factors. • where practical, all runoff from disturbance areas will be directed to sedimentation basins designed to capture the 85th percentile 5-day rainfall event. Captured water will be harvested and used for dust suppression; and • be progressively amended as required during construction.
WM 1.3.2	The following will be implemented: • measures to manage the storage and handling of hydrocarbons and other chemicals that have potential to pollute receiving waters; and • measures to manage accidental leaks and spills.
WM 1.3.3	Suitably qualified erosion and sediment control professional(s) will be commissioned to: • oversee the development of ESCPs; • inspect and audit controls; • train relevant staff; and • progressively improve methods and standards as required.
WM 1.4 water supply system	
WM 1.4.1	A water supply system will be established to supply water for potable water use and construction activities. The system will most likely source water from regional groundwater resources but will also likely source water from Tantangara and/or Talbingo Reservoirs provided required licences and approvals can be obtained. Extraction from watercourses is not proposed and will be avoided. The most suitable and available extraction locations and water sources will be established at detailed design stage.

Table B.1 Summary of proposed management measures

Measure[1]	Description
Construction phase 2 (all other construction activities)	
WM 2.1 temporary watercourse diversions	
WM 2.1.1	Where practical, all temporary watercourse diversions will: • be piped and/or surface drainage systems; • be designed and constructed to have non-erosive hydraulic capacity and be structurally sound for a design event that will be established by a risk assessment (described below); and • have adequate scour protection at the system inlets and outlets. During detailed design a risk assessment will be undertaken to identify risks associated with by-pass flows that may occur as a result of system blockage or an event greater than the design event. This process will establish the: • design capacity of the diversion; and • need for and capacity of overland flow paths or other measures to manage bypass flows.
WM 2.1.2	Where practical, temporary watercourse diversions will seek to avoid increasing flow rates in adjoining watercourses.
WM 2.1.3	All temporary watercourse diversions will be decommissioned following the completion of works. WM 3.1 applies to any permanent watercourse diversion or re-established watercourse.
WM 2.2 accommodation camps	
WM 2.2.1	Where practical, the following source controls will be applied: • the storage and handling of chemicals that have potential to contaminate the stormwater system will be undertaken in bunded areas. Any liquid waste stream will be disposed to an appropriate facility; • landscaped areas will be predominately vegetated with endemic native vegetation; and • runoff from road and other hardstand areas will be treated in vegetated swales.
WM 2.2.2	Runoff from accommodation camps will be managed by drainage systems that have a 20% AEP capacity. Overland flow paths will be provided as required.
WM 2.2.3	Runoff from accommodation camps will be treated in either sedimentation or bioretention basins. The most appropriate control will be established at detailed design with consideration of topography, soil conditions and other relevant factors.
WM 2.2.4	Overall, the stormwater management system for accommodation camps will be designed and operated to achieve the water quality characteristics described in Table 3.12.
WM 2.3 construction pads	
WM 2.3.1	Where practical, activities that have potential to contaminate stormwater runoff will be isolated from the stormwater system by covering (ie by a building or roof) and/or bunding.
WM 2.3.2	Runoff from construction pads and upslope clean water areas will be managed by a drainage system. The design capacity will be established at detailed design. Overland flow paths will be provided as required.
WM 2.3.3	Runoff from construction pads will be directed to sedimentation basins. The sedimentation basins will be designed to capture runoff from the 85^{th} percentile 5-day rainfall event. Where practicable, captured water will be harvested and used for dust suppression.
WM 2.3.4	Overall, the stormwater management system for construction pads will be designed and operated to achieve the water quality characteristics described in Table 3.15.

Table B.1 Summary of proposed management measures

Measure[1]	Description
WM 2.4 access roads	
WM 2.4.1	Any existing access tracks that will no longer be required following the construction of the new access roads will be rehabilitated.
WM 2.4.2	All cut and fill batters will be stabilised as soon as practical following construction.
WM 2.4.3	Roads surfaces will be constructed and maintained with aggregate material to reduce soil loss rates and water quality risks. The use of material that presents elevated water quality risks relative to other material available for road construction and maintenance will be avoided.
WM 2.4.4	Where practical access roads will grade to table drains that are designed and constructed to have non-erosive hydraulic capacity for the 10% AEP event. Transverse (or cross drainage) will be constructed to have the following non-erosive hydraulic capacities: • Primary roads – 1% AEP event; • Maintenance roads – 2% AEP event; and • Temporary access roads – 10% AEP event.
WM 2.4.5	Sediment traps or filters will be installed and maintained at all discharge locations to reduce coarse sediment in discharge.
WM 2.4.6	Temporary roads will be rehabilitated as soon as they are no longer needed.
WM 2.5 large temporary stockpiles	
WM 2.5.1	Excavated material will be characterised and identified contaminated soils or PAF material will be managed separately.
WM 2.5.2	An ESCP will be prepared for each stockpile. Each ESCP will: • apply the methods and principles provided in *Managing Urban Stormwater: Soils and Construction – Volume 1 – Soils and construction* (Landcom 2004) unless stated below; • consider local soil characteristics, topography and environmental constraints and proposed construction methods and identify risks associated with proposed activities; • apply clean water management controls as per: – WM 1.1 for clean water management during surface construction disturbance; and – WM 2.1 for temporary watercourse diversions around temporary surface infrastructure. • consider all practical temporary stabilisation methods and apply the most appropriate methods; • where practical, all runoff and seepage from each stockpile will drain to sedimentation basins designed to capture the 85^{th} percentile 5-day rainfall event. Captured water will be harvested and used for dust suppression; and • be progressively amended as required during construction.
WM 2.5.3	All large temporary stockpiles will be removed during the construction phase of the project and the disturbed area will be rehabilitated in accordance with the relevant rehabilitation strategy.
WM 2.6 large surface excavations	
WM 2.6.1	Water that accumulates in the sumps of large surface excavations will be either: • dewatered to the process water system (WM 2.7); • used for dust suppression; or • discharged to receiving waters if water quality monitoring can establish that water is suitable for discharge without treatment.

Table B.1 Summary of proposed management measures

Measure[1]	Description
WM 2.7 Process water	
WM 2.7.1	A process water management system will be established to: • supply water to construction activities; and • manage water that is pumped from the sumps in subsurface excavations and large surface excavations (WM 2.6). The process water system will be decommissioned once the project enters the commissioning phase and the headrace and tailrace tunnels are flooded.
WM 2.7.2	The process water system will be designed and constructed to minimise stormwater ingress into the system to reduce the volume of water that requires management.
WM 2.7.3	Where practical, the storage and handling of chemicals that have potential to contaminate the process water system will be undertaken in bunded areas. Any liquid waste streams will be disposed to an appropriate facility.
WM 2.7.4	Where practical, plant and equipment washdown will be undertaken in designated washdown bays or areas. Washdown water will be captured, treated and reused to minimise or avoid discharge into the process water system.
WM 2.7.5	Where practical, the process water system will be designed to enable emergency discharge to stormwater basins. This will reduce the risk of untreated process water entering a watercourse.
WM 2.7.6	Groundwater that accumulates in excavations where construction is complete may be diverted around the process water system (ie discharged directly to a reservoir) provided that: • water can be practically separated from the process water system and reticulated to the reservoirs; and • the water quality is similar to the water quality characteristics described in Table 4.9 for treated process water.
WM 2.7.7	All surplus process water will be treated to meet the water quality specifications provided in Table 4.6 Treated process water quality characteristics .
WM 2.7.8	All treated surplus process water will be discharged to Tantangara and Talbingo reservoirs via diffuser arrangements. Indicative discharge locations are provided in Figure 2.2. Discharges to watercourses will be avoided.
WM 2.8 potable water – no management measures required	
WM 2.9 wastewater	
WM 2.9.1	All wastewater produced will be reticulated or trucked to a wastewater treatment plant. All reticulation and storages will be designed to restrict stormwater and groundwater ingress into the wastewater system.
WM 2.9.2	Water efficient fittings will be used to minimise wastewater loads.
WM 2.9.3	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 2.9.4	No trade waste will be discharged to the wastewater system.
WM 2.9.5	Each wastewater treatment plant will include emergency storage for untreated wastewater. The storage volume will be calculated during detailed design based on analysis of response times for emergency trucking and offsite disposal.
WM 2.9.6	All wastewater will be treated to meet the water quality specifications provided in Table 5.1.
WM 2.9.7	Treated wastewater will be discharged to Talbingo and Tantangara reservoirs via diffuser arrangements. Indicative discharge locations are provided in Figure 2.2.
WM 2.10 tunnel inflows	
WM 2.10	Tunnel boring machines will be equipped with drilling machines to drill drainage holes to relieve groundwater pressures. If required, pre-excavation grouting will also be used to seal-off groundwater inflow and to improve the stability of the excavation face. Post-excavation grouting, from the segmental lining, may also be used to further consolidate the surrounding rock and/or further reduce water ingress if required.

Table B.1 Summary of proposed management measures

Measure[1]	Description
Operational phase (Phase 3)	
WM 3.1 permanent watercourse diversion	
WM 3.1.1	Any watercourse that will be permanently diverted around permanent infrastructure will: • be a piped and/or surface drainage system; • be designed and constructed to have non-erosive hydraulic capacity and be structurally sound for the 1% AEP event; and • have adequate scour protection at the system inlets and outlets. During detailed design a risk assessment will be undertaken to identify risks associated with by-pass flows that may occur as a result of system blockage or an event greater than the design event. If significant risks are identified (such as embankment failures or entrainment of materials that could pollute the receiving environment), engineered overland flow paths will be established to manage by-pass flows.
WM 3.1.2	Watercourses to be reinstated into a rehabilitated landform along either its original or an alternative alignment will be designed and constructed as a physically stable naturalised watercourse that has similar environmental values to the pre-disturbed watercourse.
WM 3.2 permanent surface infrastructure	
WM 3.2.1	Transformers and any other infrastructure that has potential for leaks or spills will be bunded in accordance with relevant guidelines.
WM 3.2.2	Runoff from permanent surface infrastructure will be managed by a drainage system that has a 1% AEP capacity. Overland flow paths will be provided as required.
WM 3.3 permanent access roads	
WM 3.3.1	Unsealed roads will be maintained with aggregate material to reduce soil loss rates and water quality risks. The use of material that presents elevated water quality risks relative to other material available for road construction and maintenance will be avoided.
WM 3.3.2	Where practical access roads will grade to table drains that are designed and constructed to have non-erosive hydraulic capacity for the 10% AEP event. Transverse (or cross drainage) will be constructed to have the following non-erosive hydraulic capacities: • Primary roads – 1% AEP event; and • Maintenance roads – 2% AEP event.
WM 3.3.3	Sediment traps or filters will be maintained at all discharge locations on unsealed roads to reduce coarse sediment in discharge.
WM 3.4 Tailrace tunnel dewatering	
WM 3.4.1	Water pumped from the tailrace tunnel to enable maintenance access will be discharged into a drainage system that will convey the water to the Yarrangobilly River. The drainage system will be designed and constructed to have non-erosive hydraulic capacity and be structurally sound for the design discharge rate and duration.
WM 3.5 Management of groundwater inflows	
WM 3.5.1	Groundwater inflows into the power station cavern, access tunnels and any other excavation that will not be flooded will be collected and pumped into the collector tunnel or tailrace surge tank.
Ancillary management measures	
Instream works 1	All permanent culverts and bridges will be designed by a suitably qualified professional in accordance with the relevant Austroads Guidelines.
Instream works 2	All service crossings of watercourses will be designed by a suitably qualified professional in accordance with best practice methods.

Notes: 1. The management measures presented are principles or design objectives, that will be further developed in the detailed design of Main Works. The measures implemented may vary from those presented but will meet the proposed discharge characteristics or other stated objectives.

Attachment C

Water balance model technical report

C.1 Purpose

This attachment to the water management report (WMR) (Annexure D to the water assessment) describes the methods and assumptions applied to developing a water balance of the project's process water system. The process water system is described in Chapter 4 of the WMR.

C.2 Process water system

The process water system will supply water to, and manage water produced by construction activities. Key water uses (or system demands) include water used for subsurface construction (primarily TBM cooling and dust suppression), concrete production and access road dust suppression. Key inflows into the system include water pumped from subsurface and large surface excavations.

The process water system will comprise separate systems at the Tantangara and Talbingo construction compounds. These systems are referred to as the Tantangara and Talbingo process water systems and will operate independently (ie they will not be connected). Each system will:

- be isolated from the stormwater management system (described in Chapter 3 of the WMR);
- discharge to a reservoir when net inflows into the system exceed net usage; and
- be toped up from the water supply system (described in Section 6.1 of the WMR) when net usage exceeds net inflows.

The water quality of process water will be influenced by the groundwater inflow quality, any degradation by construction activities and other factors. The water quality is expected to be variable, with potential for poor water quality to occur in some parts of the process water system. The following water treatment will be provided:

- all process water will be treated to a suitable quality for re-use within the process water system; and
- additional treatment will be provided for all process water that is discharged to the reservoirs.

Figure C.1 shows the conceptual framework of the process water system.

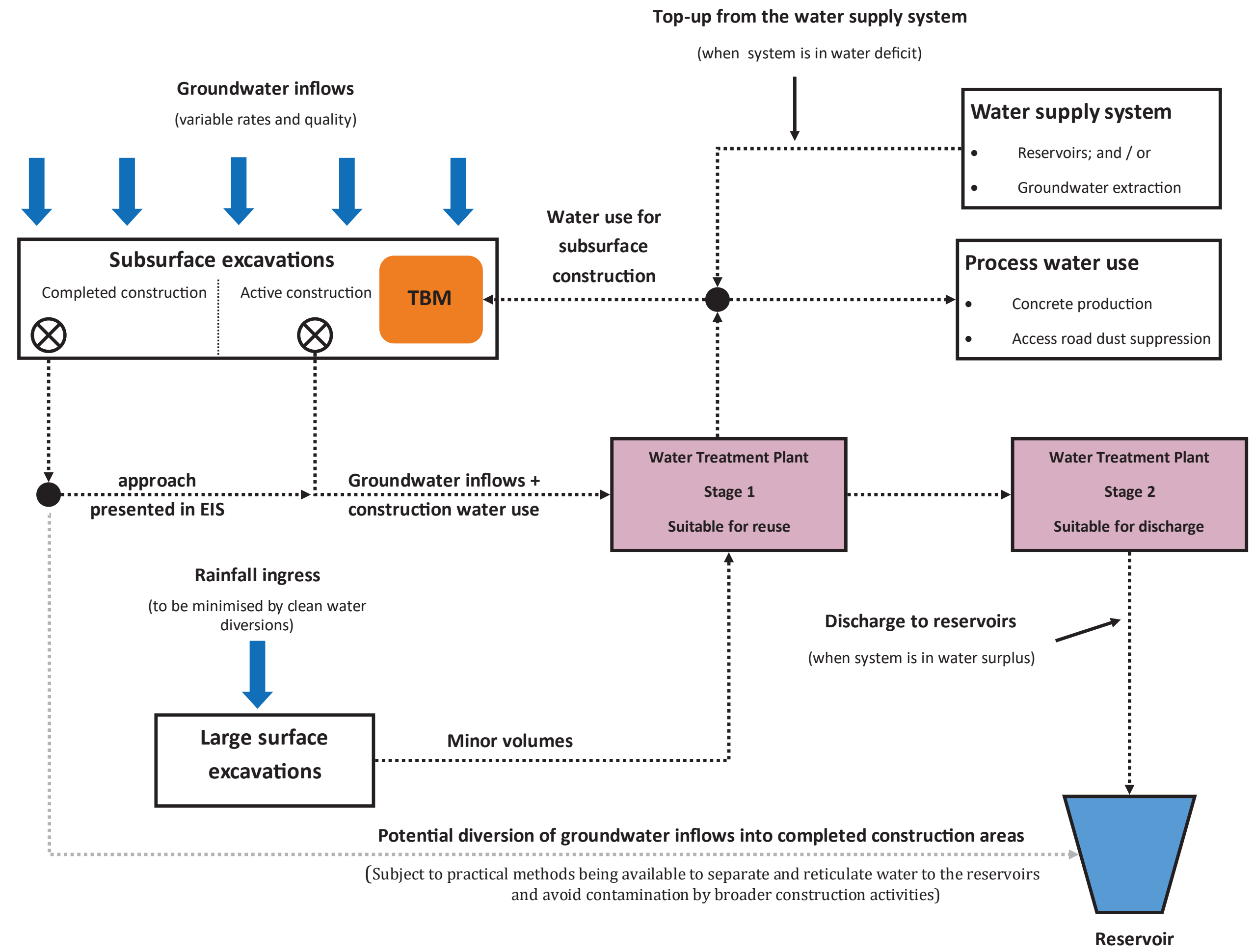


Figure C.1 Process water system – conceptual framework

C.3 Tantangara and Talbingo system extents

The Tantangara and Talbingo process water systems will manage water pumped from connected subsurface excavations. Figure 4.2 shows the extent of subsurface excavations connected to each system. As the volume and water quality of groundwater inflows will be a key contributing factor to the process water system, the following groundwater quality categories have been established to collectively describe inflows from geological units that have similar groundwater quality characteristics:

- Plateau – includes the Boggy Plains Suite, Gooandra Volcanics, Kellys Plain Volcanics, Tantangara Formation and Temperance Formation geological units.
- West ravine – includes the Ravine Beds West geological unit.
- East ravine – includes the Boraig Group and Ravine Beds East geological units.

Figure C.2 shows the extent of each groundwater quality category. The groundwater quality characteristics of each category are discussed in Section 4.3.1 of the WMR. Refer to the WCR (Annexure A to the water assessment) for more information on geological units and associated groundwater quality.

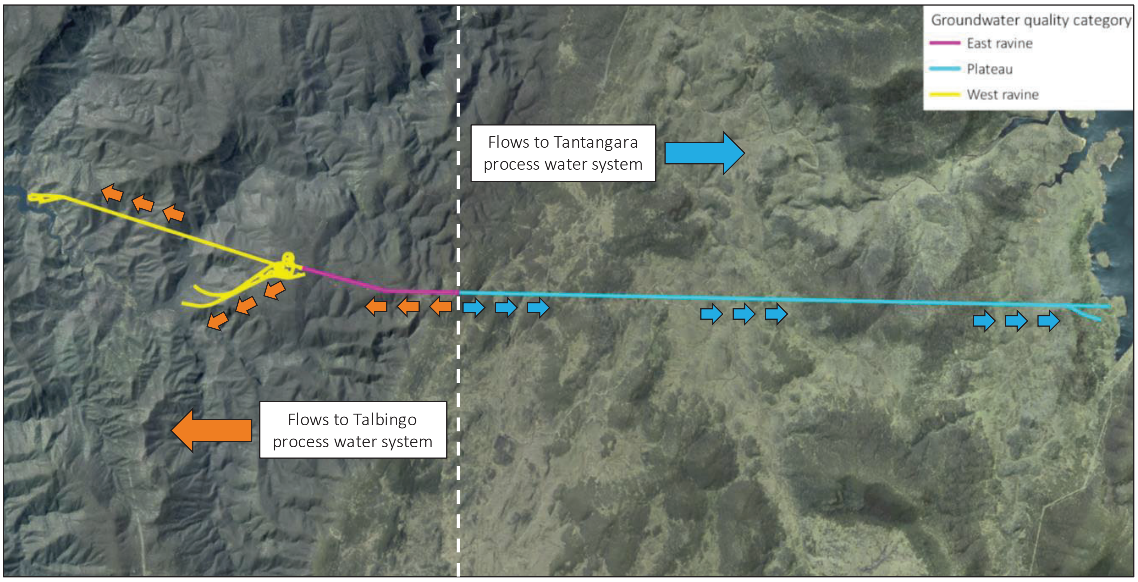


Figure C.2 Process water system extent

C.4 System inflows

As indicated in Figure C.1, the following process water system inflows will occur:

- groundwater inflows into subsurface excavations;
- water pumped from sumps of surface excavations that may have poor water quality; and
- top-up water from the water supply system.

C.4.1 Groundwater inflows

The groundwater model developed for Main Works (modelling report, Annexure B to the water assessment) provides predicted groundwater inflow volumes over the construction phase of the project. Model outputs were provided as quarterly inflow averages to each subsurface excavation component. A breakdown of the primary subsurface components is provided in Table C.1. Predicted groundwater inflows to each component under average climate conditions are shown in Figure C.3.

Table C.1 Subsurface excavation dewatering

Subsurface component	Description	Start of inflow[1]	Maximum inflow
Headrace tunnel (HRT)	Extends 17.4 km from Tantangara Reservoir in the east to the power station structure in the west.	Month 12	12.8 ML/day
Tailrace tunnel (TRT)	Extends 5.8 km from the power station structure in the east to Talbingo Reservoir in the west.	Month 6	0.7 ML/day
Main access tunnel	Extends 2.5 km from the power station structure to the north-east to Lobs Hole in the west.	Month 1	0.4 ML/day
Emergency egress, cables and ventilation tunnel	Extends 2.4 km from the power station structure to the north-east to Lobs Hole in the west. Runs adjacent to the MAT with the tunnel entrance approximately 500 m north of the MAT entrance.	Month 9	0.3 ML/day
Ancillary structures	All other underground components including, surge tanks, power station infrastructure etc.	Month 12	0.8 ML/day

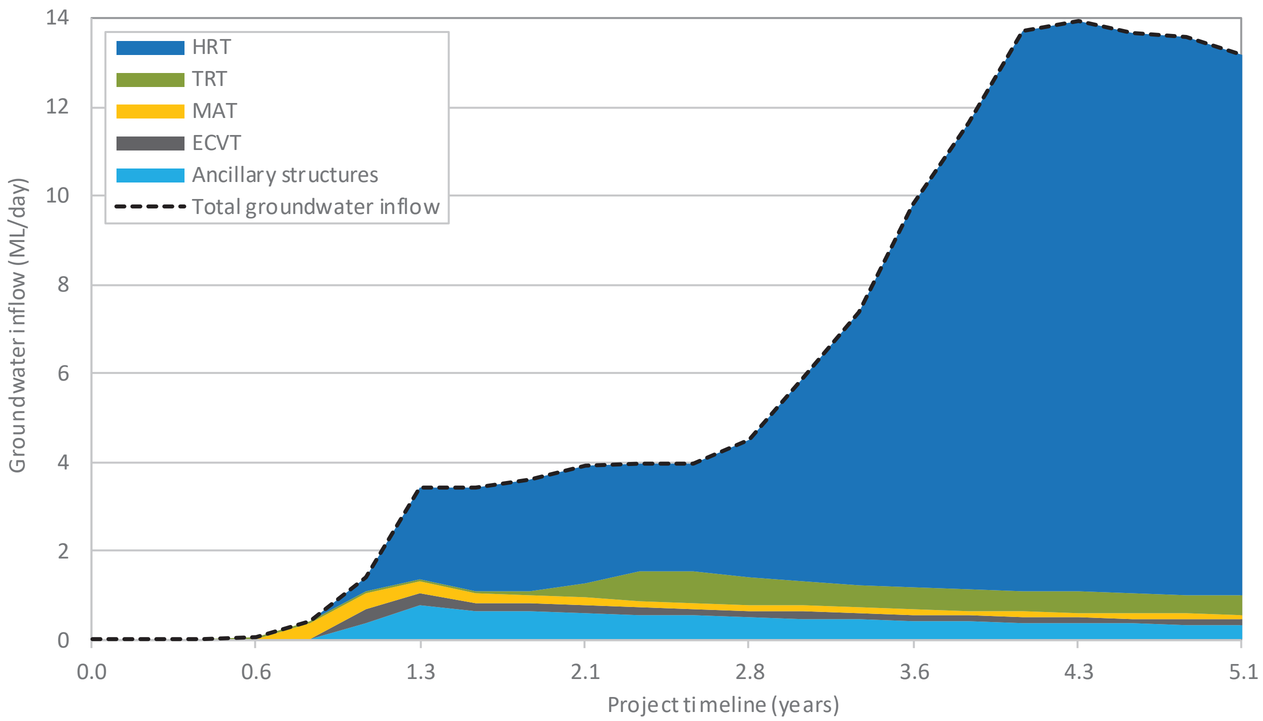


Figure C.3 Groundwater inflow predictions

C.4.2 Dewatering surface excavations

Water that accumulates in the sumps of large surface excavations such as tunnel intakes may have poor water quality due to construction activities. Accordingly, water may be dewatered to the process water system. Inflows into surface excavations will occur from direct rainfall and groundwater ingress. Estimated inflow volumes and contributing catchment areas of large surface excavations that will be connected to the process water system are described in Table C.2.

Table C.2 Large surface excavations

Large surface excavation	Contributing catchment area	Inflow volume
Tantangara intake	6 ha	36 ML/year[1]
Talbingo intake	3 ha	17 ML/year[2]

Notes: 1. Inflow volume calculated using average yearly rainfall (1,009 mm/year) for Tantangara Reservoir rainfall gauge (WCR, Annexure A to the water assessment) and a runoff coefficient (Cv) of 0.6.

2. Inflow volume calculated using average yearly rainfall (920 mm/year) for Ravine rainfall gauge (WCR, Annexure A to the water assessment) and a runoff coefficient (Cv) of 0.6.

Water dewatered from large surface excavations is not included in the water balance as the volumes are insignificant when compared to the volume of groundwater inflows.

C.4.3 Top-up from the water supply system

The process water system will be toped-up with water from the water supply system (Section 6.1 of the WMR). System top-ups will only be required when net usage exceeds net inflows.

C.5 Process water usage

Estimated process water usage for the Tantangara and Talbingo process water systems was developed as part of the concept design. Process water demands were estimated for concrete batching plants, TBMs and dust suppression. TBM demands for the Talbingo process water system were calculated separately for the Talbingo portal and main access tunnel (MAT)/emergency egress, cable and ventilation tunnel (ECVT) portals. Process water demands were estimated for a seven-year process water timeseries (period over which process water demands occur). Process water use for the Tantangara and Talbingo process water systems is presented as stacked area charts in Figure C.4 and Figure C.5 respectively.

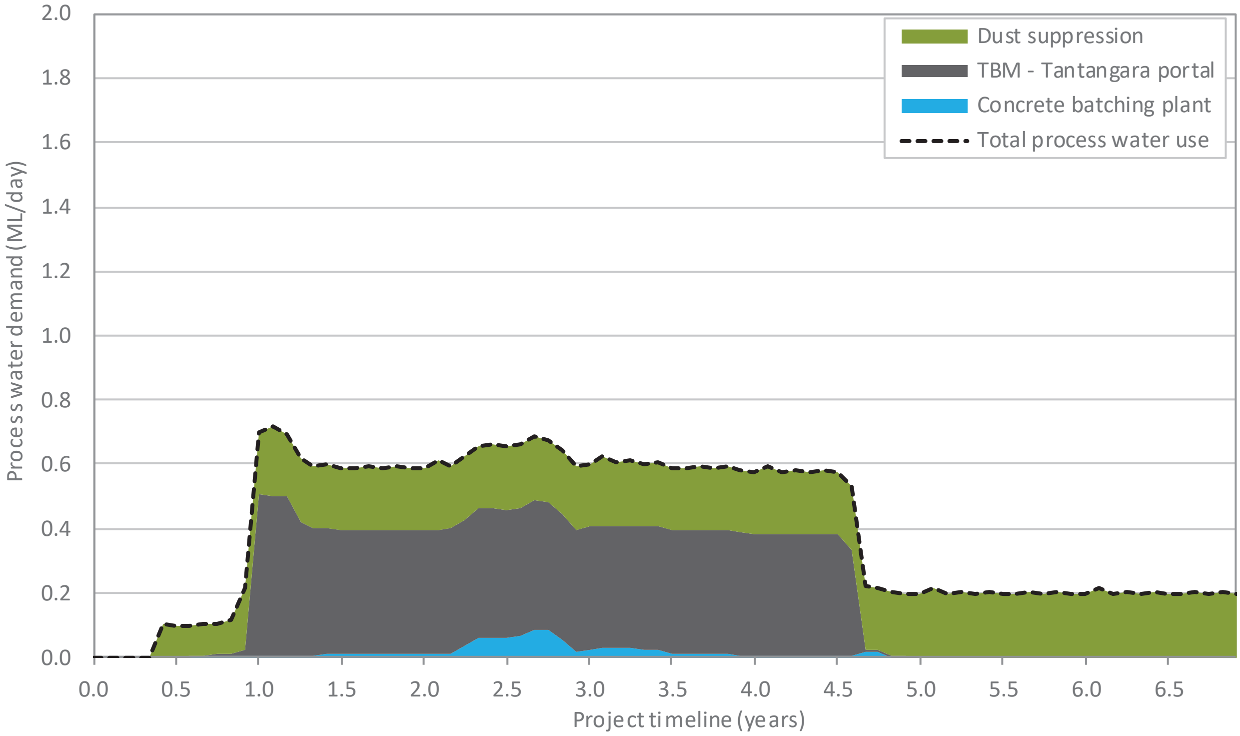


Figure C.4 Estimated process water use for the Tantangara process water system

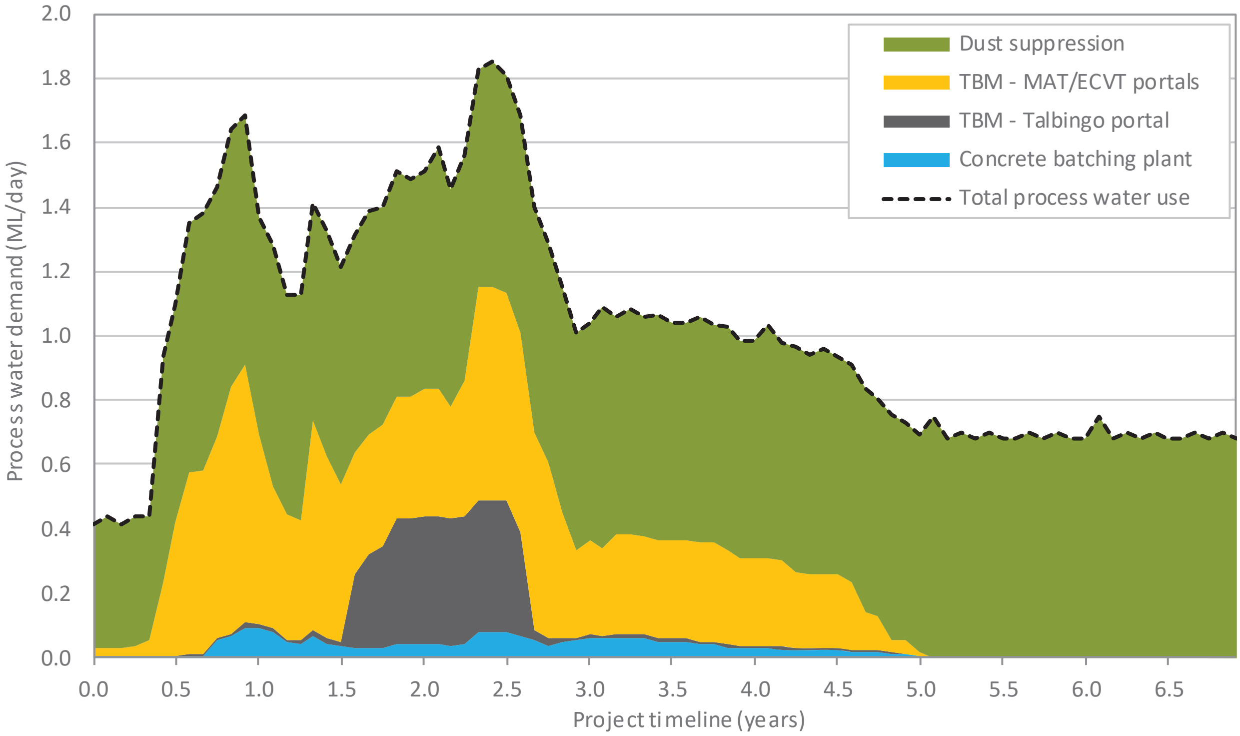


Figure C.5 Estimated process water use for the Talbingo process water system

C.6 Model assumptions

C.6.1 Groundwater inflows

The groundwater inflow dewatered to each process water system is dependent on construction timing, subsurface component and geological units intercepted. The groundwater model outputs described in Section C.4.1 provide inflows on a subsurface component basis and do not differentiate flows contributing to the separate process water systems. Hence, inflows to tunnel components that drain to both Tantangara and Talbingo process water systems (ie the HRT) required manual separation of groundwater model (modelling report, Annexure B to the Water Assessment) outputs.

The subsurface components assumed to contribute to each process water system are identified in Table C.3 and shown in Figure C.2. The groundwater inflow directed to each tunnel portal in the water balance model is shown in Figure C.6. Groundwater inflows for each groundwater quality category are shown in Figure C.7.

Table C.3 Breakdown of subsurface components

Process water system	Tunnel portal	Contributing subsurface components	Groundwater quality category
Tantangara	Tantangara	• HRT chainage 0 to 15,400 m	• Plateau
Talbingo	Talbingo	• TRT	• West ravine
	MAT/ECVT	• MAT and ECVT • HRT chainage 17,400 to 15,400 m • All other subsurface components including surge tanks, power station etc.	• West ravine • East ravine

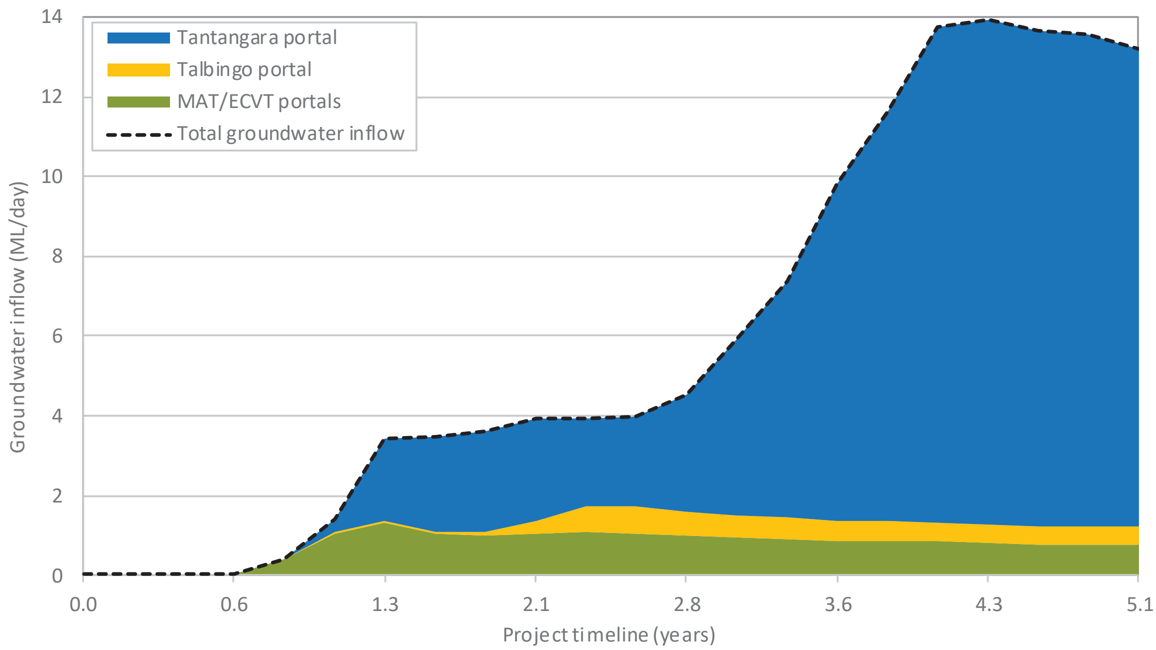


Figure C.6 Water balance model groundwater inflow – subsurface components

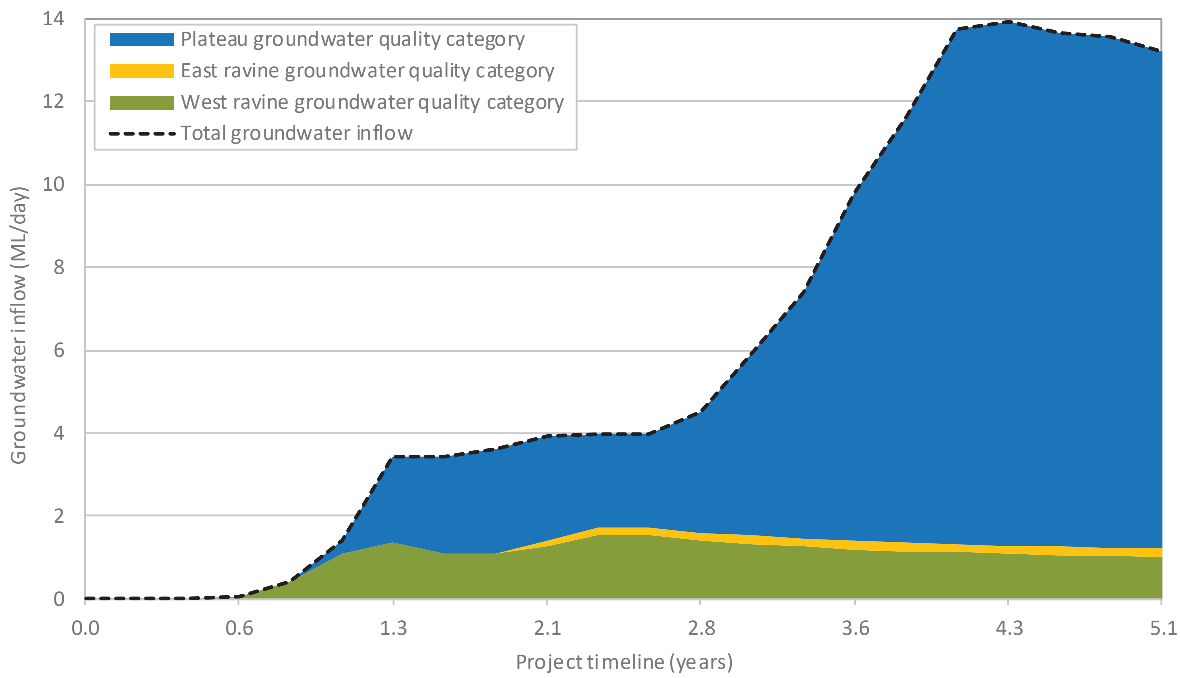


Figure C.7 Water balance model groundwater inflow – groundwater quality categories

C.6.2 Rainfall data

Direct rainfall inflows to Tantangara and Talbingo process water system surface excavations are estimated to be 36 ML/year and 17 ML/year respectively (see Section C.4.2). Subsurface excavation inflows to Tantangara and Talbingo process water systems are predicted to be up to 4,600 ML/year and 630 ML/year respectively (see Section C.6.1). Hence, rainfall occurring directly onto surface excavations is negligible compared to the predicted subsurface excavation inflows.

Rainfall has not been included in the water balance model.

C.6.3 Evaporation

No water storages have been modelled. Hence, evaporation has not been included in the water balance model.

C.6.4 Site infrastructure

i Process water demands

Monthly process water demands described in Section C.5 were converted to daily values for use in the water balance model. Daily process water demands were obtained by dividing the monthly total by the number of days in each month.

Process water for concrete batching and dust suppression at the Talbingo process water system is preferentially sourced from the MAT/ECVT portal. This assumption is based on the timing of construction (construction of MAT/ECVT commences before TRT) and has been made to simplify the modelling process. During construction, process water could be preferentially sourced from either the MAT/ECVT portal or Talbingo portal as required.

Process water used by the TBM is sourced independently at each tunnel. TBM process water is recycled through the WTP for re-use. No water losses have been assumed during the recycling process.

It is noted that some stormwater captured in sedimentation basins may also be used for dust suppression. This is not expected to materially alter the results given the dust suppression water use is minor in comparison to groundwater inflows.

ii Water management basins and sumps

Daily groundwater inflows to Tantangara and Talbingo process water systems are predicted to be substantially greater than the available storage within sumps and water management basins, resulting in short residence times (less than a daily timestep) for process water that enters these storages.

Accordingly, no water management basin, portal sump or tunnel sump storages are modelled.

iii Process water treatment plant

Process water from the Tantangara and Talbingo process water systems will be treated prior to re-use or discharge. The water treatment process does not impact the water balance. It is noted that it is assumed that no clean groundwater diversions occur.

C.6.5 Water supply system

The process water system is topped up with water from the project's water supply system (described in Section 6.1 of the WMR) when usage exceeds groundwater inflows.

C.6.6 Reservoirs

Controlled discharge to Tantangara and Talbingo reservoirs occurs when groundwater inflows exceed net process water use.

C.7 Model representation

C.7.1 Modelling approach

The water balance model was developed in GoldSim version 12.1 (GoldSim Technology 2017). The model applied a continuous simulation methodology that simulated the performance of the system over the six-year construction period.

C.7.2 Time step and simulation time

The water management system was modelled for the 84-month project timeline with daily time steps. The project timeline was assumed to commence at the beginning of the process water use time series and finish at the end of the process water use time series (see Section C.5).

C.7.3 Scenario

The groundwater model developed for Main Works (modelling report, Annexure B to the water assessment) provided outputs for dry, average and wet climate conditions. A 5% variation (0.7 ML/day) to subsurface excavation peak inflows was predicted between dry and wet climate conditions. As minor variations in predicted groundwater inflows occur due to climate conditions, the water balance model was only run using predicted groundwater inflows under average climate conditions (see Section C.6.1).

C.8 Model results

Model results are presented in Section 4.2 of the WMR. Additional results are provided in flow chart form Figure C.8 to Figure C.13. The flow charts have been prepared to describe the functionality of the process water management system for months 12, 24, 36, 48, 60 and 72 of the construction phase of the project. The flow charts show system flows for the MAT/ECVT, Talbingo and Tantangara portals separately. It is noted that the MAT/ECVT and Talbingo portals system form the Talbingo process water system and all results presented in the WMR refer to the Talbingo process water system.

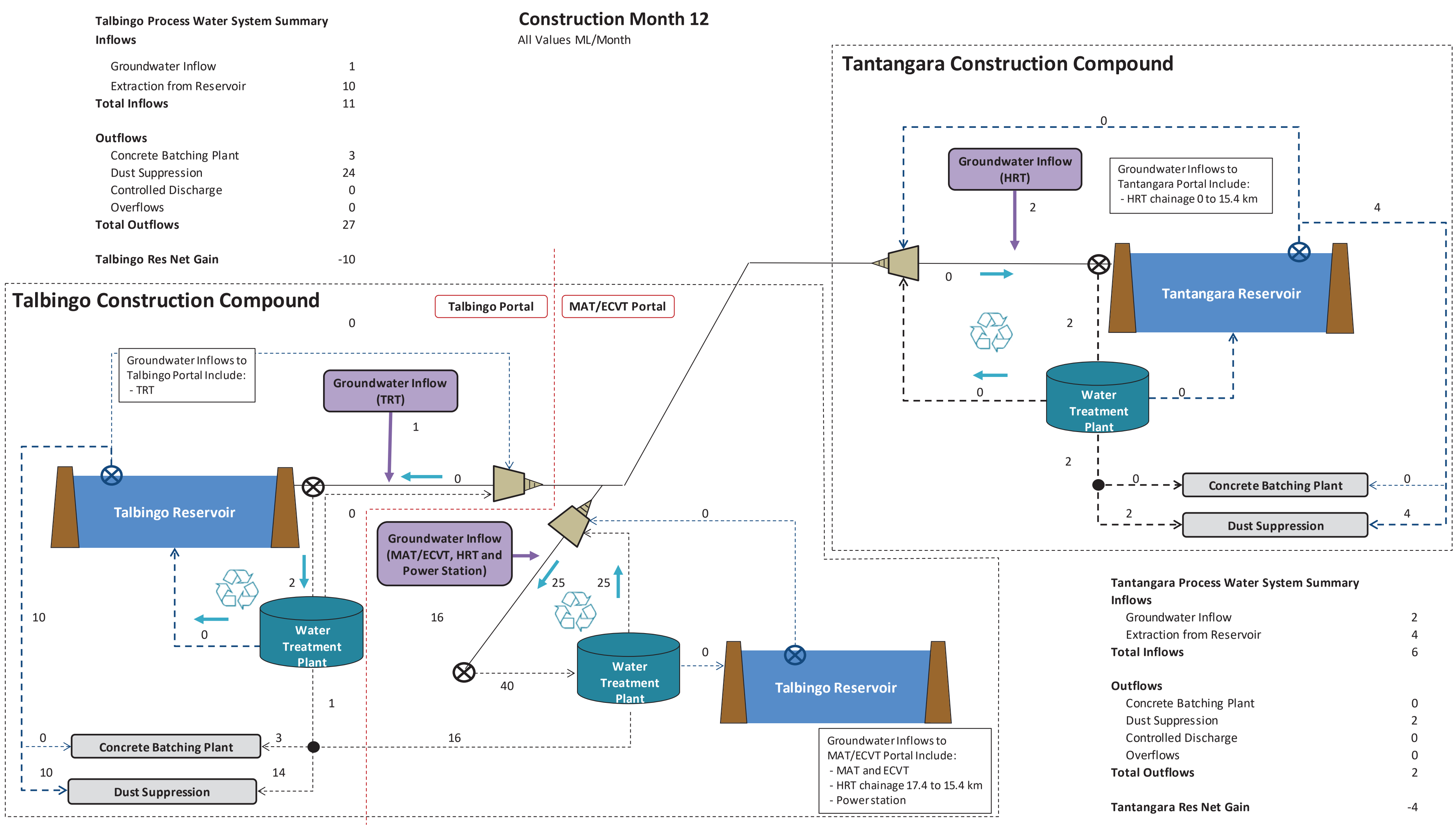


Figure C.8 Water balance results: month 12 of construction

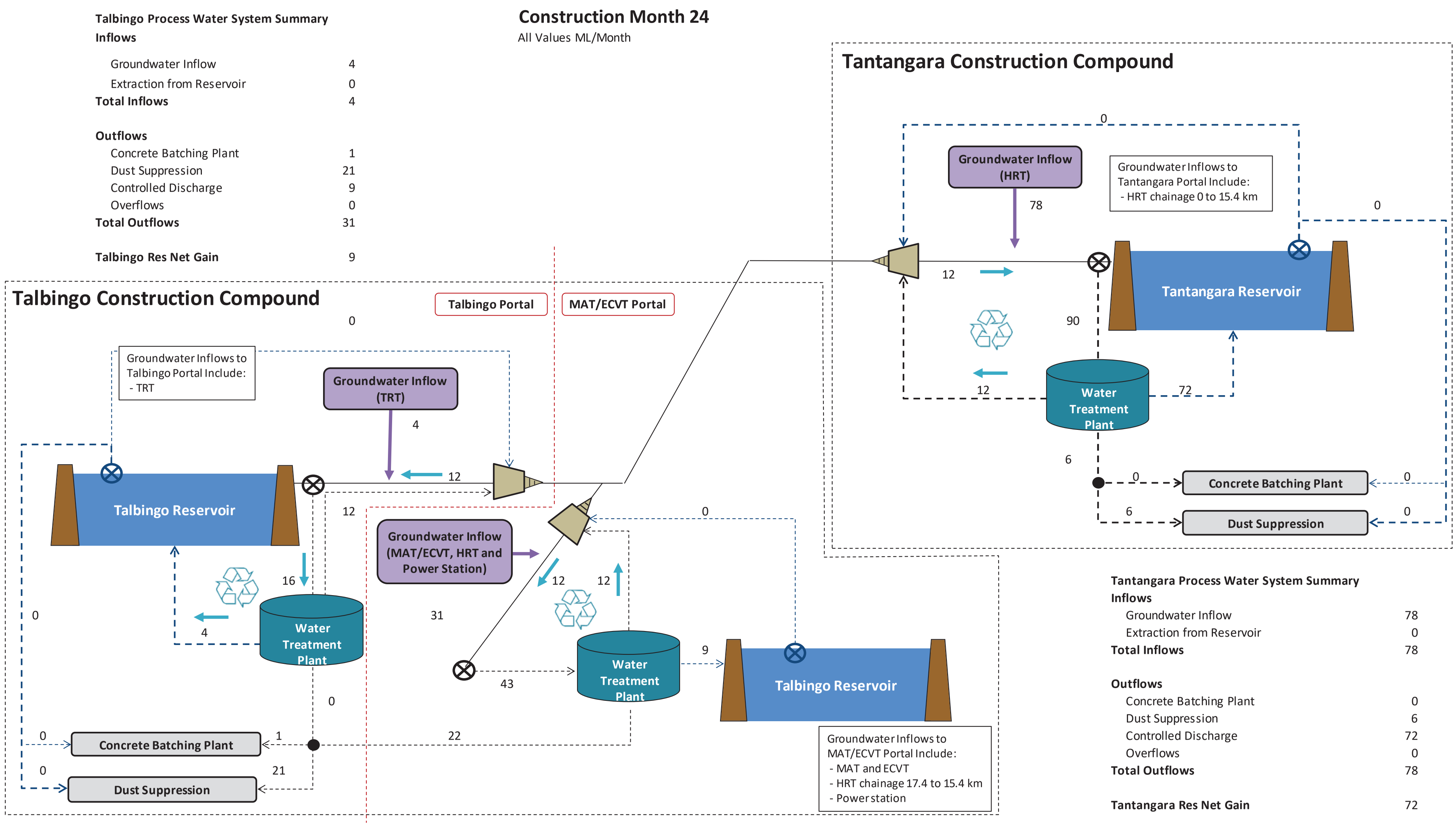


Figure C.9 Water balance results: month 24 of construction

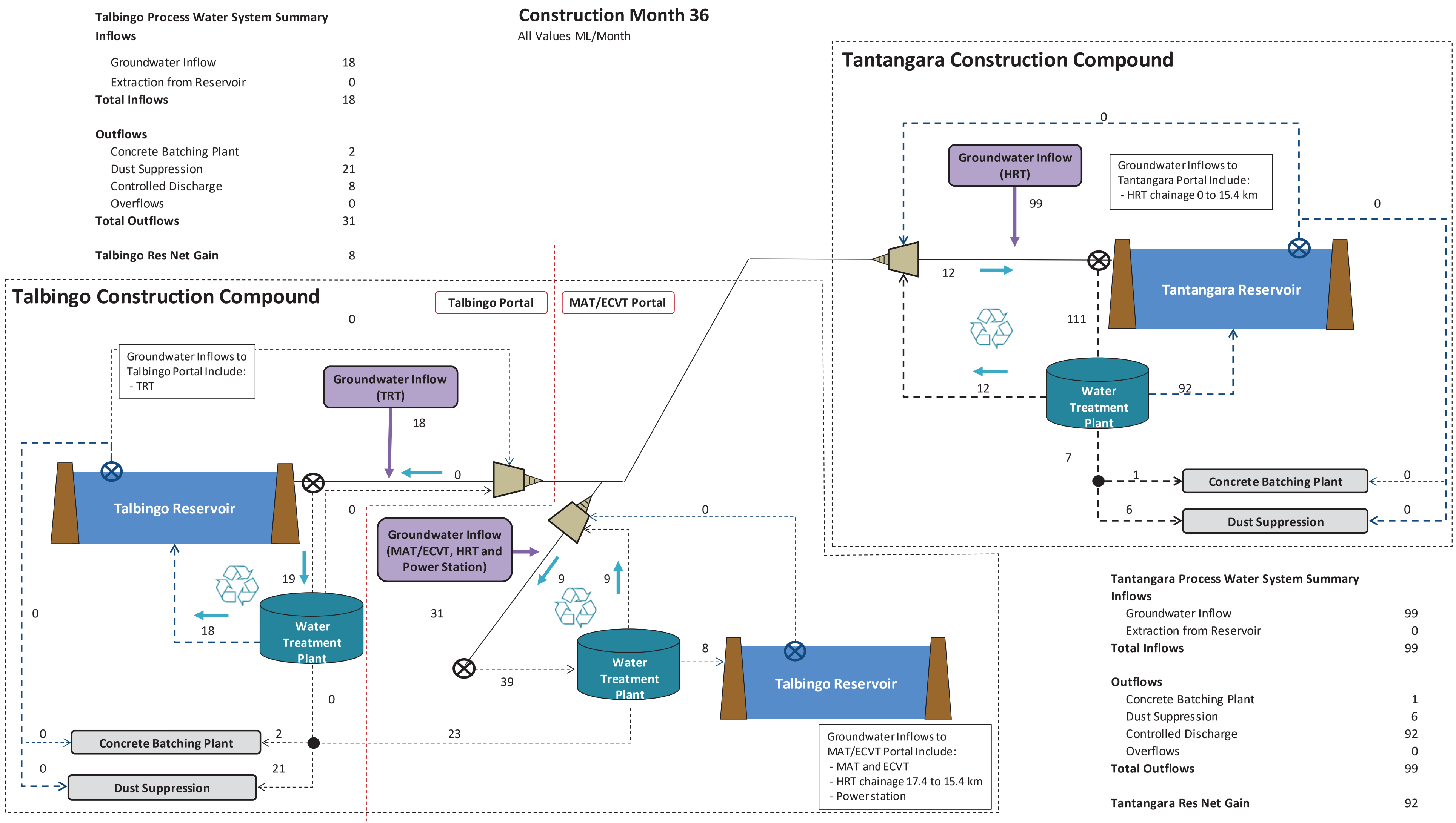


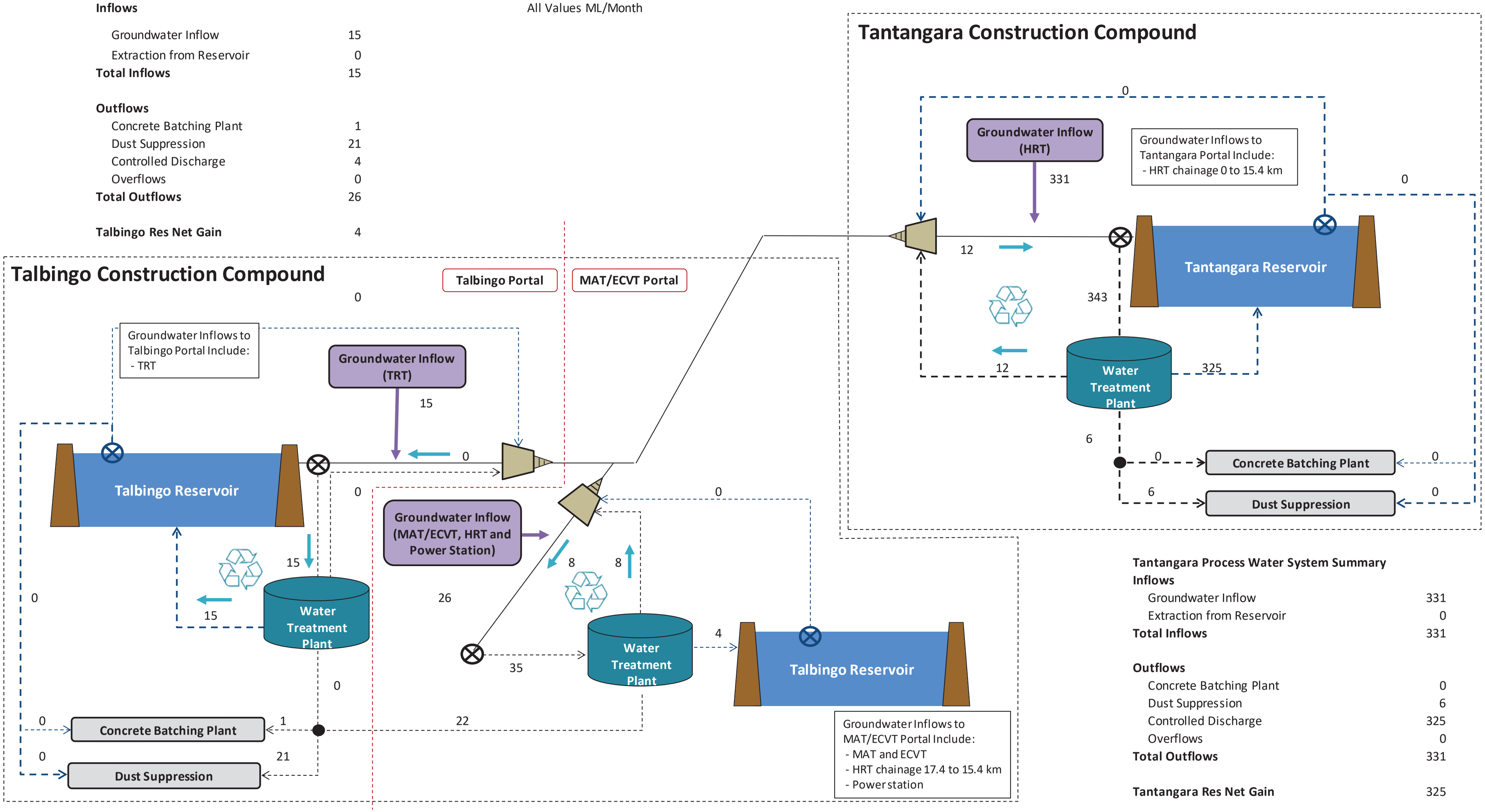
Figure C.10 Water balance results: month 36 of construction

Talbingo Process Water System Summary

Inflows	
Groundwater Inflow	15
Extraction from Reservoir	0
Total Inflows	15
Outflows	
Concrete Batching Plant	1
Dust Suppression	21
Controlled Discharge	4
Overflows	0
Total Outflows	26
Talbingo Res Net Gain	4

Construction Month 48

All Values ML/Month



Tantangara Process Water System Summary

Inflows	
Groundwater Inflow	331
Extraction from Reservoir	0
Total Inflows	331
Outflows	
Concrete Batching Plant	0
Dust Suppression	6
Controlled Discharge	325
Overflows	0
Total Outflows	331
Tantangara Res Net Gain	325

Figure C.11 Water balance results: month 48 of construction

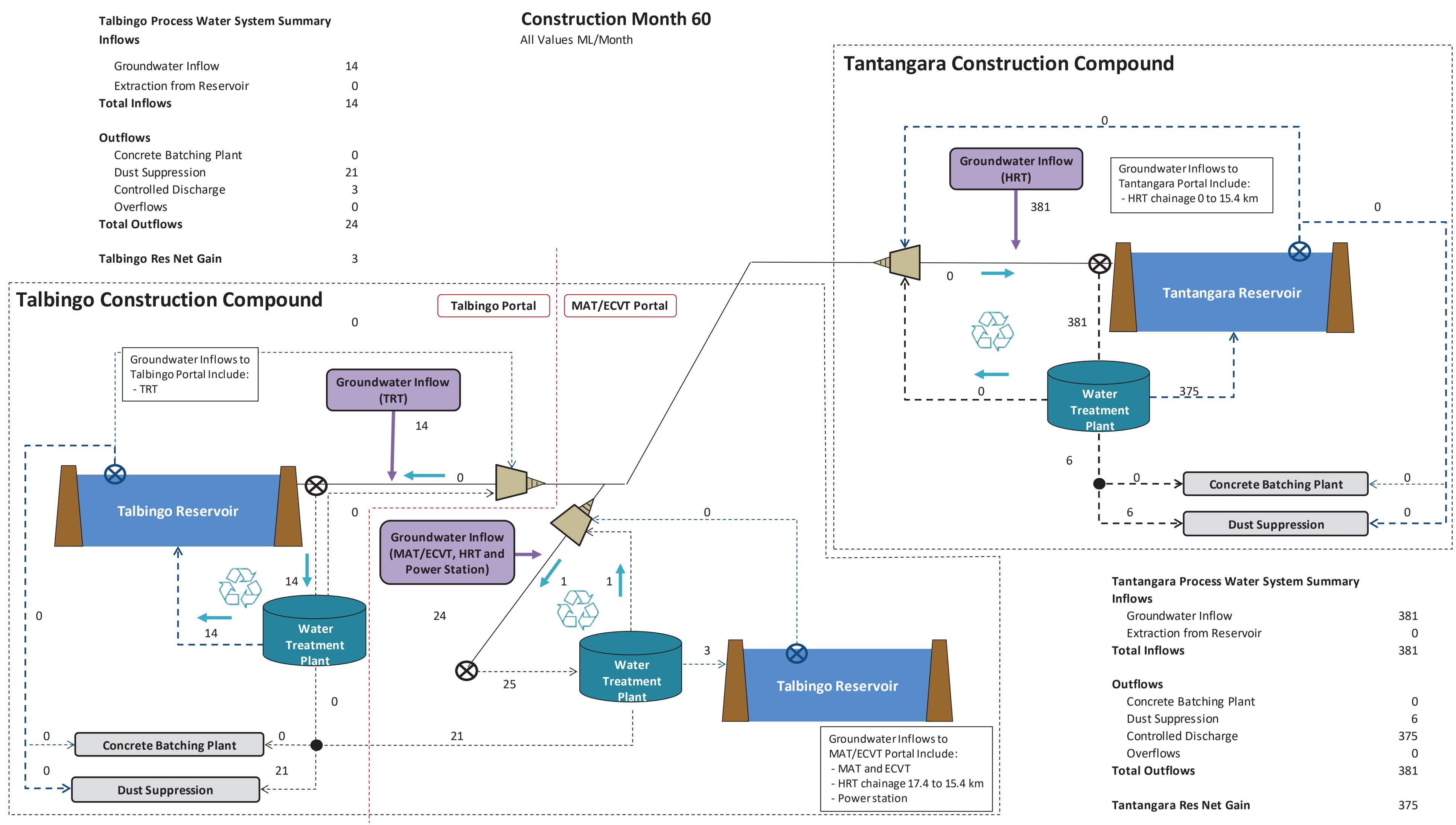


Figure C.12 Water balance results: month 60 of construction

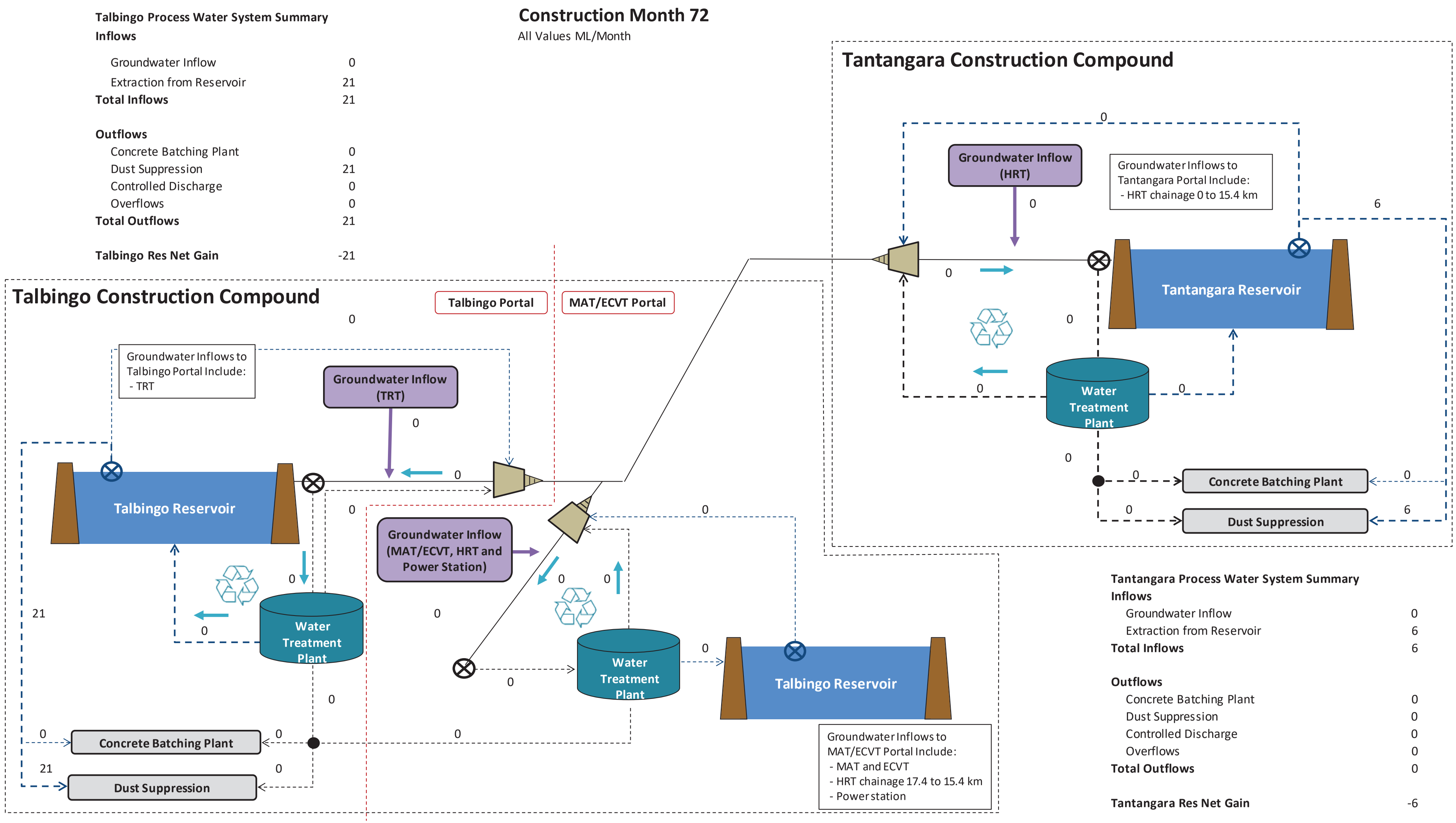


Figure C.13 Water balance results: month 72 of construction

C.9 Model sensitivity

Table C.4 describes the sensitivity of model results due to variation in the followings key water balance assumptions:

- groundwater inflows; and
- process water use.

Table C.4 Model sensitivity

Changes to assumptions	Resulting changes to model results
• Groundwater inflows lower than predicted; and/or • Process water use higher than predicted.	• Decrease in the frequency and magnitude of discharge to reservoirs. • Increase in the frequency and magnitude of top-up from the water supply system.
• Groundwater inflows higher than predicted; and/or • Process water use lower than predicted.	• Increase in the frequency and magnitude of discharge to reservoirs. • Decrease in the frequency and magnitude of top-up from the water supply system.

Attachment D

Stormwater discharge modelling

D.1 Introduction

This attachment to the water management report (Annexure D to the water assessment) describes the assumptions and methodology applied to estimate residual water quality impacts associated with stormwater runoff from the stormwater management areas described in the water management report.

This attachment is a technical account of the stormwater discharge modelling methodology, including a discussion of assumptions and limitations. Modelling results are presented and discussed in Chapter 8 of the water management report.

D.2 Model purpose

The discharge model was used to:

- estimate runoff quantity and quality from areas disturbed by the project;
- undertake dilution calculations, such that the relative impact of site runoff to receiving waterbody water quality might be estimated; and
- estimate pollutant (suspended solids, nutrient and selected dissolved and suspended metals) loads entering the Talbingo and Tantangara reservoirs within stormwater runoff.

This model does not perform an engineering design function for sediment basin sizing, nor is it suitable for use for a mixing zone analysis.

D.3 Model software

The model was built using GoldSim version 12.1. GoldSim is an industry standard water systems model which has probabilistic simulation capability. The model applied a continuous simulation methodology which gave a statistical assessment of runoff regimes and residual water quality impacts.

GoldSim was used for this assessment as it provides a user-friendly interface for the simulation of complex water systems and allows for the probabilistic use of historic climate and streamflow data.

D.4 Model design

D.4.1 Overview

The model uses historical climate data and assumptions about the runoff characteristics of the stormwater management categories to estimate runoff quantity and quality from disturbed areas over three phases of the project (as described in the water management report):

- Phase 1
  - WM 1.2 – Minor works;
  - WM 1.3 – Major works;
- Phase 2
  - WM 2.2 – Accommodation camps;

- WM 2.3 – Construction pads;
- WM 2.4 – Access roads;
- WM 2.5 – Stockpiles (earthworks).

- Phase 3
  - WM 3.2 – Permanent surface infrastructure; and
  - WM 3.3 – Permanent access roads.

The area of each type of disturbance is documented in Attachment A of the water management report.

The model was run on a daily time scale using 40 years of climate data to generate annualised statistics about the likely runoff regimes of disturbed areas.

Dilution calculations were then undertaken, comparing the estimated runoff with gauged streamflow.

A model has been built for the Yarrangobilly River, Upper Eucumbene River, and Tantangara construction compound catchments for quantitative assessment.

D.4.2 Model input data

Table D.1 documents all data used in the model and applicable modelled catchments.

Table D.1 Model input data

Data type	Data name	Data source/comments	Modelled catchment
Rainfall record	Ravine_RF_Data	Rainfall gauge record from January 1992–June 2019 located at the Yarrangobilly River in Lobs Hole, owned and operated by Snowy Hydro (SHL). Record has been infilled with SILO patched point rainfall data from 1978–2019 where gauged data was not available (lat/long: -35.80, 148.40)	Yarrangobilly River
Rainfall record	Tant_RF_Data	Rainfall gauge record from January 1991–October 2018 located at the weather station near Tantangara Reservoir, owned and operated by SHL. Record has been infilled with SILO patched point data from 1972–2019 where gauged data was not available (lat/long: -35.80, 148.65)	Tantangara construction compound
Rainfall record	Eucumbene_RF_Data	SILO patched point rainfall record for the upper reaches of the Eucumbene, from 1978–2019 (lat/long: -35.80, 148.50)	Upper Eucumbene River
Stream gauge record	Yarrangobilly_SG_Data	Stream gauge record from Bureau of Meteorology (BoM) station 410574 on Yarrangobilly River from 1972– 2019	Yarrangobilly River
Stream gauge record	Eucumbene_SG_Data	Stream gauge record from BoM station 222522 on Eucumbene River from January 1978–July 2019	Upper Eucumbene River
Stream gauge record	Murrumbidgee_SG_Data	Stream gauge record from BoM station 410535 on Murrumbidgee River from 1978–July 2019	Tantangara construction compound
Pan evaporation record	Pan_Evap	Class A Pan evaporation from SILO (lat/long: -35.80, 148.50)	All catchments

Table D.1 Model input data

Data type	Data name	Data source/comments	Modelled catchment
Runoff coefficients	Runoff_Coefficients	Runoff coefficients (C_v) for volumetric runoff from 'Blue Book' *Managing Urban Stormwater: Soils and Construction Volume 1* Table F2 (Landcom 2004). See Table D.3 for values	All catchments
Disturbed areas	Disturbed_Areas	Disturbed areas associated with stormwater management categories for assessment, as developed in water management report Attachment A. See Table D.4 for values	All catchments
Water quality inputs	WQ_Inputs	Water quality inputs as developed in water management report. See Table D.5 for values	All catchments

i Stream gauge scaling factors

Historic streamflows were scaled by catchment area to account for the difference between the catchment area upstream of the gauge location and the catchment area upstream of the modelled location. Scaling factors are given in Table D.2. The Yarrangobilly River catchment area discharges at the gauge location and does not need a scaling factor.

Table D.2 Stream gauge scaling factors

Catchment	Gauged catchment area (ha)	Modelled catchment area (ha)	Scaling factor
Eucumbene River	16,337	564	0.03
Tantangara construction compound (Kellys Plain Creek)	21,343	814	0.04

ii Runoff coefficients

The runoff coefficients used to estimate runoff from pervious areas were taken from *Managing Urban Stormwater: Soils and Construction – Volume 1* (Landcom, 2004) Table F2, presented in Table D.3.

Table D.3 Runoff coefficients

Soil Hydrologic Group	Design Rainfall depth (mm)							Runoff potential
	<20	21-25	26–30	31–40	41-50	51-60	61-80	
A	0.01	0.05	0.08	0.15	0.22	0.28	0.37	very low
B	0.10	0.19	0.25	0.34	0.42	0.48	0.57	low to moderate
C	0.25	0.35	0.42	0.51	0.58	0.63	0.70	moderate to high
D	0.39	0.50	0.56	0.64	0.69	0.74	0.79	high

Source: *Managing Urban Stormwater: Soils and Construction – Volume 1* Table F2 (Landcom 2004)

Impervious surfaces were modelled with an initial loss – continuing loss (ILCL) runoff model with a daily initial loss of 5 mm and a continuing loss of 0 mm/hr.

iii Disturbed areas

Disturbed areas were calculated as per the method outlined in Attachment A of the water management report. These values are presented in Table D.4.

Table D.4 Disturbance areas applied to discharge modelling

Stormwater management category	Disturbed area (ha)		
	Yarrangobilly River	Upper Eucumbene River	Tantangara construction compound
WM 1.2 – Minor works	111	12	98
WM 1.3 – Major works	95	8	57
WM 2.2 – Accommodation camps	11	-	7
WM 2.3 – Construction pads	25	-	11
WM 2.4 – Access roads	16	1	12
WM 2.5 – Large temporary stockpiles	18	12	5
WM 3.2 – Permanent surface infrastructure	13	-	7
WM 3.3 – Permanent access roads			
Unsealed	10	1	8
Sealed	5	-	-
WM 3.3 Total	15	1	8

Notes: Values are presented to the nearest integer.

iv Water quality inputs

The water quality of water within undisturbed streams and rivers in the project area was found through project water quality sampling to be fresh with low concentrations of dissolved metals, nutrients or suspended sediments.

For the purposes of undertaking dilution calculations, receiving waters were assumed to have a water quality profile equivalent to the values listed in the water quality objectives (WQO) in the Australian and New Zealand guidelines for fresh and marine water quality for the protection of 99% of freshwater aquatic species (ANZECC and ARMCANZ 2000).

Project level discharge characteristics were estimated for each stormwater management category for the following parameters:

- pH (note pH has been excluded from modelling as dilution calculations require complex chemical modelling);
- turbidity;
- suspended sediment;
- total nitrogen (TN);

- total phosphorus (TP);
- Aluminium (Al); and
- Copper (Cu).

The estimated discharge characteristics applied in the model are summarised in Table D.5. The approach used and assumptions made in the estimation of the discharge characteristics for each stormwater management category are presented in Chapter 3 of the water management report.

Table D.5 Model water quality factors

Stormwater management category	Turbidity	Suspended sediment	Total nitrogen	Total phosphorus	Aluminium	Copper
Units	**NTU**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Water quality objective value (WQO)	2–25	(10)[1]	0.25	0.02	0.027	0.001
Receiving waters (assumed)	25	10	0.25	0.02	0.027	0.001
WM 1.2 – Minor works	250	50	1	0.2	20 x WQO value	10 x WQO value
WM 1.3 – Major works	250	50	1	0.2	20 x WQO value	10 x WQO value
WM 2.2 – Accommodation camps	25	25	0.4	0.05	1 x WQO value	1 x WQO value
WM 2.3 – Construction pads	50	50	1	0.1	1 x WQO value	1 x WQO value
WM 2.4 – Access roads	250	50	1	0.1	10 x WQO value	1 x WQO value
WM 2.5 – Large temporary stockpiles	250	50	1	0.2	20 x WQO value	10 x WQO value
WM 3.2 – Permanent surface infrastructure	15	5	0.25	0.02	1 x WQO value	1 x WQO value
WM 3.3 – Permanent access roads	250	50	1	0.1	10 x WQO value	1 x WQO value

Notes: 1. As there is no available WQO value for suspended sediment, 10 mg/L was assumed.

D.4.3 Sedimentation basin sizes

Sedimentation basin sizes will be designed at a later stage of the project.

The 85th percentile, 5-day design rainfall depth was used to estimate possible sedimentation basin sizes.

The storage volume of basins was determined by a simplified *Managing Urban Stormwater: Soils and Construction – Volume 1* basin sizing calculation using the following formula:

$$V = \times A \times C \times R_d$$

Where:

- V is the basin design volume;
- A is the disturbed area associated with the relevant stormwater management category;
- C is the Blue Book (Table F2 – see Table D.3) runoff coefficient for the relevant soil class and design rainfall; and
- R_d is the design rainfall 85th percentile, 5-day rainfall event (Table D.6).

Table D.6 Design rainfall depths

Catchment	85th percentile, 5-day rainfall (mm)
Yarrangobilly River	28.1
Upper Eucumbene River	35.2
Tantangara construction compound	30.5

D.4.4 Runoff models

i Water management assumptions

Runoff models were developed for each type of disturbance. The management concept for each disturbance type is described in Table D.7.

Table D.7 Runoff model design assumptions

Stormwater management category	Soil Hydrologic Group[1] (% of disturbed area)	Discharge mechanisms and management measures
WM 1.2 – Minor works	Type C: 100%	All runoff will be discharged without capture or treatment mechanisms.
WM 1.3 – Major works	Type C: 100%	Runoff will be captured in basins. Basins are sized for 85th percentile, 5-day runoff. Captured water is harvested for dust suppression. Basin overflows are discharged to receiving waters.
WM 2.2 – Accommodation camps	Impervious: 70% Type B: 30%	Runoff will be captured in basins. Basins are sized to capture the 85th percentile, 5-day runoff. Captured water is harvested for dust suppression. Basin overflows are discharged to receiving waters.
WM 2.3 – Construction pads	Type D: 100%	Runoff will be captured in basins. Basins are sized to capture the 85th percentile, 5-day runoff. Captured water is harvested for dust suppression. Basin overflows are discharged to receiving waters.
WM 2.4 – Access roads	Type D: 100%	All runoff will be discharged without capture or treatment mechanisms.

Table D.7 Runoff model design assumptions

Stormwater management category	Soil Hydrologic Group[1] (% of disturbed area)	Discharge mechanisms and management measures
WM 2.5 – Large temporary stockpiles	Type B: 100%	Runoff will be captured in basins. Basins are sized to capture the 85th percentile, 5-day runoff. Captured water is harvested for dust suppression. Basin overflows are discharged to receiving waters.
WM 3.2 – Permanent surface infrastructure	Impervious: 50% Type D: 50%	All runoff will be discharged without capture or treatment mechanisms.
WM 3.3 – Permanent access roads	Impervious: 100%	All runoff will be discharged without capture or treatment mechanisms.

Notes: 1. Soil Hydrological Groups are assigned with reference to *Managing Urban Stormwater: Soils and Construction Volume 1* Table F2 (Landcom 2004)

ii Runoff model description

a Discharge without capture of treatment

Runoff from disturbance areas that was not captured and did not receive treatment was modelled using the following formula:

$$Q = C.I.A$$

Where:

- *Q* is the volumetric runoff rate [volume/day];
- *C* is the runoff coefficient for the relevant soil class and rainfall rate from Table F2 *Managing Urban Stormwater: Soils and Construction – Volume 1* (Landcom 2004);
- *I* is the rainfall rate;
- *A* is the disturbed area; and

Note that *C* as per *Managing Urban Stormwater: Soils and Construction – Volume 1* Table F2 (Landcom 2004) is generally applied to a design rainfall event (duration greater than one day) rather than a daily rainfall rate. In the model, *C* was calculated each day.

This resulted in *C* lower at the start of the event when the catchment is drier, and higher later in the event, consistent with runoff rates increasing when the catchment becomes wet.

b Runoff captured in basins and harvested for dust suppression

Runoff captured and treated in basins was modelled using the GoldSim pool stock element. This element allows the modelling of multiple direct inflow inputs, and outflows with specified priority. If there is not enough water to meet both demands, the highest priority demand will first be met, followed by the second. In this model the outflow priority was:

1. Evaporation from the water surface; and

2. Dust suppression.

Evaporation losses were calculated as follows:

$$V_{evap} = A_{basin} \,.\, E$$

Where:

- V_{evap} is the volumetric rate of evaporation loss;
- A_{basin} is the assumed total surface area of the basins, assumed equal to the volume divided by 1.5 m depth; and
- E is the evaporation rate.

Dust suppression was modelled as a function of daily evaporation (based on historical record) and daily rainfall. The volume of water required for dust suppression was calculated by the following formula:

$$V_{DS} = [(S \,.\, E) - R + L] \times A$$

Where:

- V_{DS} is the volume required for dust suppression;
- S is the shading multiplier which accounts for reduction in evaporation potential due to shading, taken to be 0.8;
- E is the evaporation rate;
- R is the rainfall rate;
- L is a loss factor, applied as 3 mm/day; and
- A is the area over which dust suppression is required.

Dust suppression demands were modelled such that if the above equation has a negative solution (ie when daily rainfall exceeds dust suppression demands) the dust suppression demand is 0 ML.

The area requiring dust suppression was estimated to be half of the sum of the following areas:

- WM 1.2 – minor works;
- WM 2.4 – access roads; and
- WM 2.5 – stockpiles (earthworks).

The dust suppression demand calculation used only half the disturbance areas because:

- it was assumed that some locations requiring dust suppression would be better served from the project water supply; and
- there would likely be logistical challenges associated with concentrating water truck movements at basins.

In project phase 2, three disturbance types were modelled with sedimentation basins. The dust suppression demand was split between these basins proportional to their volume; more dust suppression water was taken from the larger basin.

When basins were filled, excess water was discharged via an overflow process. Overflowing water was used in subsequent water quality dilution calculations.

D.4.5 Water quality model

i Impacts to watercourses

The total site runoff was calculated each model day, and assigned a water quality profile as per Table D.5. The water quality in the receiving water post-stormwater discharge was then calculated, following the formula:

$$WQ_{average} = \frac{\sum WQ_j . V_j + WQ_{RW} . V_{RW}}{\sum V_j + V_{RW}}$$

Where:

- $WQ_{average}$ is the weighted average water quality characteristics of the receiving waters post-stormwater dischage;
- j is the number of disturbance types;
- WQ_j is the water quality characteristics for water discharged from disturbance area j;
- WQ_{RW} is the water quality characteristics for the receiving waters;
- V_j is the volume of stormwater discharged from disturbance area j; and
- V_{RW} is the daily flow of water in the receiving creek or river.

ii Discharge to reservoirs

Model outputs have also been used to assess the predicted water quality characteristics of treated wastewater, treated process water and stormwater discharges to Talbingo and Tantangara reservoirs as a result of Snowy 2.0.

Modelled cumulative stormwater discharge from disturbed areas for each project phase were used to calculate pollutant loads in stormwater runoff for total nitrogen and total phosphorus using the formula:

$$L_{i,j} = V_j \times C_{i,j}$$

Where:

- $L_{i,j}$ is the pollutant load for pollutant *i* entering the reservoir from disturbed areas associated with stormwater management category *j* [kg/day];
- V_j is the cumulative discharge volume from disturbed areas associated with stormwater management category *j* [ML/day]; and
- C_{ij} is the assumed concentration of pollutant *i* for stormwater management category *j* [mg/L].

D.5 Calibration and validation

The model has not been calibrated or validated because no disturbance has yet occurred in these areas. Results are therefore indicative only, and further assessment of stormwater discharge will be required during detailed design. Monitoring and management of discharges will be required.

D.6 Model sensitivity

Model sensitivity is discussed in WMR Section 8.2.5.

D.7 Assumptions and limitations

Model assumptions are documented, and the associated limitations are discussed, in Table D.8.

Table D.8 Model assumptions

Assumption	Discussion
Climate data	
Use of historical rainfall and stream gauge records to model climatic variability	Historical climate data provides actual climatic scenarios and so gives a good indication of climatic conditions at the project location. However, future climatic conditions may differ from historical conditions. This model is not able to predict future conditions and does not account for climate variability outside of the 40-year record used in the model.
Use of pan evaporation for basin evaporation and dust suppression; non-varying evaporation across modelled catchments	Historical pan evaporation records were used to calculate dust suppression demands and evaporation from basin surface. Evaporation has been assumed to be constant across the three catchments. This is adequate to reflect likely climatic conditions, where greater volumes of captured water are required for dust suppression during periods with low rainfall.
Scaling gauged data to modelled discharge point	The scale factors applied to the gauged data for the Eucumbene River and Murrumbidgee River gauges assumes consistent runoff characteristics across the catchment. Although rainfall and runoff characteristics can vary significantly over a catchment area; climate data across the project area suggests that project catchments are generally uniform in their characteristics.

Table D.8 Model assumptions

Assumption	Discussion
Water quality inputs	
No variability in modelled receiving water quality	This model does not account for natural seasonal variability in receiving waters. As per the conceptual model and water characterisation report, water quality in receiving waters shows seasonal variability due to varying water sources. The modelled receiving water quality affects the dilution assessment where an assumed water quality profile for receiving waters is applied. Further characterisation of season variability in receiving waters would allow a varying modelled receiving water quality.
Modelled receiving water quality matches the water quality objective water quality profile	Baseline data collected for the EIS indicates water quality in receiving waters is generally lower than the values in the WQOs. As such, the water quality profile applied to the receiving waters likely overestimates concentration of the modelled parameters (and may also at times underestimate concentrations). The absence of long-term historical baseline data on which to base the modelled water quality parameters is a weakness and source of uncertainty in the model.
Basin discharge water quality	Basins will have some treatment impacts to overflows. Treatment methods of captured water have not yet been determined for this project and therefore treated discharge quality cannot reasonably be modelled without significant assumptions about the expected level of treatment. Further assessment will be required during detailed design.
No change in captured water quality due to evaporation losses	This model has not simulated increases in concentrations for the modelled parameters due to evaporation losses. Evaporation losses represent a small portion of captured water.
Runoff modelling assumptions	
Runoff coefficients using Blue Book Table F2	Runoff coefficients have been approximated using Blue Book Table F2 for the five-day rainfall. This is an atypical application of these runoff coefficients which allows the approximation of increased runoff potential due to antecedent surface wetness, as saturated soils will produce more runoff than unsaturated soils.
Initial loss of 5 mm for impervious surfaces	Impervious surfaces are assumed to have an initial loss of 5 mm and then have a runoff coefficient of 1 (ie all rainfall becomes runoff apart from the first 5 mm). This accounts for losses associated with surface irregularity.
Storage assumptions	
Basin volume sizing to 85^{th} percentile, 5-day design event.	Basins have been applied to the model as a volume which approximates Blue Book sizing methods for the full catchment area to the 85^{th} percentile 5-day rain based on historical rainfall records. Actual basin sizing will be determined as part of detailed design.
Basin surface area	Basin surface area for direct rainfall inflows and evaporation losses has been calculated assuming a basin depth of 1.5 m. This is a standard depth for basins due to the increased design requirements associated with greater basin depths. Actual basin depths and surface areas will be determined as part of detailed design. This may affect the amount of water lost from the system as evaporation losses and therefore the discharge volumes, however, as evaporation losses are a small percentage of total model inflows, this is not anticipated to significantly change results.
Direct rainfall to basin surface area	Rainfall has been applied to the full catchment area for runoff calculations, as well as directly to the basin surface as rainfall. This represents an overlap of disturbed surface area (and therefore an overestimation of total inflows). However, as basin surface areas make up approximately 1% of total catchment area this is not anticipated to significantly impact model outputs.

Table D.8 Model assumptions

Assumption	Discussion
Basins modelled as single basin for each catchment and stormwater management category	In the absence of a detailed design plan, it was assumed that all water from each catchment area drains to a single basin. This should not materially change discharge volumes as basins will be sized during detailed design proportionally to the captured area.

D.8 Results

Impacts to streamflow regimes due to stormwater runoff are presented in section 8.2.4 of the water management report.

Modelled changes to watercourse water quality due to stormwater runoff are presented in section 8.2.5 of the water management report.

Impacts to reservoirs are discussed in section 8.3 of the water management report. Discharge loads from stormwater runoff, treated process water discharge and treated wastewater discharge are presented in Table D.9 to Table D.14.

Table D.9 Talbingo Reservoir stormwater discharge loads – construction phase 1

	Units	Drought flows[1]			Summer/autumn			Winter/spring		
Combined reservoir inflows		Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus
Mean flow	ML/season[2]		4,600			22,250			89,087	
Median concentration		160 µS/cm	0.10 mg/L	0.01 mg/L	160 µS/cm	0.10 mg/L	0.01 mg/L	70 µS/cm	0.10 mg/L	0.01 mg/L
Median load	kg/season[2]	404,800	460	46	1,958,000	2,225	223	3,429,850	8,909	891
Combined stormwater discharges										
Mean discharge	ML/season[2]		156			230			356	
Median concentration		30 µS/cm	1.00 mg/L	0.20 mg/L	30 µS/cm	1.00 mg/L	0.20 mg/L	30 µS/cm	1.00 mg/L	0.20 mg/L
Mean load	kg/season[2]	2,574	156	31	3,795	230	46	5,874	356	71
Treated wastewater										
Max discharge	ML/season[2]		-			-			-	
Median concentration		-	-	-	-	-	-	-	-	-
Mean load	kg/season[2]	-	-	-	-	-	-	-	-	-
Treated process water										
Max discharge	ML/season[2]		-			-			-	
Median concentration		-	-	-	-	-	-	-	-	-
Mean load	kg/season[2]	-	-	-	-	-	-	-	-	-
Combined discharge	ML/season[2]		4,756			22,480			89,443	
Combined load	kg/season[2]	407,374	616	77	1,961,795	2,271	239	3,435,724	9,265	962

Notes:
1. Drought flows derived from 2006–2007 summer/autumn (December–May) period.
2. Seasons defined as summer/autumn (December–May) and winter/spring (June–November).
3. Factor of 0.55 used to convert salinity (as measured by electrical conductivity) from µS/cm to mg/L (SA Government 2015).

Table D.10 Talbingo Reservoir stormwater discharge loads – construction phase 2

	Units	Drought flows[1]			Summer/autumn			Winter/spring		
Combined reservoir inflows		Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus
Mean flow	ML/season[2]		4,600			22,250			89,087	
Median concentration		160 µS/cm	0.10 mg/L	0.01 mg/L	160 µS/cm	0.10 mg/L	0.01 mg/L	70 µS/cm	0.10 mg/L	0.01 mg/L
Median load	kg/season[2]	404,800	460	46	1,958,000	2,225	223	3,429,850	8,909	891
Combined stormwater discharges										
Mean discharge	ML/season[2]		44			70			120	
Median concentration		30 µS/cm	1 mg/L	0.10 mg/L	30 µS/cm	1 mg/L	0.10 mg/L	30 µS/cm	1 mg/L	0.10 mg/L
Mean load	kg/season[2]	726	42	5	1,155	66	8	1,980	112	13
Treated wastewater										
Max discharge	ML/season[2]		36			36			36	
Median concentration		700 µS/cm	0.35 mg/L	0.06 mg/L	700 µS/cm	0.35 mg/L	0.06 mg/L	700 µS/cm	0.35 mg/L	0.06 mg/L
Mean load	kg/season[2]	13,860	13	2	13,860	13	2	13,860	13	2
Treated process water										
Max discharge	ML/season[2]		182			182			182	
Median concentration		700 µS/cm	0.25 mg/L	0.02 mg/L	700 µS/cm	0.25 mg/L	0.02 mg/L	700 µS/cm	0.25 mg/L	0.02 mg/L
Median load	kg/season[2]	70,070	46	4	70,070	46	4	70,070	46	4
Combined discharge	ML/season[2]		4,862			22,538			89,425	
Combined load	kg/season[2]	489,456	561	57	2,043,085	2350	237	3,515,760	9080	910

Notes:
1. Drought flows derived from 2006–2007 summer/autumn (December–May) period.
2. Seasons defined as summer/autumn (December–May) and winter/spring (June–November).
3. Factor of 0.55 used to convert salinity (as measured by electrical conductivity) from µS/cm to mg/L (SA Government 2015).

Table D.11 Talbingo Reservoir stormwater discharge loads – operational phase (phase 3)

	Units		Drought flows[1]			Summer/autumn			Winter/spring	
Combined reservoir inflows		Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus
Mean flow	ML/season[2]		4,600			22,250			89,087	
Median concentration		160 µS/cm	0.10 mg/L	0.01 mg/L	160 µS/cm	0.10 mg/L	0.01 mg/L	70 µS/cm	0.10 mg/L	0.01 mg/L
Median load	kg/season[2]	404,800	460	46	1,958,000	2,225	223	3,429,850	8,909	891
Combined stormwater discharges										
Mean discharge	ML/season[2]		44			55			75	
Median concentration		30 µS/cm	0.63 mg/L	0.06 mg/L	30 µS/cm	0.63 mg/L	0.06 mg/L	30 µS/cm	0.63 mg/L	0.06 mg/L
Mean load	kg/season[2]	726	25	2	908	31	3	1,238	43	4
Treated wastewater										
Max discharge	ML/season[2]		-			-			-	
Median concentration		-	-	-	-	-	-	-	-	-
Mean load	kg/season[2]	-	-	-	-	-	-	-	-	-
Treated process water										
Max discharge	ML/season[2]		-			-			-	
Median concentration		-	-	-	-	-	-	-	-	-
Mean load	kg/season[2]	-	-	-	-	-	-	-	-	-
Combined discharge	ML/season[2]		4,644			22,305			89,162	
Combined load	kg/season[2]	405,526	485	48	1,958,908	2256	226	3,431,087	8952	895

Notes:
1. Drought flows derived from 2006–2007 summer/autumn (December–May) period.
2. Seasons defined as summer/autumn (December–May) and winter/spring (June–November).
3. Factor of 0.55 used to convert salinity (as measured by electrical conductivity) from µS/cm to mg/L (SA Government 2015).

Table D.12 Tantangara Reservoir stormwater discharge loads – construction phase 1

	Units	Drought flows[1]			Summer/autumn			Winter/spring		
Combined reservoir inflows		Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus
Mean flow[4]	ML/season[2]		13,105			45,222			198,727	
Median concentration		32 µS/cm	0.10 mg/L	0.01 mg/L	32 µS/cm	0.10 mg/L	0.01 mg/L	26 µS/cm	0.10 mg/L	0.01 mg/L
Median load	kg/season[2]	230,648	1,311	131	795,907	4,522	452	2,841,796	19,873	1,987
Combined stormwater discharges										
Mean discharge	ML/season[2]		163			207			331	
Median concentration		30 µS/cm	1.00 mg/L	0.20 mg/L	30 µS/cm	1.00 mg/L	0.20 mg/L	30 µS/cm	1.00 mg/L	0.20 mg/L
Mean load	kg/season[2]	2,690	163	33	3,416	207	41	5,462	331	66
Treated wastewater										
Max discharge	ML/season[2]		-			-			-	
Median concentration		-	-	-	-	-	-	-	-	-
Mean load	kg/season[2]	-	-	-	-	-	-	-	-	-
Treated process water										
Max discharge	ML/season[2]		-			-			-	
Median concentration		-	-	-	-	-	-	-	-	-
Mean load	kg/season[2]	-	-	-	-	-	-	-	-	-
Combined discharge	ML/season[2]		13,268			45,429			199,058	
Combined load	kg/season[2]	233,338	1,474	164	799,323	4,729	493	2,847,258	20,204	2,053

Notes:
1. Drought flows derived from 2006–2007 summer/autumn (December–May) period.
2. Seasons defined as summer/autumn (December–May) and winter/spring (June–November).
3. Factor of 0.55 used to convert salinity (as measured by electrical conductivity) from µS/cm to mg/L (SA Government 2015).
4. Mean flow at the Murrumbidgee River gauged (410535) have been scaled up to reflect total inflows to Tantangara Reservoir. Murrumbidgee River gauge flows account for 58% of total inflow to Tantangara Reservoir (WCR, Annexure A to the water assessment).

Table D.13 Tantangara Reservoir stormwater discharge loads – construction phase 2

	Units	Drought flows[1]			Summer/autumn			Winter/spring		
Combined reservoir inflows		Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus
Mean flow[4]	ML/season[2]		13,105			45,222			198,727	
Median concentration		32 µS/cm	0.10 mg/L	0.01 mg/L	32 µS/cm	0.10 mg/L	0.01 mg/L	26 µS/cm	0.10 mg/L	0.01 mg/L
Median load	kg/season[2]	230,648	1,311	131	795,907	4,522	452	2,841,796	19,873	1,987
Combined stormwater discharges										
Mean discharge	ML/season[2]		33			44			77	
Median concentration		30 µS/cm	1 mg/L	0.1 mg/L	30 µS/cm	1 mg/L	0.1 mg/L	30 µS/cm	1 mg/L	0.1 mg/L
Mean load	kg/season[2]	545	31	3	726	41	4	1,271	71	8
Treated wastewater										
Max discharge	ML/season[2]		18			18			18	
Median concentration		700 µS/cm	0.35 mg/L	0.06 mg/L	700 µS/cm	0.35 mg/L	0.06 mg/L	700 µS/cm	0.35 mg/L	0.06 mg/L
Mean load	kg/season[2]	6,930	6	1	6,930	6	1	6,930	6	1
Treated process water										
Max discharge	ML/season[2]		2,257			2,257			2,257	
Median concentration		150 µS/cm	0.25 mg/L	0.02 mg/L	150 µS/cm	0.25 mg/L	0.02 mg/L	150 µS/cm	0.25 mg/L	0.02 mg/L
Mean load	kg/season[2]	186,203	564	45	186,203	564	45	186,203	564	45
Combined discharge	ML/season[2]		15,413			47,541			201,079	
Combined load	kg/season[2]	424,325	1,912	180	989,766	5,133	502	3,036,199	20,514	2,041

Notes:
1. Drought flows derived from 2006–2007 summer/autumn (December–May) period.
2. Seasons defined as summer/autumn (December–May) and winter/spring (June–November).
3. Factor of 0.55 used to convert salinity (as measured by electrical conductivity) from µS/cm to mg/L (SA Government 2015).
4. Mean flow at the Murrumbidgee River gauged (410535) have been scaled up to reflect total inflows to Tantangara Reservoir. Murrumbidgee River gauge flows account for 58% of total inflow to Tantangara Reservoir (WCR, Annexure A to the water assessment).

Table D.14 Tantangara Reservoir stormwater discharge loads – operational phase (phase 3)

	Units	Drought flows[1]			Summer/autumn			Winter/spring		
Combined reservoir inflows		Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus
Mean flow[4]	ML/season[2]		13,105			45,222			198,727	
Median concentration		32 µS/cm	0.10 mg/L	0.01 mg/L	32 µS/cm	0.10 mg/L	0.01 mg/L	26 µS/cm	0.10 mg/L	0.01 mg/L
Median load	kg/season[2]	230,648	1,311	131	795,907	4,522	452	2,841,796	19,873	1,987
Combined stormwater discharges										
Mean discharge	ML/season[2]		28			33			47	
Median concentration		30 µS/cm	0.63 mg/L	0.06 mg/L	30 µS/cm	0.63 mg/L	0.06 mg/L	30 µS/cm	0.63 mg/L	0.06 mg/L
Mean load	kg/season[2]	462	20	2	545	23	2	776	71	3
Treated wastewater										
Max discharge	ML/season[2]		-			-			-	
Median concentration		-	-	-	-	-	-	-	-	-
Mean load	kg/season[2]	-	-	-	-	-	-	-	-	-
Treated process water										
Max discharge	ML/season[2]		-			-			-	
Median concentration		-	-	-	-	-	-	-	-	-
Mean load	kg/season[2]	-	-	-	-	-	-	-	-	-
Combined discharge	ML/season[2]		13,133			45,255			198,774	
Combined load	kg/season[2]	231,110	1,331	133	796,452	4,545	454	2,842,572	19,944	1,990

Notes:
1. Drought flows derived from 2006–2007 summer/autumn (December–May) period.
2. Seasons defined as summer/autumn (December–May) and winter/spring (June–November).
3. Factor of 0.55 used to convert salinity (as measured by electrical conductivity) from µS/cm to mg/L (SA Government 2015).
4. Mean flow at the Murrumbidgee River gauged (410535) have been scaled up to reflect total inflows to Tantangara Reservoir. Murrumbidgee River gauge flows account for 58% of total inflow to Tantangara Reservoir (WCR, Annexure A to the water assessment).

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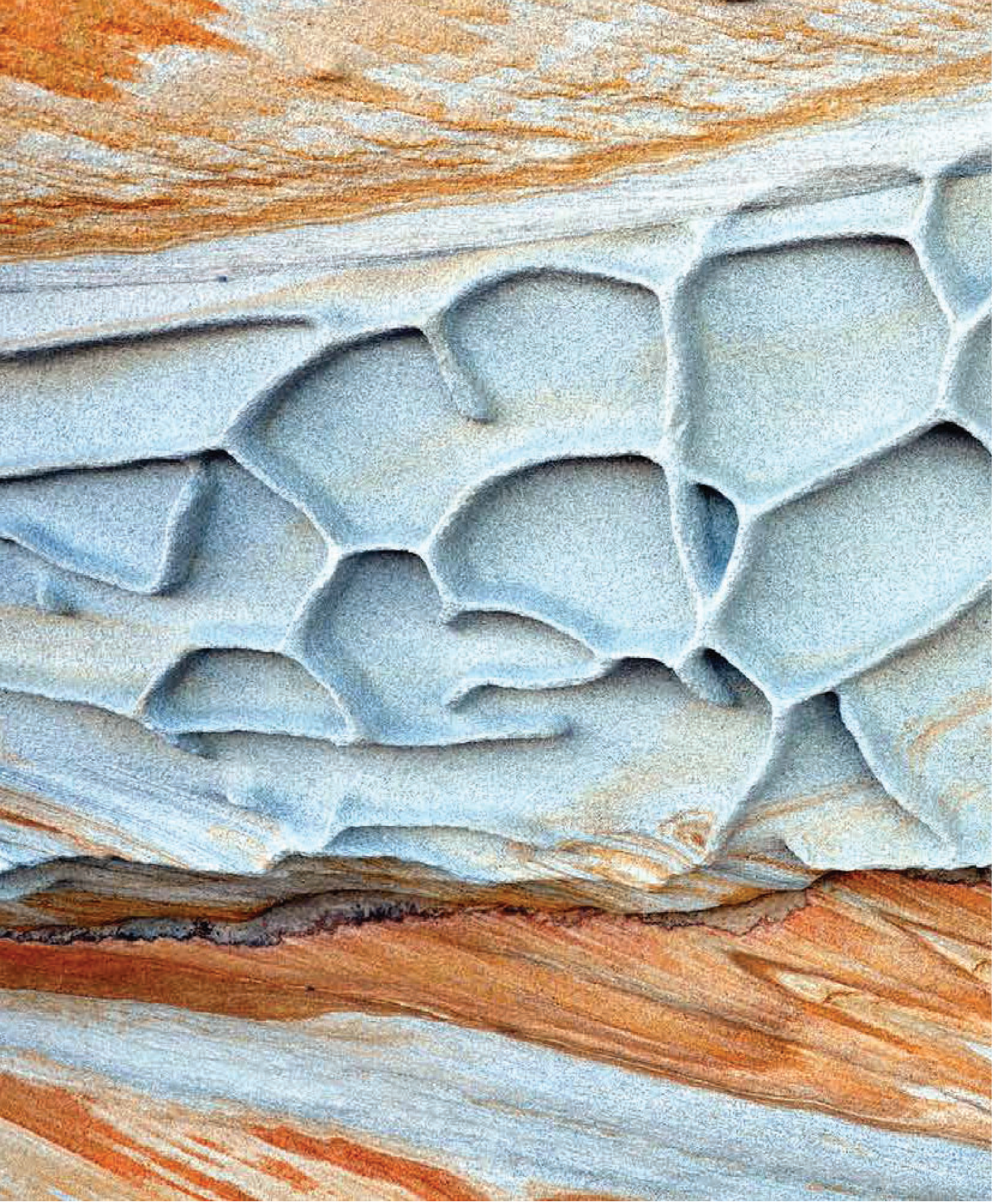

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