Appendix I. Surface water quality, hydrology and geomorphology assessment report

Shoalhaven Hydro Expansion Project - Main Works Environmental Impact Statement

SSI-10033

Origin Energy Eraring Pty Ltd

November 2022

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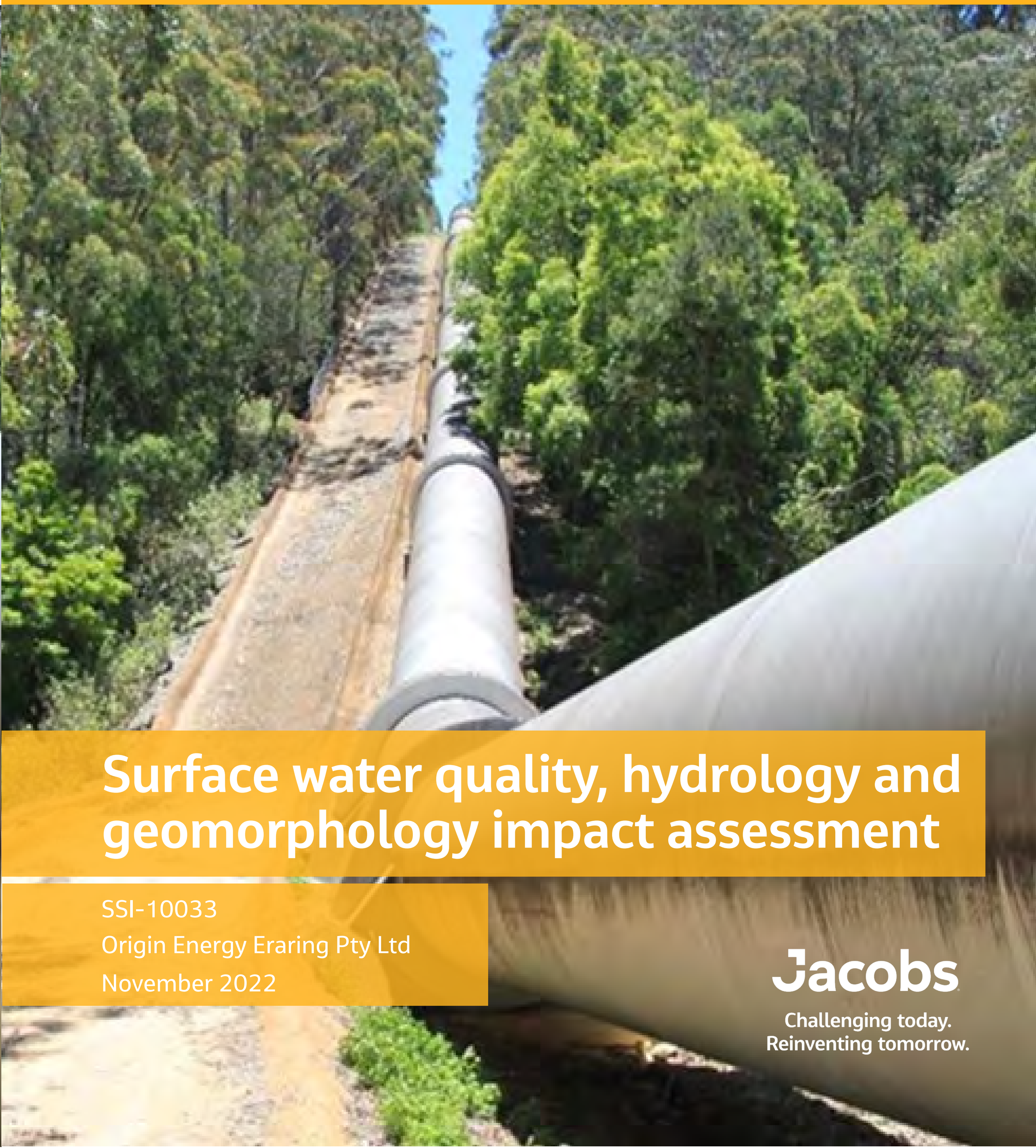
Shoalhaven Hydro Expansion Project - Main Works



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Executive summary

Origin proposes to develop the Shoalhaven Hydro Expansion Project, to construct and operate a new pumped hydro power station on and under the land between the Fitzroy Falls Reservoir and Lake Yarrunga (the Project). The Project would draw on Origin's existing water allocations to pump water up from Lake Yarrunga consuming energy when it is in less demand. Energy would then be generated through the return of water from Fitzroy Falls Reservoir to Lake Yarrunga when demand for energy increases.

The Project would involve almost doubling the electricity generation capacity of the existing scheme, providing an approximate additional 235 megawatts (MW) of generation capacity. The operation of the scheme would respond to the needs of the National Energy Market (NEM) involving up to one pumping and generation cycle per day. Each generation cycle is anticipated to involve up to 8 hours of generation and 16 hours of pumping, each of which could be divided into shorter durations to best satisfy the needs of the NEM.

The purpose of this report has been to identify and assess the risk of impacts of construction and operation of the Shoalhaven Hydro Expansion Project on surface water quality, hydrology and geomorphology, and recommend mitigation measures to manage the risks. The assessment has been conducted to address Secretary's Environmental Assessment Requirements relevant to water.

Methodology

The surface water quality, hydrology and geomorphology assessment for the construction and operation of the Project has been prepared based on a review and analysis of available water level and water quality data, aerial photography, relevant literature and background reports, applicable legislation, policies and guidelines, and a site visit comprising of waterway condition assessment.

Existing environment

The desktop review identified that key waterways and waterbodies within the study area form part of the Sydney Water Drinking Catchment, as well as provide raw drinking water supply to Kangaroo Valley Water Filtration Plant for use by Kangaroo Valley township. The Project is surrounded by Morton National Park in the Upper portion of the study area. Key waterways within the study area include Fitzroy Falls Reservoir and Fitzroy Falls Upper Canal, Trimbles Creek and several tributaries of Trimbles Creek, Yarrunga Creek and several tributaries of Yarrunga Creek, Bendeela Pondage, Kings Creek, Kangaroo River (upstream of the full supply level (FSL) of Lake Yarrunga) and several tributaries of Kangaroo River, as well as Lake Yarrunga.

Analysis of existing water quality data included comparison of key water quality indicators against relevant water quality guidelines (ANZG, 2018; NHMRC, 2011) as well as legislated standards for raw water supply (WaterNSW, 2021; DPI, 2013b). Indicators which were analysed included turbidity, total suspended solids, pH, electrical conductivity, dissolved oxygen, nutrients, some heavy metals, algal count and toxic cyanobacteria counts. The analysis found that water quality of the drinking water supply storages and waterways which flow to catchment storages (Kangaroo River, Yarrunga Creek, Lake Yarrunga and Fitzroy Falls Reservoir) was variable with only around half of the indicators complying with relevant guidelines and standards. Indicators which generally did comply included pH, turbidity, dissolved oxygen and dissolved metals (dissolved iron, aluminium and manganese). Those that generally did not comply with guideline trigger values were nutrients (nitrogen and phosphorus in various forms), electrical conductivity, and total metals (total iron and aluminium). Compliance with algal and toxic cyanobacteria standards was also variable.

Waterway condition assessment identified that waterways and waterbodies within the study area were in fair to good condition, and all waterways and waterbodies were identified as sensitive receiving environments (SREs). It was noted however that the level of sensitivity varied for different waterways based on their human and aquatic ecosystem values. Waterways which were identified as highly sensitive SREs were Kangaroo River / Lake Yarrunga, Kings Creek, Unnamed tributary of Kangaroo River (Lower Scheme), Bendeela Pondage, and Fitzroy Falls Reservoir. All other waterways were considered to have low or very low sensitivity, with the exception of Fitzroy Canal which was classified as medium sensitivity due to its connection with Fitzroy Falls Reservoir.

With respect to geomorphology, the banks of Lake Yarrunga appeared to be generally stable. Historic photographic evidence suggested there were no obvious signs of bank instability, although some notching of the bank was evident. Some sedimentation in the formation of bar development was noted in the channel which is to be expected in the upper section of the weir pool. Fitzroy Falls Reservoir and Bendeela Pondage were considered to have low erosion potential due to the constructed nature of these storages, as well as the shallow gradient of shoreline and vegetated cover along the perimeter of Fitzroy Falls Reservoir.

Construction impacts

Upon review of the Project design, construction methodology and proposed construction activities, it was determined that without management, risks to water quality, hydrology and geomorphology during construction could be:

- Erosion and sedimentation of downstream waterways from vegetation clearing, earthworks, overflow discharges of sediment basins, movement of spoil, spoil stockpiling and emplacement, and instream works
- Mobilisation of poor-quality construction or stormwater runoff to downstream waterways during road works and from activities carried out at site laydown / work areas (i.e. Use of site facilities, concrete works, rock blasting and steel works)
- Mobilisation of tannin leachate from vegetation clearing
- Mobilisation of acid leachate from low risk potentially acid-forming rock transported to and placed in the spoil emplacement area
- Release of poor-quality tunnel process water (including groundwater) and construction sediment basin discharges to downstream waterways,
- Temporary water table drawdown and minor reduction in groundwater baseflows in Kings Creek as a result of tunnelling and underground works.

With the implementation of mitigation measures outlined below, it was determined that risk of these impacts occurring were very low or low for waterways and waterbodies within the study area. The only waterway that was identified as having a medium risk was Lake Yarrunga. This was because construction activities are expected to occur within and in close proximity of this sensitive waterway therefore the likelihood of impact was slightly higher. It is expected, however, that identified nominated water quality mitigation measures will adequately mitigate the risks. As such, the Project is expected to have a neutral effect on water quality during construction.

Operational impacts

During operation, risks to water quality, hydrology and geomorphology were identified as:

- Release of poor-quality groundwater seepage during operational discharges
- Erosion and sedimentation of downstream Trimbles Creek during discharge of the Penstock Pipeline for maintenance
- Bank erosion in Lake Yarrunga from repeated wetting and drying of the same section of the riverbank from the increased rate of water fluctuation in the reservoirs (when the existing scheme and new scheme are being operated at the same time).

With the implementation of mitigation measures outlined below, it was determined that risk of these impacts occurring were low for waterways and waterbodies within the study area. The only waterway that was identified as having a medium risk was Lake Yarrunga due to possibility of increased bank erosion. Despite this slightly higher risk, it is expected that the Project would be designed and operated to reduce this risk. As such, the Project is expected to have a neutral effect on water quality during operation.

Identified mitigation measures

To reduce the risk of identified impacts on water quality, hydrology and geomorphology, it is recommended that the Project implement a suite of mitigation measures.

During construction, these measures would be outlined in a Construction Soil and Water Management Plan (CSWMP) and should include but not be limited to:

- Measures to minimise/manage erosion and sediment transport within the disturbance area and offsite, including development of site-specific Erosion Sediment Control Plans
- Measures to manage spoil and stockpiles including transport between area, stockpile locations, sediment controls and stabilisation
- Measures to manage accidental spills in accordance with WaterNSW incident management protocols
- Measures to manage potential tannin leachate

- Details of surface water quality monitoring to be undertaken prior to, throughout and following construction
- Measures to treat water collected in sediment basins for reuse on-site or discharge to downstream waterways
- Measures to manage groundwater ingress into vertical shafts and tunnels and tunnel process water including dewatering
- Procedures to capture, contain and appropriately dispose of any concrete wastes from concrete works
- Where possible, concrete structures to be pre-fabricated prior to installation instream or within the riparian zone (40m of any waterway), where practicable
- Prior to controlled discharge of collected construction water, water should be treated to the appropriate standard specified in the CSWMP and repurposed on site wherever possible. For instance, for dust suppression activities
- A construction discharge water treatment plant will be designed to treat groundwater seepage and tunnel process water
- Site specific trigger values will be developed during construction planning to set the discharge water treatment plant and sediment basin discharge criteria ensuring water will be treated to a level that is representative of background concentration of a suitable reference site and/or the ANZG (2018) guidelines
- Water that cannot be repurposed on site may be discharged locally provided the Construction Contractor obtains an EPL for this activity. The Construction Contractor would therefore be required to adhere to regulations specified in the EPL which would include specified discharge locations, and water quality concentration limits to be met prior to discharge
- Monitoring at all discharge points undertaken prior to and during construction to determine background water quality and detect any environmental degradation as a result of the construction works. This will also allow for understanding treatment to be applied to sediment laden water.

During operation, the following mitigation measures have been identified and would be outlined in the Operational Management Plan:

- The operational surface water quality monitoring program will be based on the construction monitoring program but refined to target issues relating to the operation of the Project, e.g. monitoring of Trimbles Creek at the Penstock should water require discharging from the pipeline
- Erosion and sediment controls during operation would be outlined in the Operational Management Plan and would detail procedures and protocols for maintaining scour protection measures at the outlets, groundwater seepage, and ongoing rehabilitation of disturbed areas
- A permanent water treatment facility will be designed to treat groundwater seepage generated from groundwater ingress in the main access tunnel and caverns, and runoff from operation in the caverns. The collected water will be separated via an oily water separator and treated to an acceptable standard (where required) prior to being injected into the tailrace tunnel where it would be further diluted and representative of the water quality of inside the tailrace tunnel, which would flow out to Lake Yarrunga or Fitzroy Falls during generation / pumping. The level of treatment provided will consider the characteristics of the receiving environment.

Overall, on the basis of the assessment of the existing environment, the design of the Project, and on the assumption that identified mitigation measures are implemented, the assessment concludes that there would be minimal impacts to the surface water quality, hydrology or geomorphology of waterways and waterbodies within the study area. As such, aquatic and human environmental values of waterways and waterbodies within the study area are expected to be protected and a neutral effect on water quality met.

Summary

This report has been necessarily prepared on the basis of the reference concept as described in the EIS. The Project water impacts, and identified mitigation measures are suggested on the basis of reasonable worst case assumptions and are subject to detailed design. Based on these identified impacts and mitigation, monitoring and adaptive management responses it is considered that the Project would have a neutral outcome on existing water quality.

Contents

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Glossary and terms

Term	Definition
ADWG	Australian Bureau of Statistics
AHD	Australian Height Datum
Al	Aluminium
Al_2SO_4	Alum
ANZECC/ARMCANZ	Australian and New Zealand Environment and Conservation Council / Agriculture and Resource Management Council of Australia and New Zealand
ANZG	Australian and New Zealand Governments
BC Act	*Biodiversity Conservation Act 2016*
BOD	Biochemical Oxygen Demand
BOL	Bottom Operating Limit
BOM	Bureau of Meteorology
Cells/mL	Cells per millilitre
Chl-a	Chlorophyll-a
CSSI	Critical State Significant Infrastructure
CSWMP	Construction Soil and Water Management Plan
CU	Colour Units
DEC	Department of Environment and Conservation NSW (former)
DECCW	Department of Environment and Climate Change and Water NSW (former)
DCCEEW	Commonwealth Department of Climate Change, Environment, Energy and Water
DO	Dissolved Oxygen
DPE	Department of Planning and Environment
DPI	Department of Industry
EC	Electrical Conductivity
EEC	Endangered Ecological Community
Environmental value	The agreed community values and uses (i.e. healthy aquatic ecosystem, water suitable for recreation or drinking water) for NSW waterways.
EPA	Environmental Protection Authority
Ephemeral stream	An ephemeral stream has flowing water only during, and for a short duration after, precipitation events in a typical year.
EP&A Act	*Environmental Planning and Assessment Act 1979*
EP&A Regulation	Environmental Planning and Assessment Regulation 2000
EPL	Environmental Protection Licence
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ESC	Erosion Sediment Controls
ESCP	Erosion Sediment Control Plan
Fe	Iron
$FeCl_3$	Ferric Chloride
FM Act	*Fisheries Management Act 1994*

Term	Definition
FSL	Full Supply Level
GWh	Gigawatt hour
HRC	Healthy Rivers Commission
KFH	Key Fish Habitat
kL/day	Kilolitres per day
LGA	Local Government Area
Lower Scheme	Project works to be conducted in the Kangaroo Valley region
Lower Study Area	The lower study area in the Kangaroo Valley region
L/s	Litres per second
m	Metre
m/day	Metres per day
m^3	Cubic metre
m^3/day	Cubic metres per day
mm^3/day	Cubic millimetres per day
mg/L	Milligrams per litre
mm	Millimetre
mRL	Metres relative level
ML	Megalitres
ML/month	Megalitres per month
Mn	Manganese
MNES	Matters of National Environmental Significance
MOL	Minimum Operating Level
MW	Megawatt
NAF	Non-acid forming
NEM	National energy market
NHMRC	National Health and Medical Research Council
NH^3	Ammoniacal nitrogen
NorBE	Neutral or Beneficial Effect
NO_x	Oxidised nitrogen
NSW	New South Wales
NTU	Nephelometric turbidity unit
NWQMS	National Water Quality Management Strategy
OEH	Office of Environment and Heritage
PAF	Potentially acid forming
Penstock	Water transfer pipeline and associated infrastructure
Perennial stream	A perennial stream is a stream that has continuous flow of surface water throughout the year in at least parts of its catchment during seasons of normal rainfall
POEO Act	*Protection of the Environment Operations Act 1997*
RUSLE	Revised Universal Soil Loss Equation
SRE	Sensitive receiving environment
SSTV	Site specific trigger value

Term	Definition
Strahler stream order	The Strahler stream classification system where waterways are given an order according to the number of additional tributaries associated with each waterway
Study Area	The disturbance area and a 'zone of impact' assessed as part of the surface water quality, hydrology and geomorphology impact assessment. The disturbance area is referred to the Project area in the EIS
The existing scheme	The existing Shoalhaven Pumped Hydro Scheme (owned and operated by Origin).
The Project	Shoalhaven Pumped Hydro Expansion Project
The Blue Book	Managing Urban Stormwater, Soils and Construction, Volume 1 (Landcom, 2004), and Volume 2 (DECCW, 2008)
t	Tonnes
TARP	Trigger Action Response Plan
TDS	Total dissolved solids
TN	Total nitrogen
TOL	Top Operating Level
TP	Total phosphorus
TPH	Total petroleum hydrocarbons
TSS	Total suspended solids
Upper Scheme	Project works to be conducted along the plateau near the Fitzroy Falls region.
Upper Study Area	The upper study area along the plateau near the Fitzroy Falls region.
WAL	Water Access Licence
Waterway	River, creek or drainage channel
Waterbody	Permanent lake or reservoir
WFP	Water Filtration Plant
WM Act	*Water Management Act 2000*
WNSW Act	*WaterNSW Act 2014*
WNSW Regulation	*WaterNSW Regulation 2013*
Water Supply Work and Water Use Approval	Approval under the water sharing plan for the Greater Metropolitan Regional Unregulated River Water Source which authorises Origin's use and operation of the water supply works for the existing Shoalhaven Pumped Hydro Scheme
WQO	Water Quality Objective
µg/L	Micrograms per litre
µS/cm	Microsiemens per centimetre
%	Percent
%Sat	Percent saturation

1. Introduction

1.1 Project overview

Origin proposes to develop the Shoalhaven Hydro Expansion Project, to construct and operate a new pumped hydro power station on and under the land between the Fitzroy Falls Reservoir and Lake Yarrunga (the Project). The Project would draw on Origin's existing water allocations to pump water up from Lake Yarrunga consuming energy when it is in less demand. Energy would then be generated through the return of water from Fitzroy Falls Reservoir to Lake Yarrunga when demand for energy increases.

The Project would involve almost doubling the electricity generation capacity of the existing scheme, providing an approximate additional 235 megawatts (MW) of generation capacity. The operation of the scheme would respond to the needs of the National Energy Market (NEM) and involving up to one pumping and generation cycle per day. Each generation cycle is anticipated to involve up to 8 hours of generation and 16 hours of pumping, each of which could be divided into shorter durations to best satisfy the needs of the NEM.

The Project location is shown in **Figure 1-1**. An indicative Project layout based on the current reference design is provided in **Figure 1-2** and consists of the construction and operation of:

- Upper scheme components (Upper Scheme) including:
  - Connection to existing upper intake control structure at the southern end of the Fitzroy Canal
  - A surface penstock (water transfer pipeline and associated infrastructure) from the existing Fitzroy Canal control structure to the vicinity of the Existing Scheme surge tank
  - A new surge tank adjacent to the Existing Scheme surge tank
  - A further section of surface penstock, adjacent to the existing scheme, from the new surge tank to the high pressure shaft
- Underground works including:
  - Vertical shaft and headrace tunnel connecting to the southern end of Upper Scheme surface penstock to an underground power station
  - An underground power station cavern housing a transformer, reversible motor generator and pump turbine capable of supplying a nominal 235 MW of hydroelectric power
  - Associated access tunnel and multipurpose (egress, ventilation and services) tunnel with an entrance in the vicinity of the existing Kangaroo Valley Power Station
  - A tailrace tunnel, including an underground surge chamber located just downstream of the underground power station, terminating west of the existing Bendeela Power Station on Lake Yarrunga
- Lower scheme surface components (Lower Scheme) including:
  - Lower intake /outlet structure west of the Bendeela Power Station connected to the tailrace tunnel
  - Spoil emplacement facility east of Bendeela Pondage
  - High voltage network connection to existing Kangaroo Valley substation
  - Operational surface infrastructure including administration building, water treatment infrastructure and ventilation building.

The Project would also require ancillary works which may include the carrying out of works to upgrade or construct access roads, spoil disposal sites, utilities infrastructure, construction compounds and construction power and water supply.

Importantly, the Project essentially duplicates the existing scheme and as such, the Project does not propose any new water storages or connections between waterbodies that have not already been utilised for the existing scheme. In addition, no transmission line augmentations are required to receive or distribute electricity from the existing Kangaroo Valley Power Station substation.

A full Project description is provided in Chapter 3 of the Environmental Impact Statement (EIS). Key components of the Project of relevance to this report are provided in **Table 1-1**.

1.2 Project location

The Shoalhaven Hydro Expansion Project is to be carried out in the Wingecarribee and Shoalhaven Local Government Areas (LGAs). Access to the upper portion of the Project on the plateau, for pipeline, surge tank and vertical shaft construction would be via the Promised Land Trail. The Promised Land Trail is accessed from Moss Vale Road and traverses both WaterNSW land and the Morton National Park and was constructed as part of the original scheme. Access to the lower portion of the Shoalhaven Hydro Expansion Project within Kangaroo Valley would be via Bendeela Road from Moss Vale Road in the vicinity of the townships of Kangaroo Valley and Barrengarry.

Table 1-1 Assumptions for Project works for use in this assessment

Project Element	Description	Assumption
Construction		
Road works and access track upgrade	Initial roadworks at the intersection with Moss Vale Road / Nowra Road, as well as the Promised Land Trail would involve: ▪ Road widening, levelling and resurfacing ▪ Brush cutting of vegetation along the sides of the access track.	Road and access track upgrades would take place prior to any other works in the Upper Scheme. The road would be sealed at the road intersection. The access track along Promised Lands Trail can be sealed, along steep or uneven sections of the track, and have appropriate road drainage which would be captured in drainage sumps.
Laydown / Work Areas and Access Tracks	All Project construction works will be carried out within Laydown / Work Areas as shown in **Figure 1-2**. Works which would be undertaken in these areas include: ▪ Vegetation clearing ▪ Earthworks ▪ Concrete works ▪ Steel works ▪ Rock blasting (limited) ▪ Spoil stockpiling and movement ▪ Site facilities and material laydown.	Erosion and sediment control measures will be established as early as possible following commencement of works, in Laydown / Work Areas. Laydown / Work Areas will be contained so that no construction runoff will be able to mobilise offsite without management. Steep sections of the Laydown / Work Areas will be initially covered with shotcrete or otherwise stabilised to reduce sediment mobilisation. Water collected in construction sediment basins will be treated prior to discharge.
Penstock	The new penstock to be constructed adjacent to the existing pipeline within the existing pipeline easement. Works which would be undertaken to build the pipeline include: ▪ Steelworks ▪ Concrete works and spraying of shotcrete ▪ Earthworks ▪ Material laydown.	The new penstock will be progressively built from anchor locations and adjacent to the existing scheme penstock. Material that is excavated from the footing sites will be immediately collected and transported via truck for management. No spoil stock piling along the penstock easement is proposed. Temporary stockpiling within works areas may be considered where space permits. Construction staging will include progressive rehabilitation of disturbance areas to minimise erosion potential to match capability of established controls. To stabilise the surface in steep sections of the disturbance areas along the penstock alignment, soil stabilisers will be applied.

Project Element	Description	Assumption
Penstock Anchor Block	The new Penstock Anchor Block to be constructed adjacent to the existing penstock anchor block within the existing easement. Works which would be undertaken to construct the new penstock anchor block include: ▪ Vegetation clearance ▪ Steelworks ▪ Concrete works and spraying of shotcrete ▪ Earthworks ▪ Material laydown.	The new penstock anchor block will be built within the existing instream works area of Trimbles Creek (refer to **Appendix F** for visual context). Erosion and sediment control measures will be established prior to any vegetation clearing or earthworks at the penstock anchor block area. Steep sections around the disturbance areas at the penstock anchor block area will have soil stabilisers applied to stabilise the surface. Clean water diversions would be provided to minimise water requiring management. Water collected in construction sediment basins will be treated prior to discharge.
Surge Tank	The new surge tank to be constructed in proximity of the existing surge tank. Works which would be undertaken to construct the new penstock anchor block include: ▪ Vegetation clearance ▪ Steelworks ▪ Concrete works ▪ Earthworks ▪ Material laydown.	As per works areas assumption.
Underground Works	Underground works will involve: ▪ Initial cut and cover at access portal and tailrace ▪ Tunnelling for the access tunnels head race tunnels and tail race tunnels ▪ Excavation of the caverns ▪ A pilot bore at the vertical shaft location ▪ Raise boring for the vertical shaft	Groundwater seepage and tunnel process water will be collected and treated at a water quality treatment plant prior to discharge. The pilot bore for the vertical shaft will be undertaken from within Laydown / Work Area 3.

Project Element	Description	Assumption
	▪ Discharge of groundwater seepage ▪ Concrete works and spraying of shotcrete.	Erosion and sediment control measures will be established prior to any vegetation clearing or earthworks in Laydown / Work Area 3 and 5.
Spoil Emplacement	Spoil that is excavated during underground works unable to be reused will be placed in a permanent emplacement area. Works will include: ▪ Establishment of the emplacement area ▪ Movement of spoil material to emplacement area ▪ Spoil management including classification and management of non-acid forming (NAF) and low risk potentially acid forming (PAF) rock ▪ Neutralisation or encapsulation of PAF with establishment of water management controls to capture, monitor and if necessary treat discharge.	Erosion and sediment control measures will be established prior to any vegetation clearing or earthworks at the spoil emplacement area. Water collected in construction sediment basins will be treated prior to discharge.
Lower Intake / Outlet Structure	The lower intake / outlet structure to be constructed west of the existing intake / outlet structure at Bendeela Power Station. Works would be primarily carried out in Laydown / Works Area 6 but will additionally include instream works within Lake Yarrunga. Works will involve: ▪ Vegetation clearance ▪ Earthworks ▪ Concrete works ▪ Steel works ▪ Rock blasting ▪ Instream works.	Erosion and sediment control measures will be established prior to any vegetation clearing or earthworks at the Laydown / Works Area 6 or instream in Lake Yarrunga. Steep sections of the disturbance area at Laydown / Works Area 6 will be initially covered with shotcrete to stabilise the surface. Construction and dewatering of an instream cofferdam, rock or other water quality alternative may be required to minimise impacts to water quality from the rock blasting and earthworks at the earthen block bank. Dewatering of the instream area will be placed into the construction sediment basin for treatment prior to being discharged.
Operation		

Project Element	Description	Assumption
Groundwater seepage dewatering	On-going groundwater seepage anticipated to occur from underground caverns and the access tunnel. Works will involve: ▪ Collection of groundwater seepage ▪ Operational discharges.	A permanent water treatment facility will be designed to treat ground water seepage generated from groundwater ingress in the main access tunnel and caverns. Discharge from the water treatment facility during the operation of the Project will be required to meet specific discharge criteria as per the operational discharge concentration limits set out in the Project Environmental Protection Licence (EPL). The discharge concentration limits of the EPL will be developed from site specific trigger values (SSTVs) of Lake Yarrunga, and with reference to other relevant guidelines (ANZG, 2018).
Structural design and operational management of the scheme	Water transferred between Lake Yarrunga and Fitzroy Falls Reservoir via the new scheme for the purpose of electricity generation.	The structural design and operational management of the scheme will apply flow rates and water level fluctuations so that impacts to the structural integrity of the banks of the reservoirs are minimised.
Maintenance discharges of the penstock	Water discharged from the new penstock pipeline from the release valve at the penstock anchor block for maintenance, inspection, repair, or in the event of an emergency.	The release valve to be installed on the new penstock will have the same discharge capacity as the existing penstock. It is intended to adopt the current release schedule in place at the existing pipeline for the new pipeline when maintenance works are required. Under most circumstances this would involve progressive dewatering over a 45-hour period to avoid unnecessarily high flows down Trimbles Creek. If however the pipeline needs to be dewatered in an emergency, it will have the ability to be safely drained in 13 hours which is consistent with the existing release schedule. Scour protection measures to minimise scour and erosion at the downstream area will be identified as part of the detailed design.

Legend

- Points of interest
- Indicative Project footprint
- Project location
- NPWS Reserve
- State Forest

0 5 10 km

1:300,000 at A4

GDA2020 MGA Zone 56

Data sources

Jacobs 2022
Department of Planning and Environment 2022
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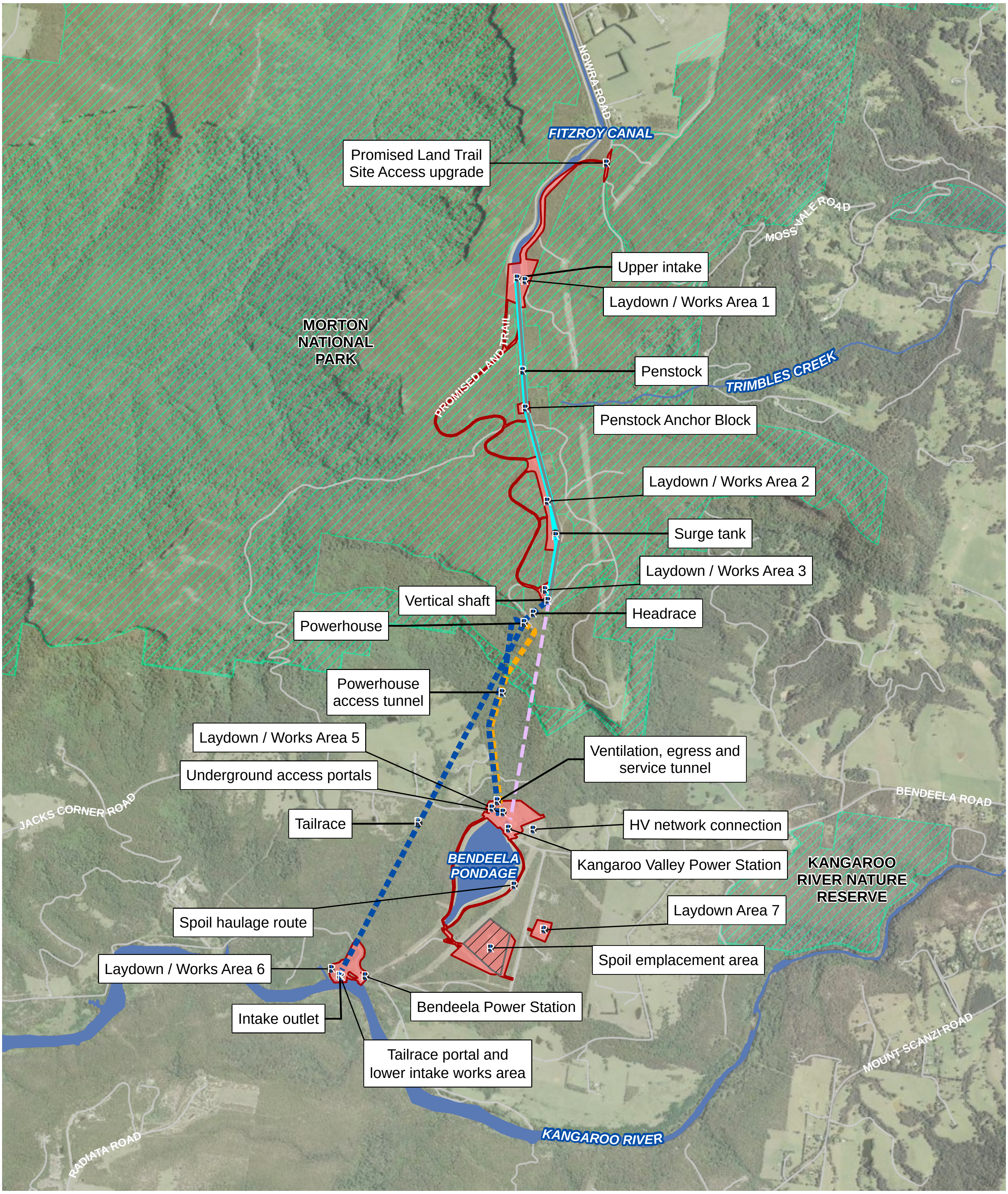
Figure 1-1 Project location



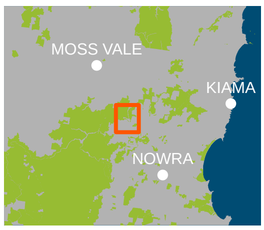
Legend

Points of interest	Waterway
Existing KV tunnel alignment	Road
Existing scheme pipeline	NPWS Reserve
Indicative above ground pipeline	Waterbody
Indicative tunnel alignment	
Indicative access tunnel	
Disturbance area	
Spoil site	

0 1 2 km

1:40,000 at A4

GDA2020 MGA Zone 56



Data sources

Jacobs 2022
Department of Planning and Environment 2022
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Figure 1-2 Indicative Project layout

1.3 Secretary's Environmental Assessment Requirements

This assessment forms part of the EIS for the Project. The EIS has been prepared under Division 5.2 of the EP&A Act. This assessment has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) relating to water impacts and will assist the Minister for Planning to make a determination on whether or not to approve the Project.

Table 1-2 outlines the SEARs relevant to this assessment along with a reference to where these are addressed.

Table 1-2 SEARs relevant to water impacts

Secretary's requirement	Where addressed in this report
Water – including:	
an assessment of the impacts of the project on groundwater aquifer and groundwater dependent ecosystems having regard to the NSW Aquifer Interference Policy and relevant Water Sharing Plans;	Impacts to groundwater are detailed in Appendix J of the EIS (Groundwater impact assessment). Groundwater drawdown and groundwater seepage discharges during construction and operation are discussed in **Chapter 6** and **Chapter 7**, respectively.
a detailed site water balance for the project, including water supply and wastewater disposal arrangements;	Details of the site water balance for both construction and operation are provided in **Chapter 8.**
an assessment of whether the project would have a neutral or beneficial effect (NorBE) on water quality;	Outcomes of the NorBE Assessment are provided in **Chapter 9**.
where the project involves works within 40 metres (m) of the high bank of any river, lake or wetlands (collectively waterfront land), identify likely impacts to the waterfront land, and how the activities are to be designed and implemented in accordance with the *DPI Guidelines for Controlled Activities on Waterfront Land* (2018) and (if necessary) *Why Do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings* (DPI, 2003); and *Policy & Guidelines for Fish Habitat Conservation & Management* (DPI, 2013); and,	Potential impacts to waterways and waterbodies from Project construction and operational activities on waterfront land have been described and assessed in **Chapter 6** and **Chapter 7**, respectively. The assessment has considered the *DPI Guidelines for Controlled Activities on Waterfront Land* (2018) and *Why Do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings* (DPI, 2003); and *Policy & Guidelines for Fish Habitat Conservation & Management* (DPI, 2013) throughout the assessment.
a strategy to manage spoil.	Spoil management with regard to protecting water quality is discussed in **Chapter 6.** A spoil management strategy has been separately developed and is available in Appendix K of the EIS (Spoil Management Strategy).

1.4 Structure of this report

The structure and content of this report are outlined in **Table 1-3**.

Table 1-3 Structure and content

Chapter	Description
Chapter 1 Introduction	Outlines key elements of the Project, SEARs and the purpose of this report (this Chapter)
Chapter 2 Policy and planning setting	Provides an outline of the statutory context, including applicable legislation and planning policies
Chapter 3 Assessment methodology	Provides a description of the assessment methodology for this assessment.
Chapter 4 Existing environment	Provides a preliminary description of the existing environment.
Chapter 5 Water quality controls	Provides a discussion on the water quality controls that have been proposed during construction of the Project.
Chapter 6 Potential construction impacts	Presents the outcomes of the construction impact assessment.
Chapter 7 Potential operational impacts	Presents the outcomes of the operational impact assessment.
Chapter 8 Water Balance	Presents a detailed site Water Balance for construction and operation.
Chapter 9 Neutral or Beneficial Effect (NorBE) Assessment	Presents the outcomes of the Neutral or Beneficial Effect (NorBE) on water quality assessment.
Chapter 10 Potential cumulative impacts	Presents the qualitative assessment of potential cumulative construction and operational water impacts with other Projects near the Project.
Chapter 11 Mitigation measures	Presents the water mitigation measures applicable for the Project.
Chapter 12 Conclusion	Summarises the findings of this report.

2. Legislative and policy context

2.1 Commonwealth legislation

2.1.1 Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) aims to protect Matters of National Environmental Significance (MNES). Under the EPBC Act, where an action has potential to have a significant impact on a MNES, the Project is referred to the Commonwealth Department of Climate Change, Environment, Energy and Water (DEECCW). The referral process involves a decision on whether or not the Project is a "controlled action". When a Project is declared a controlled action, approval from the Minister for the Environment is required.

On 28 September 2022, the Project was determined to be a controlled action, requiring approval under the EPBC Act from the Commonwealth Minister for the Environment due to its potential impact on the following MNES:

- Listed threatened species and communities (sections 18 & 18A).

The Project would be assessed under the bilateral agreement between the Commonwealth and NSW Governments and DEECCW has issued its assessment requirements which have been incorporated into the SEARs for the Project.

2.2 State legislation

2.2.1 Environmental Planning and Assessment Act 1979 and Environmental Planning and Assessment Regulation 2000

The EP&A Act and the *Environmental Planning and Assessment Regulation 2000* (the Regulation) provide the framework for development assessment in NSW. The EP&A Act and the Regulation include provisions to ensure that the potential environmental impacts of a development are considered in the decision-making process prior to proceeding to construction. The Project is declared Critical State Significant Infrastructure (CSSI) and an environmental impact statement has been prepared under Division 5.2 of the EP&A Act. The SEARs have been issued and this report considers those requirements as relevant to surface water and groundwater resources (refer to **Section 1.3**).

Under section 5.23 of the EP&A Act, the requirement for an activity approval under section 91 of the *Water Management Act 2000* (WM Act) does not apply to a CSSI Project.

2.2.2 Water Management Act 2000

The WM Act is the key piece of legislation for the management of water in NSW and contain provisions for the licensing of water access and use.

The aims of the WM Act are to provide for the sustainable and integrated management of the State's water sources for the benefit of both present and future generations. The WM Act implicitly recognises the need to allocate and provide water for the environmental health of rivers and groundwater systems, while also providing license holders with more secure access to water and greater opportunities to trade water through the separation of water licenses from land. The WM Act enables the State's water resources to be managed under water sharing plans, which establish the rules for the sharing of water in a particular water source between water users and the environment, and rules for the trading of water in a particular water source.

For surface water, the Project is located within the Shoalhaven River Water Source of the Water Sharing Plan for the *Greater Metropolitan Region Unregulated and Alluvial Water Sources* 2011. This plan applies to surface water resources and includes rules for protecting the environment, water extraction, managing licence holders' water accounts, and water trading within the plan which establish rules for the sharing of water, in particular, water source between water uses and the environment, and rules for the trading of water in a particular water source.

Section 91 of the WM Act requires an 'activity approval' to carry out a 'controlled activity' in, on or under waterfront land. The definition of a controlled activity includes carrying out of the work, the removal of material or vegetation from land, the deposition of material on land and the carrying out of any other activity that affects the quality of flow of water in a water source. 'Waterfront land' is defined as including the bed and banks of rivers as well as land that is 40 m inland of the highest bank of the river. The Project is primarily within and along the banks of Kangaroo River / Lake Yarrunga, as well as other creeks and tributaries. These areas are covered by the definition as the Act protects all riparian zones. In general, the WM Act requires:

- A water use approval to use the water
- A water management works approval, particularly a water supply work approval to construct and use a specified water supply work at a specified location
- A Water Access Licence (WAL) to take water.

As described in **Section 2.2.1**, however, an activity approval under section 91 of the WM Act does not apply to a CSSI Project, by force of section 5.23 of the EP&A Act. Despite the exemption, the Project has considered the Guidelines for Controlled Activities on Waterfront Land (DPI, 2018) as per the SEARs.

The Water Access Licence and Water Supply Work and Water Use licences currently held for the existing scheme are discussed below.

2.2.2.1 Water Access Licence

A WAL authorises the taking of a share of water from a specified water source in accordance with the volumetric entitlement in the WAL. That entitlement is measured by the number of units assigned to the WAL and the annual volumetric value of a unit for that water source as determined by the Minister administering the WM Act. Units can be transferred from one WAL to another. A WAL is held personally and may be transferred and otherwise dealt with in accordance with the WM Act.

Origin Energy currently holds a WAL (no. WAL27432) under the water sharing plan for the Greater Metropolitan Regional Unregulated River Water Source to extract water for the purposes of electricity generation (DPI, 2013a). Under the WAL, Origin must adhere to the conditions outlined within the WAL some of which include volumetric limits for water transfers between Fitzroy Falls Reservoir and Lake Yarrunga per generation cycle, ensuring the volume of water in Bendeela Pondage does not exceed 880ML and to divert water to Lake Yarrunga for the purposes of electricity generation when Fitzroy Falls Reservoir is spilling into Yarrunga Creek.

2.2.2.2 Water Supply Work and Water Use

Origin Energy currently holds a Water Supply Works and Water Use Approval under the water sharing plan for the Greater Metropolitan Regional Unregulated River Water Source which authorises them to use and operation the water supply works (DPI, 2013b). Origin Energy are subject to a number of conditions of approval which are relevant to the operation of this Project including (but not limited to):

- Origin must not interchange water when Cyanobacteria is greater than or equal to 50,000cells/ml *Microcystin aeruginosa* or the biovolume equivalent is greater than or equal to 4mm^3/L for the combined total of all cyanobacteria
- Undertaken water quantity monitoring using metering equipment
- Undertake cyanobacteria monitoring at a minimum of weekly between 1 October and 31 May and monthly between 1 June to 30 September at nominated sites and procedures outlined in Attachment 3 and 4 of the Approval and detailed in **Table 11-3**).

2.2.3 WaterNSW Act 2014 and WaterNSW Regulation 2013

The purpose of the *WaterNSW Act 2014* (WNSW Act) is to define the functions and objectives of WaterNSW, and the WaterNSW Regulation 2013 (WNSW Regulation) provides WaterNSW with the legal authority to enforce access restrictions. The principal objectives of WaterNSW under the WNSW Act are related to the capturing, storing and releasing of water in a responsible manner, supplying water in compliance with appropriate standards of quality; and to ensure that declared catchment areas and water management areas are managed so as to promote water quality, protect public health and the environment. Among others, the primary function of WaterNSW under the Act is to release water to water supply authorities including Sydney Water and other authorities/local councils prescribed by the regulations and manage and protect the declared catchment areas.

The WNSW Act sets out an objective to provide for the planning, design, modelling and construction of water storages and other management works. The Project is in keeping with this objective.

The entire study area falls within the Sydney Drinking Water Catchment and specifically the waterbodies of Fitzroy Falls reservoir in the upper portion of the study area and Lake Yarrunga in the lower portion of the study area are declared as “Schedule 2 – Special Area”. Restricted access and stringent environmental regulations for protecting water quality are imposed by WaterNSW for these Special Areas.

2.2.4 Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations Act 1997* (NSW) (POEO Act) is administered by the Environmental Protection Authority (EPA). The POEO Act regulates air and water pollution, noise control and waste management. The Act contains pollution controls and requirements for granting EPLs for scheduled activities under Schedule 1, which includes electricity generation, as well as for unscheduled activities or prescribed matters (as listed in Schedule 5 of the Protection of the Environment Operations (General) Regulation 2009) that cover the discharge of water that may cause pollution.

Kangaroo Valley Power Station and Bendeela Power Station operate under EPL No. 140226. The power stations are currently classed as “Electricity Generation – Generation of electrical power otherwise than from coal, diesel or gas” with a scale of “0 – 250 GWh generated”. The EPL currently has no specific operational water discharge concentration limits, except that the licensee must comply with section 120 of the POEO act, which states there will be “no pollution of waters”.

Under the POEO Act, there is a legal responsibility to ensure that runoff leaving a site meets an agreed water quality standard, including water being discharged from construction sediment basins after storm events, as well as operational discharges. The construction contractor will be responsible for obtaining and complying with an EPL during construction. Following construction, the construction EPL would either be transferred to Origin for operational purposes, a new EPL sought or the existing EPL No. 140226 would be varied as necessary to incorporate any new scheduled activities including any operational discharge requirements.

The design and management of erosion and sediment controls associated with the construction of the Project as well as permanent drainage infrastructure would be confirmed during detailed design to achieve applicable water quality standards.

2.2.5 Fisheries Management Act 1994

The *Fisheries Management Act 1994* (FM Act) provides for the protection of threatened fish and marine vegetation and is administered by NSW Fisheries. The FM Act aims to conserve, develop and share fishery resources and conserve marine species, habitats and diversity.

Waterways within the study area have been categorised with regards to DPIE key fish habitat (KFH) mapping and threatened species distribution mapping (refer to **Section 4.2** for further detail). Threatened species listed under the FM Act which have been mapped as having predicted habitat in the waterways and water bodies in the study area include:

- Fitzroy Falls Spiny Crayfish (*Euastacus dharawalus*) – predicted distribution within Fitzroy Falls Reservoir and upstream in Wildes Meadow Creek.
- Macquarie Perch (*Macquaria australasica*) – predicted distribution approximately 3.5 river kilometres (km) upstream of the Project in Kangaroo River.

Impacts to the Fitzroy Falls Spiny Crayfish and Macquarie Perch are assessed in Appendix F of the EIS (Biodiversity development assessment report) for the Project, however indirect impacts to these species due to changes in water quality and flows are described and assessed in this report

2.2.6 Biodiversity Conservation Act 2016

The *Biodiversity Conservation Act 2016* (BC Act) provides for the protection and management of biodiversity in NSW, including the conservation of threatened species, communities and habitats. The BC Act is administered by the Environment and Heritage division of the Department of Planning and Environment (DPE), formerly known as the Office of Environment and Heritage (OEH).

The *River Flat Eucalypt Forest River Flat Eucalypt Forest* ecological community which is listed as an endangered ecological community (EEC) under Schedule 2, Part 2 of the BC Act, is known to occur within the catchment and within and around waterways and waterbodies in the study area (refer to **Section 4.2** for further detail).

Impacts to the EEC are assessed in the Appendix F of the EIS (Biodiversity development assessment report) for the Project, however indirect impacts due to changes in water quality and flows are described and assessed in this report.

2.3 Regulatory policies and relevant guidelines

2.3.1 National Water Quality Management Strategy

The National Water Quality Management Strategy (NWQMS) (Australian Government, 2018) was formulated with the objective of achieving sustainable use of the nation's water resources by protecting and enhancing water quality whilst maintaining economic and social development.

The NWQMS contains guidelines for setting water quality objectives to sustain current or likely future environmental values for water resources. The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG, 2018) are part of the NWQMS and are relevant to the Project as discussed in **Section 2.3.2**.

2.3.2 Australian and New Zealand Water Quality Guidelines for Fresh and Marine Water Quality

The Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ) published *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000) to provide benchmarks against which to assess the existing water quality of waterways. The guidelines were updated in 2018 to incorporate new science and knowledge developed over the past 20 years (ANZG, 2018), and several parameters have again been updated in 2021.

The ANZG (2018) *National Water Quality Guidelines for Fresh and Marine Water Quality* (referred to herein as the ANZG (2018) Water Quality Guidelines) have been applied with guidance from the *Using the ANZECC Guidelines and Water Quality Objectives in NSW* (DEC, 2006) booklet to understand the current health of the waterways in the study area and the ability to support nominated water quality objectives, particularly the protection of aquatic ecosystems. The ANZG (2018) Water Quality Guidelines provide default guideline values to be considered when describing the existing water quality and key indicators of concern. However, many of the guideline values are still in a draft form. Currently, physical and chemical stressors for aquatic ecosystems for the Southeast Coast (the geographic region relevant to this Project) have not yet been completely updated.

The ANZG (2018) Water Quality Guidelines are not intended to directly apply to contaminant concentrations in industrial discharges or stormwater quality (unless stormwater systems are regarded as having relevant community value). They have been derived to apply to the ambient waters that receive effluent or stormwater discharges and protect the water quality objectives they support.

2.3.3 Australian Drinking Water Guidelines

The Australian Drinking Water Guidelines (ADWG) (NHMRC, 2011) are the primary guidance document on drinking water quality in Australia. They are designed to provide an authoritative reference on what defines safe, good quality water, how it can be achieved and how it can be assured. They are concerned both with safety from a health point of view and with aesthetic quality. The ADWG are not mandatory standards, however, they provide a basis for determining the desirable quality of water to be supplied to consumers following treatment of raw water in all parts of Australia.

2.3.4 NSW Water Quality Objectives

The NSW Water Quality Objectives (WQOs) (DECCW, 2006) are the agreed long-term goals for NSW's surface water, as determined by the then Department of the Environment, Climate Change and Water (now Department of Planning and Environment). They set out:

- The community's values and uses (i.e. healthy aquatic ecosystem, water suitable for recreation or drinking water etc) for our waterways (rivers, creeks, lakes and estuaries)
- A range of water quality indicators to assess whether the current condition of the waterway supports these values and uses.

The WQOs identify environmental values for NSW waters and the ANZG (2018) guidelines provide the technical guidelines to assess the water quality needed to protect these values.

The study area falls within the Shoalhaven River Catchment which has been connected to the Hawkesbury-Nepean Catchment for drinking water supply purposes. At the time that WQOs were approved by the NSW Government (September 1999) for catchments across NSW, the Hawkesbury-Nepean catchment and Shoalhaven River Catchment were subject to an independent inquiry by the Healthy Rivers Commission (1998) (HRC). The HRC inquiry outlined WQOs and recommended water quality guideline values for the Hawkesbury-Nepean and Shoalhaven River systems, based on the identified 'environmental values' and uses for waterways. These WQOs were agreed to by the NSW Government through a statement of Joint Intent in 2001.

Environmental values outlined in the HRC Inquiry align with environmental values set out by the NSW Water Quality Objectives (ANZG, 2018). The ANZG (2018) recommended guideline values for water quality take precedence for assessment of the existing water quality of the receiving environments as they supersede the values recommended in the HRC Inquiry (HRC, 1998).

The catchment area is categorised as "Drinking Water Catchment". Corresponding environmental values (DECCW, 2006) that have been nominated for this land use category are detailed in **Section 3.2.2**. Associated default guideline values (ANZG, 2018; NHMRC, 2011) applicable to the environmental values are provided in **Appendix A**.

2.3.5 Neutral or Beneficial Effect on Water Quality Assessment Guideline

The Project SEARs indicate that an assessment of whether the Project will have Neutral or Beneficial Effect on Water Quality must be carried out as the Project falls within the Sydney Water Drinking Catchment (refer to **Section 1.3**).

The Neutral or Beneficial Effect on Water Quality Assessment Guideline (WaterNSW, 2015) is expected to be utilised as a framework to consider development proposals under the EP&A Act. These assessment guidelines outline the meaning of a NorBE on water quality, how to achieve it, and the process of assessment against the NorBE water quality test using the 'Neutral or Beneficial Effect on Water Quality Assessment Tools' (the NorBE tool).

Outcomes of the NorBE Assessment are provided in **Chapter 9**.

2.3.6 Managing Urban Stormwater: Soils and Construction and Main Road Construction

Managing Urban Stormwater, Soils and Construction, Volume 1 (Landcom, 2004), and Volume 2 (DECCW, 2008) (commonly referred to as the "Blue Book"), as well as Managing Urban Stormwater, Volume 2D: Main Road Construction (DECCW, 2008) are the key guideline documents used in NSW for stormwater management during construction. They provide basic principles and guidance on design and construction of sediment and erosion control measures to protect downstream water quality, thereby improving the health, ecology and amenity of rivers and streams.

2.3.7 Guidelines for Managing Risks in Recreational Waters

The Guidelines for Managing Risks in Recreational Water (NHRMC, 2008) aim to protect the health of humans from threats posed by the recreational use of coastal, estuarine and fresh waters.

The guidelines provide recommended values for indicators that may pose a risk to human health. These indicators are relevant for waterways that are being used for recreation but have the potential to be polluted. These guidelines are applicable to this assessment because the waterways in proximity of the Project have been nominated the environmental values of 'Primary contact recreation' and 'Secondary contact recreation'. This is further detailed in **Section 3.2.2.**

2.3.8 Policy and Guidelines for Fish Habitat Conservation and Management

The *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013c) is the guideline applicable to all planning and development proposals and various activities that affect freshwater ecosystems in NSW. The aims of this guideline are to maintain and enhance fish habitat for the benefit of native fish species, including threatened species in freshwater environments. First published in 1999, the 2013 updated document assists developers, consultants and government and non-government organisations to ensure their actions comply with legislation, as well as policies and guidelines that relate to fish habitat conservation and management. It is also intended to inform land use and natural resource management planning, development planning and assessment processes, and to improve awareness and understanding of the importance of fish habitats and how impacts can be mitigated, managed and offset. The guidelines outlined in this document are taken into account when NSW Fisheries assesses proposals for developments and other activities that affect fish habitats. The document contains:

- Background information on aquatic habitats and fisheries resources in NSW
- An outline of the legislative requirements relevant to planning and development which may affect fisheries or aquatic habitat in NSW

- General policies and classification schemes for the protection and management of fish habitats and an outline of the information that NSW Fisheries requires to be included in development proposals that affect habitat
- Specific policies and guidelines aimed at maintaining and enhancing the free passage of fish through instream structures and barriers
- Specific policies and guidelines for foreshore works and waterfront developments
- Specific policies and guidelines for the management of other activities that affect watercourses.

The surface water assessment has taken into account requirements of these guidelines.

2.3.9 Guidelines for Controlled Activities on Waterfront Land

Controlled activities carried out in, on or under waterfront land are regulated by the WM Act. This Act defines waterfront land to include the bed and bank of any river, lake or estuary and all land within 40 m of the highest bank of the river, lake or estuary.

Under section 5.23 of the EP&A Act, an activity approval (including a controlled activity approval) under section 91 of the WM Act is not required for CSSI. The former NSW Department of Primary Industries, Office of Water prepared guidelines for controlled activities which provide information on the design and construction of a controlled activity, and other ways to protect waterfront land.

Despite the exemption, the design and construction of the Project would take into account the NSW DPI (2018) Guidelines for Controlled Activities on Waterfront Land.

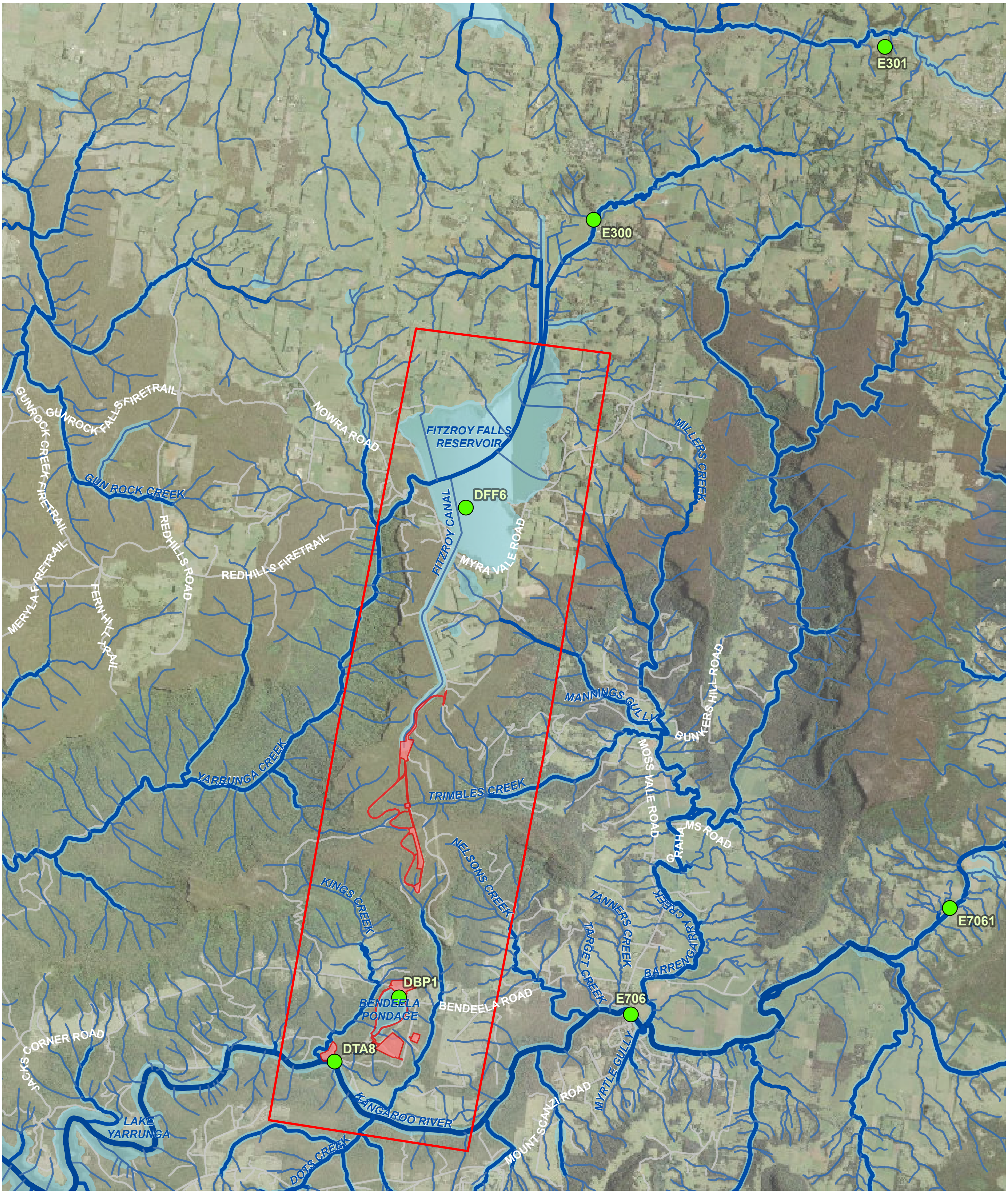
3. Assessment methodology

The methodology for assessment of potential surface water quality, hydrology and geomorphology impacts arising from the Project is outlined in the following sections and has broadly included:

- Desktop review and analysis of available information to understand the existing environment and identify potential waterway-specific and geomorphological risks
- A qualitative assessment of the quality and quantity of pollutants that may be introduced during construction and operation, and the impact that this may have on surface water (with reference to the ANZG (2018) Water Quality Guidelines), and with regard to the relevant water quality objectives and environmental values as identified in the DECCW (2006) NSW Water Quality Objectives
- A qualitative assessment of changes to water level and flows that would occur during construction and the impact that this may have on river geomorphology, and hydrological regime of waterways and waterbodies within the catchment
- Recommendations for appropriate treatment measures to mitigate the impacts of construction and operation on surface water quality, hydrology, and geomorphology including water quality controls, flow controls and recommendations for a water quality monitoring program during pre-construction, construction and operation of the Project.

3.1 Study Area

The Study Area for the surface water quality, hydrology and geomorphology assessment is the area directly affected by the Project and any additional areas likely to be affected by the Project either directly or indirectly. For the purposes of this report, the study area comprises the disturbance area (as shown **Figure 3-1**) and a 'zone of impact', which consists of a 500 m buffer around the Project, Fitzroy Falls Reservoir and Lake Yarrunga to 500 m upstream and downstream of the instream footprint.



Legend

- WaterNSW Routine Monitoring Site

Strahler stream order

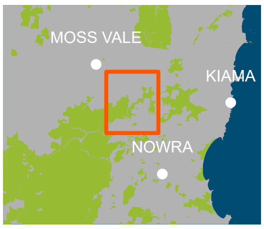
- 1
- 2
- 3
- 4
- 5
- 6

- Project Study Area
- Construction disturbance area
- Key fish habitat
- Road

0 1 2 km

1:90,000 at A4

GDA2020 MGA Zone 56



Data sources

Jacobs 2022
Department of Planning and Environment 2022
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Figure 3-1 Study area - surface water quality, hydrology and geomorphology

3.2 Desktop assessment

3.2.1 Desktop review

The desktop assessment involved a review of existing conditions across the study area to assess the likely and potential impacts of the Project on surface water quality, hydrology and flooding during construction and operation. The review of information has included a review of literature, water quality data, background information on land use and information on the design and operation of the Project. Information sources included:

- Independent Inquiry into the Shoalhaven River System – Final Report. (HRC, 1998)
- NSW Water Quality Objectives (DECCW, 2006)
- ANZG 2018 Water Quality Guidelines (ANZG, 2018)
- Sydney Drinking Water Catchment – Shoalhaven Catchment (WaterNSW, 2022)
- Shoalhaven Pumped Hydro - Water Access Licence (WAL27432) (DPI, 2013a)
- Shoalhaven Pumped Hydro - Water Supply Works and Water Use Licence (DPI, 2013b)
- WaterNSW Dams – Fitzroy Falls Reservoir (WaterNSW, 2022)
- Bureau of Meterology (BOM) Climate Data Online (BOM, 2022a; BOM, 2022b)
- NSW soil and land information database “eSPADE” (DPE, 2022)
- NSW Fisheries Data Portal (DPI, 2022)
- Water quality data collected by WaterNSW:
  - Lake Yarrunga at Kangaroo River at Bendela Pumping Station
  - Kangaroo River at Hampden Bridge
  - Kangaroo River at Oakdale
  - Bendeela Pondage
  - Yarrunga Creek at Wildes Meadow
  - Lake Fitzroy Falls at midlake
  - Caalang Creek at Old Kangaloon Road Ford.

3.2.2 Environmental values

The study area is located in the region of the Shoalhaven Catchment which has been categorised as “Drinking Water Catchment” in the HRC guidelines (1998). The waterways within the footprint area have been nominated a number of environmental values which correspond with the definitions of the environmental values outlined by DECCW (2006). The environmental values for the waterways and reservoirs within the footprint area include:

- **Protection of aquatic ecosystems**: Aquatic ecosystems comprise the animals, plants and micro-organisms that live in water and the physical and chemical environment in which they interact. Aquatic ecosystems have historically been impacted upon by multiple pressures including changes in flow regime, modification and destruction of key habitats, development and poor water quality. There are a number of naturally occurring physical and chemical stressors that can cause degradation of aquatic ecosystems. These parameters include nutrients, dissolved oxygen, pH, salinity and turbidity (suspended solids). The objectives for aquatic ecosystems are consistent with the agreed national framework for assessing water quality set out in the ANZG (2018) guidelines
- **Visual amenity**: The aesthetic appearance of a waterbody is an important aspect with respect to visitation and recreation. The water should be free from noticeable pollution, floating debris, oil, scum and other matter. Substances that produce objectionable colour, odour, taste or turbidity and substances and conditions that produce undesirable aquatic life should not be apparent (NHMRC, 2008). The key aesthetic indicators are transparency, odour and colour
- **Secondary contact recreation:** Secondary contact recreation implies some direct contact with the water would be made but ingestion is unlikely in activities such as boating, fishing and wading. Bacteriological indicators are used to assess the suitability of water for recreation

- **Primary contact recreation:** Primary contact recreation implies some direct contact with the water would be made during activities such as swimming in which there is a high probability of water being swallowed. Bacteriological indicators, nuisance organisms, algal blooms, pH, temperature, chemical contaminants, surface films, visual clarity and colour are used to assess the suitability of water for recreation
- **Livestock water supply:** The purpose of the livestock water supply objective is to protect water quality to maximise the production of healthy livestock. Indicators monitored for this objective include algae and blue-green algae, salinity, faecal coliforms and chemical contaminants
- **Irrigation water supply:** The purpose of the irrigation water supply objective is to protect quality of waters applied to crops and pasture. Indicators monitored for this objective include algae and blue-green algae, salinity, faecal coliforms and heavy metals
- **Drinking water – Clarification and disinfection:** The purpose of the drinking water objective is to protect water quality for human consumption following appropriate treatment. Indicators monitored for this objective include blue-green algae, turbidity, Salinity (electrical conductivity), faecal coliforms, total coliform, dissolved oxygen, pH and chemical contaminants.

These environmental values have been considered in the assessment of existing water quality and potential impacts as a result of the Project.

Further to the nominated environmental values outlined in the HRC Guidelines, the catchment is subject to raw water supply agreements that are held between WaterNSW and Sydney Water. Raw water supplied for treatment is required to conform to specific standards which are based on treatment capabilities of Kangaroo Valley and Wingecarribee Water Filtration Plants (WFP). This ensures that raw water conforms with or can be treated to meet ADWG requirements. Fitzroy Falls Reservoir, Bendeela Pondage and Lake Yarrunga are additionally subject to algal content conditions outlined in the Water Supply Work and Water Use licence held by Origin for the existing scheme (refer to **Section 2.2.2.2**).

As such, the default trigger values (DTVs) for the environmental values of "Protection of aquatic ecosystems" and "Visual amenity" (ANZG, 2018), the ADWG (NHMRC, 2011) health guideline values and the site-specific values specified in the raw water supply agreement to the Kangaroo Valley and Wingecarribee WFPs (WaterNSW, 2019) have been considered in the assessment of potential impacts to existing water quality as a result of the Project. These values and indicators are provided in **Appendix A.**

3.2.3 Existing water quality data review

Water quality data used in this report to establish existing water quality is sourced from available routine monitoring data (WaterNSW, 2022), and in-situ physiochemical water quality data collected for the Project from nominated sites on waterways and waterbodies within the study area (refer to **Section 3.3**).

Table 3-1 provides details of WaterNSW water quality monitoring locations. The locations of existing water quality monitoring sites are provided on **Figure 3-1.**

Table 3-1 Available water quality data (Data source: WaterNSW)

Site Number	Monitoring location name	Coordinates		Date range	Monitoring timeframe
		Easting	Northing		
DBP1	Bendeela Pondage	269177	6154618	April 2017 – March 2022	Variable Quarterly 2017 no data for Jan 2018 to Jun 2019 Monthly July 2019-2022

Site Number	Monitoring location name	Coordinates		Date range	Monitoring timeframe
		Easting	Northing		
DTA8	Lake Yarrunga @ Kangaroo R at Bendeela PS	268073	6153519	Jan 2017 – March 2022	Monthly
DFF6	Lake Fitzroy Falls @ Midlake	270321	6163008	Jan 2017 – March 2022	Monthly
E300	Wildes Meadow Creek @ gauge	272510	6167939	Jan 2017 – March 2022	Monthly
E301	Caalang Ck Old Kangaloon Rd Ford	277500	6170900	Jan 2017 – March 2022	Monthly
E706	Kangaroo River @ Hampden Bridge	273148	6154326	Jan 2017 – March 2022	Monthly
E7061	Kangaroo River @ Oakdale	278612	6156149	Jan 2017 – March 2022	Monthly

The methodology for determining existing water quality conditions included:

- Collating water quality data and calculating summary statistics for each site including number of samples, mean, median, maximum value, minimum value and percent compliance with applicable ANZG (2018) default guideline values (DGVs) for nominated environmental values. Note – when a data point for an indicator was below the detection limit, the data point was determined to be half the value of the detection limit
- Reporting the 20th percentile, median, and 80th percentile data and average in-situ data in comparison with applicable DGVs.

3.3 Field assessment

Field assessment for water quality condition was undertaken by environmental scientists at nominated sites on the 19th and 20th February 2019. The purpose of the site visit was to visually assess the condition of waterways and waterbodies at the sites. A particular focus was placed on Fitzroy Falls reservoir as the waterway condition assessment was coupled with targeted species surveys for the Fitzroy Falls Spiny Crayfish. Further information is provided in Appendix F of the EIS (Biodiversity development assessment report).

A total of 5 sites within Fitzroy Falls Reservoir, as well as one site at Bendeela Pondage and one site at Lake Yarrunga (Kangaroo River) were assessed. Nominated sites are listed in **Table 3-2** and **Figure 4-5**.

Table 3-2 Monitoring location descriptions

Site number	Site name	Description
Fitzroy Falls Reservoir		
1	FFR: North-west	North-western edge of Fitzroy Falls Reservoir, accessed via Vermont Lane.
2	FFR: South	Southern edge of Fitzroy Falls Reservoir, accessed via the Fitzroy Falls Reservoir Picnic Area. Located 100 north-east of the Fitzroy Falls Upper Canal.
3	FFR: East	Eastern edge of the Fitzroy Falls Reservoir, accessed via WaterNSW maintenance road from Myra Vale Road.

Site number	Site name	Description
4	FFR: North	Northern edge of the Fitzroy Falls Reservoir, accessed via WaterNSW maintenance road from pumping station at Wildes Meadow. Located 85 m west of Wildes Meadow Creek and immediately adjacent to Wildes Meadow Canal.
7	FFR: South-west	South-western edge of Fitzroy Falls Reservoir, accessed via Fitzroy Falls Reservoir Picnic Area. Located immediately south of the Southern Highlands Sailing Club.
Lake Yarrunga (Kangaroo River upstream)		
5	LY: Kangaroo River	Upstream of Lake Yarrunga on Kangaroo River, accessed via Bendeela Recreational Area.
Bendeela Pondage		
6	BP: North-east	North-eastern edge of Bendeela Pondage, accessed via WaterNSW maintenance road. Immediately adjacent to Kangaroo Valley Power Station.

3.4 Sensitive receiving environments

Sensitive receiving environments (SREs) have a high conservation value or support ecosystems/human uses of water that are particularly sensitive to pollution or degradation of water quality. It is important to identify SREs that are directly impacted by the Project or are located downstream of Project activities so that these values may be adequately protected.

Typically SREs are determined using identified aquatic habitat and aquatic ecosystem values as indicators (DPI, 2013c). For the purposes of this Project however, all perennial waterways, tributaries which flow to these waterways and permanent waterbodies have been considered SREs because they are situated within Schedule 2 Special Area (restricted entry) of the Sydney Drinking Water Catchment, and/or flow through Morton National Park.

While all waterways and waterbodies have been considered SREs, the sensitivity of the SRE has been defined on a four-point scale from Very Low to High depending on the receptor's surface water features, as well as the aquatic and human values. The scale is defined in **Table 3-3**.

Table 3-3 Sensitivity of receptor

Sensitivity	Description	Indicators
High	Attribute has a high quality and rarity on regional or national scale	▪ Water directly used for drinking water supply ▪ Supports pristine ecosystems including water dependent MNES ▪ Supports EPBC listed, FM listed and BC listed aquatic species and endangered ecological communities ▪ Contains freshwater aquatic habitat features in good condition ▪ Attributes of water system are unique to the region ▪ Water level highly responsive to change in water level.
Medium	Attribute has a high quality and rarity on a local scale	▪ Water quality suitable for agricultural or stock use ▪ Water supports slightly disturbed ecosystems ▪ Contains freshwater aquatic habitat features in good condition ▪ Attributes of the water system are locally unique but have few regional equivalent.

Sensitivity	Description	Indicators
Low	Attribute has a medium quality and rarity on local scale	▪ Water quality suitable for aquaculture or industrial use ▪ Water supports moderately to very disturbed ecosystems ▪ Contains freshwater aquatic habitat features in poor condition ▪ Attributes of the water system are common on a local, regional and national basis and therefore have local equivalents.
Very Low	Attribute has a low quality and rarity on local scale	▪ Water quality unsuitable for any practical use ▪ System completely resilient to change ▪ Does not contain substantial aquatic habitat.

SREs have been classified in **Section 4.3**, taking into consideration the above indicators, as well as the hydrological characteristics of the waterway.

3.5 Approach to assessment of potential impacts

3.5.1 Assessment of construction impacts

The assessment of the potential impacts on surface water during construction has involved:

- Identification of potential direct and indirect impacts to the surface water quality, quantity and geomorphology of waterways and waterbodies from construction activities associated with the Project and identification of the receivers that are at risk from potential impacts. These may include:
  - Potential changes to water quality from sedimentation and contaminated runoff and tunnel dewatering
  - Potential changes to environmental water availability and flows, particularly regarding changes due to impacts on surface creek baseflows as a result of groundwater drawdown
  - Potential geomorphological changes to waterways and waterbodies resulting from construction discharges and instream works
- Description of recommended water quality treatment measures to mitigate water quality impacts of construction in accordance with the Blue Book (Landcom, 2004)
- Description of other recommended mitigation measures to mitigate potential impacts to surface water from construction activities
- A risk assessment (further described in **Section 3.5.3**) of identified potential impacts to each receiver, with consideration given to the proposed water quality controls (erosion and sediment) and other nominated mitigation measures.

3.5.2 Assessment of operational impacts

The assessment of the potential impacts during operation involved:

- Identification of potential direct and indirect impacts to the surface water quality, quantity and geomorphology of waterways and waterbodies from operational infrastructure or activities associated with the Project, and identification of the receivers that are at risk from potential impacts. These may include:
  - Potential changes to water quality from operational discharges, water transfers, maintenance activities
  - Potential changes to environmental water availability and flows, particularly regarding changes due to impacts on surface creek baseflows as a result of groundwater drawdown
  - Potential geomorphological changes to waterways and waterbodies resulting from discharges and water level changes from reservoirs
- Description of recommended mitigation measures to mitigate impacts of the operational phase

- A risk assessment (further described in **Section 3.5.3**) of identified potential impacts to each receiver, with consideration given to proposed nominated mitigation measures.

3.5.3 Risk assessment

A risk assessment approach has been adopted for determining the level of risk to waterways within the study area. The risk assessment uses a combination of *likelihood* and *consequence* to determine the level of risk.

Likelihood is typically based on the chance of an event or impact occurring (refer to **Table 3-4**). Consequence is based on the predicted response if the threat occurs and is based on sensitivity to the threat (refer to **Table 3-5**).

The combination of likelihood and consequence results in a risk ranking (refer to **Table 3-6**). **Table 3-7** provides a summary description of the risk categories and implications for identified values.

Table 3-4 Likelihood criteria for standard risk assessments

Score	Likelihood	Description
1	Rare	The outcome is not expected to occur; no record of occurring but not impossible; may occur in exceptional circumstances
2	Unlikely	The outcome will only occur in a few circumstances; uncommon but know to occur elsewhere
3	Possible	The outcome may occur; some evidence to support it will happen
4	Likely	The outcome will occur in most circumstances
5	Almost certain	The outcome is expected to occur

Table 3-5 Consequence of potential impact

Consequence	Description	Example
High	Results in loss of attribute	Irreversible or persistent high-severity impact likely No recovery within foreseeable future Impacts are at a regional, national or international scale Impact would result in significant departure from Federal or State policy or guidance.
Moderate	Results in impact on integrity of attribute or loss of part of attribute	Moderate severity impacts likely to persist over time or high-severity impacts that have a short duration only, with rapid recovery upon activity completion Impact extends across regional areas Impact would result in departure from Federal or State policy or guidance.
Minor	Results in some measurable changes in attributes quality or vulnerability	Low severity impacts are likely to persist over time, or moderate-severity impacts are likely to have a short duration only, with rapid recovery when the activity is completed Impact extends beyond the area of activity or footprint Impact would result in minor departure from Federal or State policy or guidance.
Negligible	Results in an impact on an attribute but of insignificant	Low severity and short-term impacts restricted to the immediate area of activity or footprint No medium or long-term impacts on receptors

Consequence	Description	Example
	change to quality or vulnerability	Impact would result in insignificant departure from Federal or State policy or guidance.

Table 3-6 Risk ranking

Likelihood	Consequence			
	Negligible	**Minor**	**Moderate**	**High**
Almost certain	Low	Medium	High	Severe
Likely	Low	Medium	Medium	Severe
Possible	Low	Low	Medium	High
Unlikely	Very low	Low	Low	Medium
Rare	Very low	Very low	Low	Medium

Table 3-7 Summary of risk impact descriptions

Risk ranking	Description of significance
Severe	Significant impact with high likelihood of impact to a highly sensitive environmental value on a regional or national scale. Impact results in irreversible or persistent high severity impact on the quantity, quality or availability of surface or ground water with little or no chance of recovery in the foreseeable future.
High	The environmental value which has a medium or high sensitivity on a local scale would be degraded by the impact of high severity with impacts persisting over time, or as a result of a short-term impact that recovers immediately upon completion of the activity. The impact may extend over regional scale or across multiple aquifer units.
Medium	The environmental value, which has moderate or high sensitivity on a local scale, will be affected by a low severity impact. Impacts are likely to be of short duration and to have rapid recovery when the activity is completed.
Low	The environmental value, which has low or moderate sensitivity on a local scale, will be affected by a low severity impact. Impacts are likely to be of short duration and to have rapid recovery when the activity is completed.
Very low	A very low impact exists to an environmental value. The impact is of low severity and restricted to environmental values with very low sensitivity. There are no medium- or long-term impacts and recovery is rapid.

3.5.4 Assessment of cumulative impacts

The assessment of surface water cumulative impacts involved:

- Identification of major Projects that is likely to overlap with the Project
- Identification of common sensitive receivers for each Project, assessment of likely cumulative impacts and identification of mitigation measures.

3.5.5 Water balance

A detailed water balance was prepared for the construction phase of the Project taking into consideration water supply sources including groundwater inflows, treated Project water and make-up water supplies, and separating the Project into the Upper Scheme and Lower Scheme working areas. Water demands and groundwater inflow rates have been calculated on a monthly basis. The resulting water balance provides an assessment of monthly and total water surplus, requiring treatment and discharge; and water deficit, requiring make-up water supplies over the duration of Project construction.

Ongoing groundwater seepages to drained structures, requiring treatment and discharge, and water uses and sources during Project operation are also identified.

It is noted that while the reference design and associated scheduling may vary at construction, the resulting water balance demonstrates the key aspects of water supply, demand and management that are anticipated for the Project.

The water balance is detailed in **Chapter 8**.

3.5.6 Neutral or Beneficial Effect (NorBE) Assessment

An assessment was undertaken to ascertain whether the Project will have a neutral or beneficial effect on water quality. The NorBE assessment utilised the assessment approach outlined in the Neutral or Beneficial Effect on Water Quality (NorBE) Assessment Guideline (2015).

Outcomes of the NorBE assessment is provided in **Chapter 9.**

4. Existing environment

4.1 Catchment overview

Broadly, the Project is situated in the Shoalhaven River Catchment in southern NSW, which drains a total area of approximately 5,640 square km (km^2). The Shoalhaven River spans approximately 300 river km from its headwaters near Braidwood in the south-west to the river mouth and estuarine system at Shoalhaven in the north-east. The four key tributaries of the Shoalhaven River are the Mongarlowe River, Corang River, Endrick River and Kangaroo River. Other tributaries include Ettrema, Boro, Reedy, Danjerra, Yalwal, Broughton, Broughton Mill and Yarrunga Creeks.

Lake Yarrunga, formed by Tallowa Dam at the confluence of the Shoalhaven and Kangaroo Rivers, is the centrepiece of the region's water supply. Tallowa Dam, Bendeela Pondage, Fitzroy Falls and Wingeecarribee Reservoirs are linked by a series of pipelines, canals and pumping stations and are collectively known as the Shoalhaven Scheme. The Shoalhaven Scheme was built in the 1970's to top up the Sydney and Illawarra water supply systems during drought. The scheme also supplies local communities including Goulburn, Shoalhaven and Nowra. Kangaroo Valley township is supplied from Shoalhaven City Council's treatment plant and draws water from Bendeela Pondage.

4.1.1 Land use

Land uses in the Shoalhaven River Catchment consist of several agricultural practices (approximately 36 per cent of the catchment) and large forested areas including national parks (31 per cent) and areas utilised for forestry (27 per cent). Cattle and sheep grazing are the largest single land uses, although the catchment also supports horse studs, piggeries, dairies and poultry as well as vineyards, olive groves, and canola and cereal crops. The catchment also includes protected "Special Areas" in proximity of Tallowa Dam, Lake Yarrunga and Fitzroy Falls Reservoir. These special areas protect water quality by providing a buffer zone of bushland around the dams and immediate catchment areas. Only a small portion of the catchment is urbanised, with Nowra being the largest urban centre in the catchment.

The Project spans across the Shoalhaven LGA and Wingecarribee LGA. The majority of the Project would be carried out on land owned by WaterNSW that is associated with the existing Kangaroo Valley and Bendeela Power Stations and water transfer operations. WaterNSW land includes land either side of the existing penstock and surge tank in the upper portion the Project, and land between Jacks Corner Road and Lake Yarrunga in the lower portion of the Project. All WaterNSW landholdings are zoned SP2 infrastructure – Water Supply System. Immediately north of the Fitzroy Falls Reservoir is zoned C3 – Environmental Management. On the plateau, Morton National Park is located adjacent to the Project on either side of the WaterNSW landholdings corridor and is zoned as C1 – National Parks and Reserves. Further south in the valley, the area is mixture of RU1 – Primary production, RU2 – Rural landscape, C2 – Environmental Conservation and E3 – Environmental Management. The major features of the area surrounding the Project include:

- The existing scheme
- Morton National Park
- Bendeela Recreation Area
- Rural landholdings and associated private dwellings.

4.1.2 Climate

Overall, the study area generally experiences a warm-temperate climate typical of its location in south-eastern Australia, with mild to hot summers and cool-mild winters. More specifically, however, the upper portion of the Project is located in the southern highlands and the lower portion of the Project falls within a valley between Berry Mountain and the Illawarra Escarpment therefore temperature and rainfall conditions can vary.

Review of data available through BOM Climate Data Online (BOM, 2022a; BOM, 2022b) indicated that the nearest BOM weather stations to the upper and lower portions of the study area are at Fitzroy Falls (Red Hills) (#68248) and Hampden Bridge (Kangaroo River) (#68181), respectively. The Fitzroy Falls (Red Hills) Weather Station is positioned approximately 5.5 km west of the Project at its nearest point, and Hampden Bridge (Kangaroo River) Weather Station is positioned approximately 5.2 km east of the Project.

Utilising the BOM climate database, the average total rainfall for each calendar month from January 2003 to December 2021 (19 years) was calculated and is summarised in **Table 4-1** and presented in **Figure 4-1**. Rainfall trends indicate that the region experiences highest rainfall in late summer/early autumn (February and March), but also receives significant amounts in June. Rainfall in the upper portion of the Project tends to receive larger amounts of rainfall than the lower portion. This is expected to be due to orographic lift phenomenon whereby rain clouds form above a geographical feature such as a mountain or cliff.

Table 4-1 Average total monthly rainfall recorded at Fitzroy Falls (Red Hills) Weather Station (#68248) and Hampden Bridge (Kangaroo River) (#68181)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Fitzroy Falls (Red Hills) Monthly Average Total Rainfall (mm)	71.8	172.6	140.1	60.1	68.9	133.1	59.0	78.9	55.2	79.2	111.1	75.9	1097.2
Hampden Bridge (Kangaroo River) Monthly Average Total Rainfall (mm)	61.9	145.3	118.2	65.8	60.4	91.1	52.5	76.9	38.4	62.0	91.3	57.5	842.6

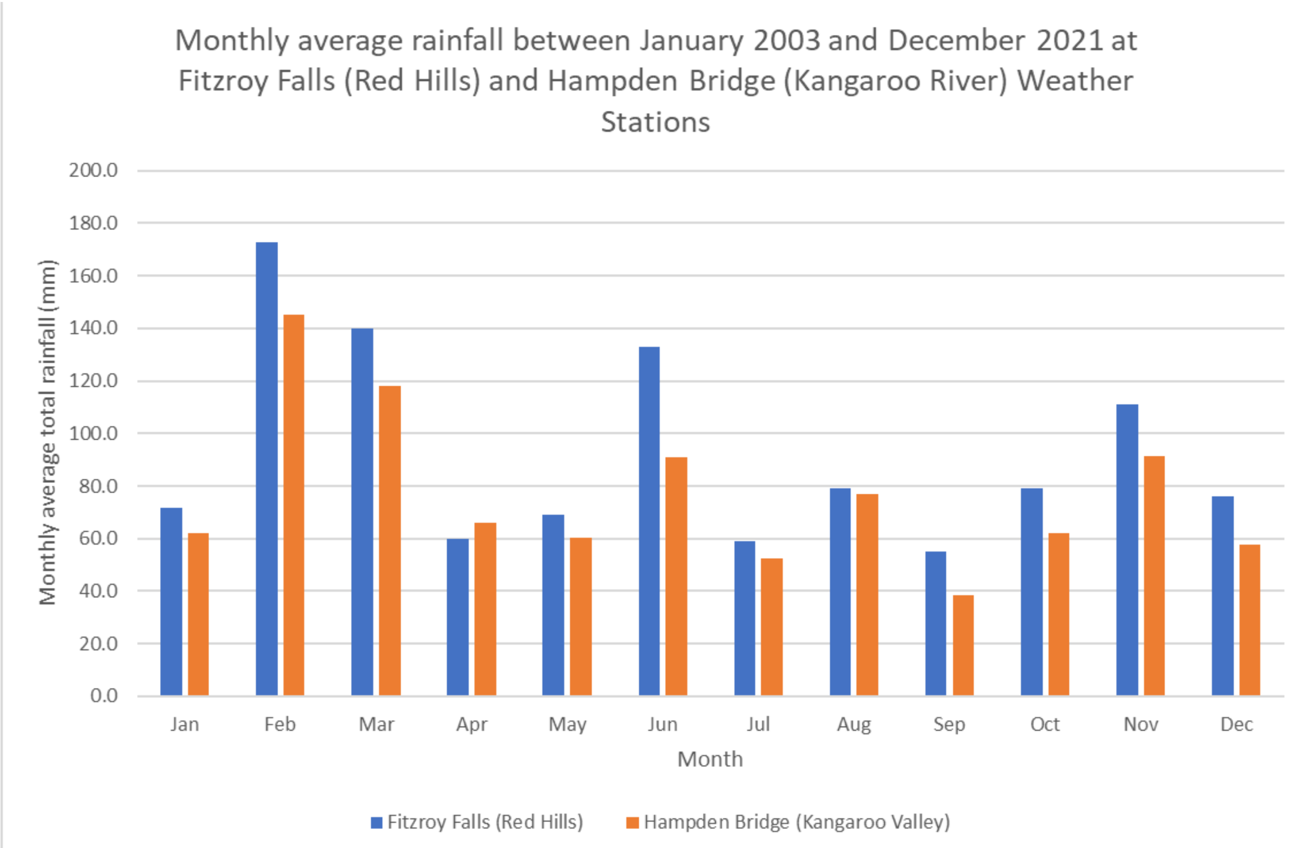


Figure 4-1 Average total monthly rainfall between 2003 and 2021, as recorded by Fitzroy Falls (Red Hills) and Hampden Bridge (Kangaroo River) Weather Stations

The closest weather station with long term temperature data was Moss Vale AWS (#68239), which is located approximately 13.5 km from Fitzroy Falls Reservoir. Monthly average minimum and maximum ambient temperatures experienced in the region are presented in **Figure 4-2**.

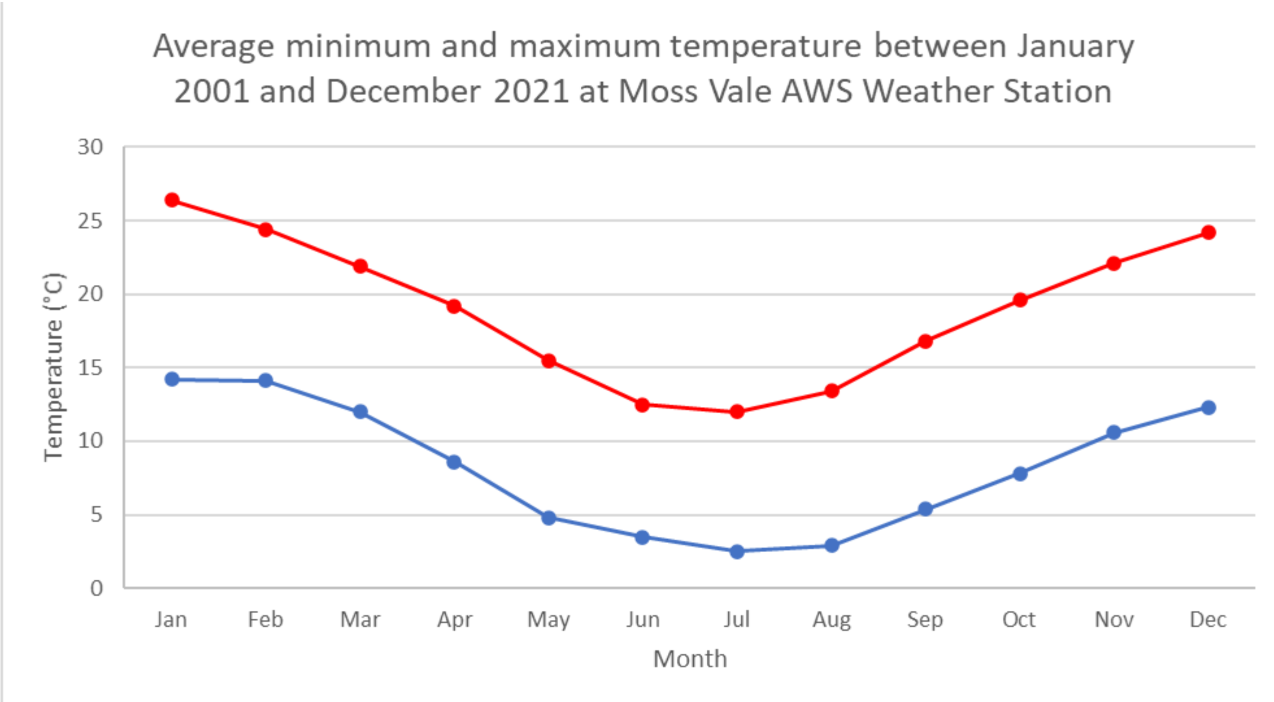


Figure 4-2 Average minimum and maximum temperature between 2001 and 2021, as recorded at Moss Vale AWS Weather Station

Available temperature data indicates that the region is positioned within a temperate climatic region characterised by mild to warm summer and cool winters. Average minimum and maximum temperatures range from approximately 12 – 27 Degrees Celsius (December to February) and 3 – 13 Degree Celsius (June to August) seasonally, with predominantly mild temperatures in the autumn and spring months. While no data was available for the lower study area in Kangaroo Valley, it is expected that temperatures would be slightly warmer during summer months and colder during winter months than what is experienced in the upper portion of the Project on the plateau.

4.1.3 Topography and drainage

The Project extends from low elevation areas in the southern extent of the study area at the Kangaroo River in Kangaroo Valley to the northern extent of the study area at the upper plateau near Fitzroy Falls. Elevations across the overall study area range between approximately 60 m AHD at Kangaroo River to up to 670 m AHD on the plateau. The plateau continues to the Fitzroy Falls Reservoir. As such, the area can be approximately divided into two distinct areas, the lower Study Area which spans from the Kangaroo River valley until the base of the escarpment (steep rise) and the upper study area, which consists of the Fitzroy Falls Reservoir, the plateau and its slopes on both sides (refer to **Figure 4-3**).

4.1.3.1 Upper Study Area

The upper Study Area is largely forested with some areas of rural farmland on the eastern and northern sides of the Fitzroy Falls Reservoir. Infrastructure related to the existing Shoalhaven Scheme extends southward along the upper study area and includes the Fitzroy Falls Reservoir and Canal, the existing surface pipeline and easement, surge tank and high-pressure shaft.

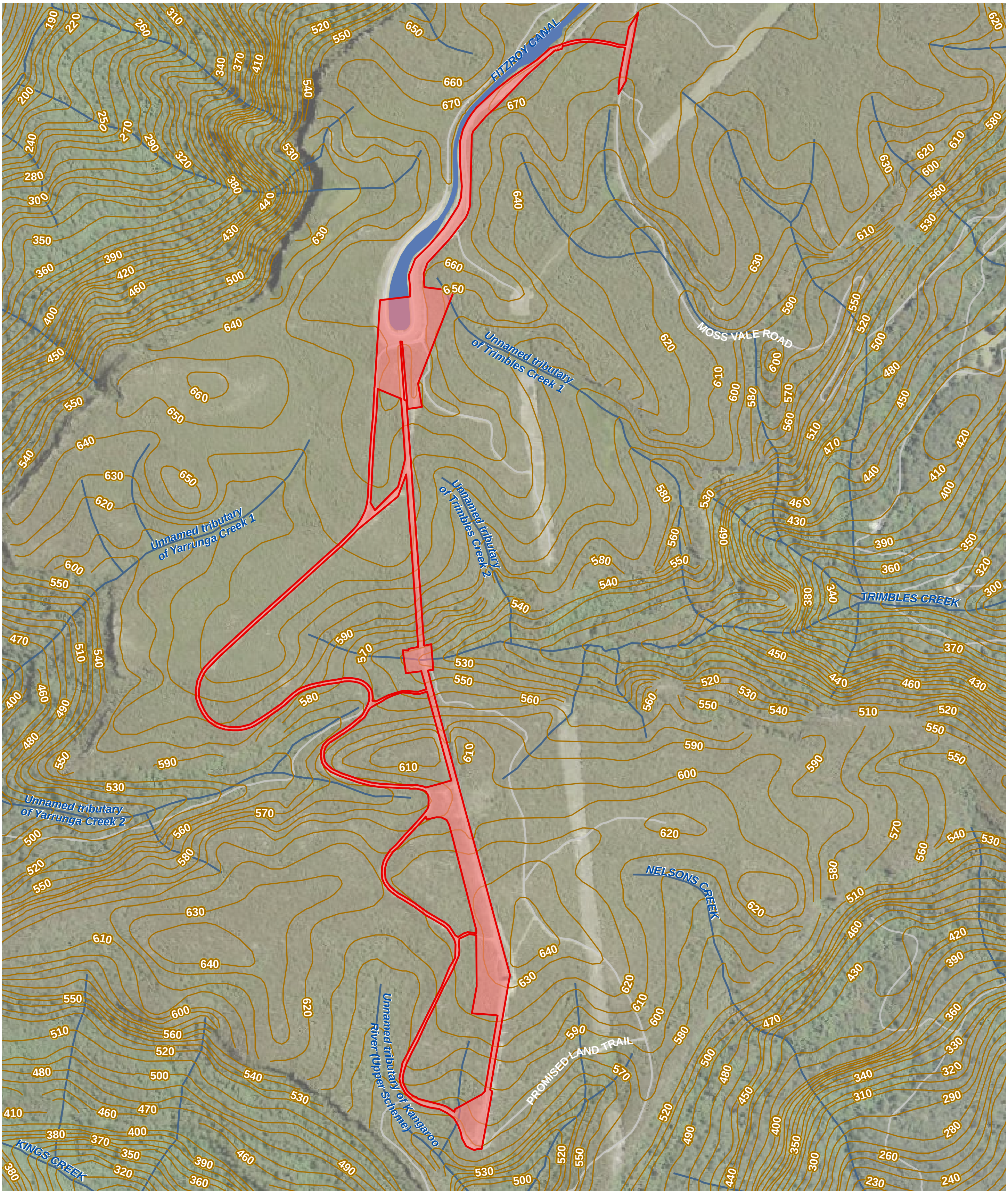
The Fitzroy Canal connects the Fitzroy Falls Reservoir to the northern extent of the surface pipeline on the plateau. There is significant topographic variation along the plateau, in particular, there is a steep slope that dips south from the upper intake control structure to the anchor block at the base of the valley, which is located within Trimbles Creek. Elevation gradually rises from the anchor block to another high point at the surge tank. From this point, elevation gradually decreases along the slope from the surge tank to the high pressure shaft. Approximately 50 m south of the base of the high pressure shaft, elevation rapidly decreases, creating a cliff-like topographic feature (the escarpment). At the south-west extent of the plateau there are several drainage lines down the escarpment. The headwaters of Kings Creek rise to the west of the plateau and follow the base of the escarpment before turning south and flowing to Kangaroo River. Drainage lines also drain west toward Yarrunga Creek which flows west before turning to the south and connecting with the Kangaroo River. To the south-east of the plateau, drainage lines lead into Nelsons Creek which also flows into the Kangaroo River. To the east of the plateau, drainage lines lead into Trimbles Creek which flows east off the escarpment and connects to Millers Creek.

Along the top of the escarpment the Fitzroy Canal connects the Fitzroy Falls Reservoir and the Upper Intake. The escarpment is largely flat with a gentle slope towards the edges of the escarpment and away from the canal as such minimal rainfall runoff will enter the canal.

4.1.3.2 Lower Study Area

The lower area beneath the escarpment until the Kangaroo River and the southern end of the study area is a mix of vegetation, farmland and built areas relating to the Kangaroo Valley Power Station as well as a small number of houses and farm buildings.

From the base of the escarpment the area gradually slopes south until an area of flat ground where several farms, the Kangaroo Valley Power Station and Bendeela Pondage are located. The area again slopes south toward Kangaroo River. There are two main drainage lines running north to south through the area connecting the escarpment with the Kangaroo River. Kings Creek flows on the western side of the Kangaroo Valley Power Station as well as a significant, but unnamed drainage line to the east of the power station.



Legend

- Contour 10m
- Waterway
- Road
- Construction disturbance area

0 0.3 0.6 km

1:16,000 at A4

GDA2020 MGA Zone 56

Data sourcesa

Jacobs 2022
Department of Planning and Environment 2022
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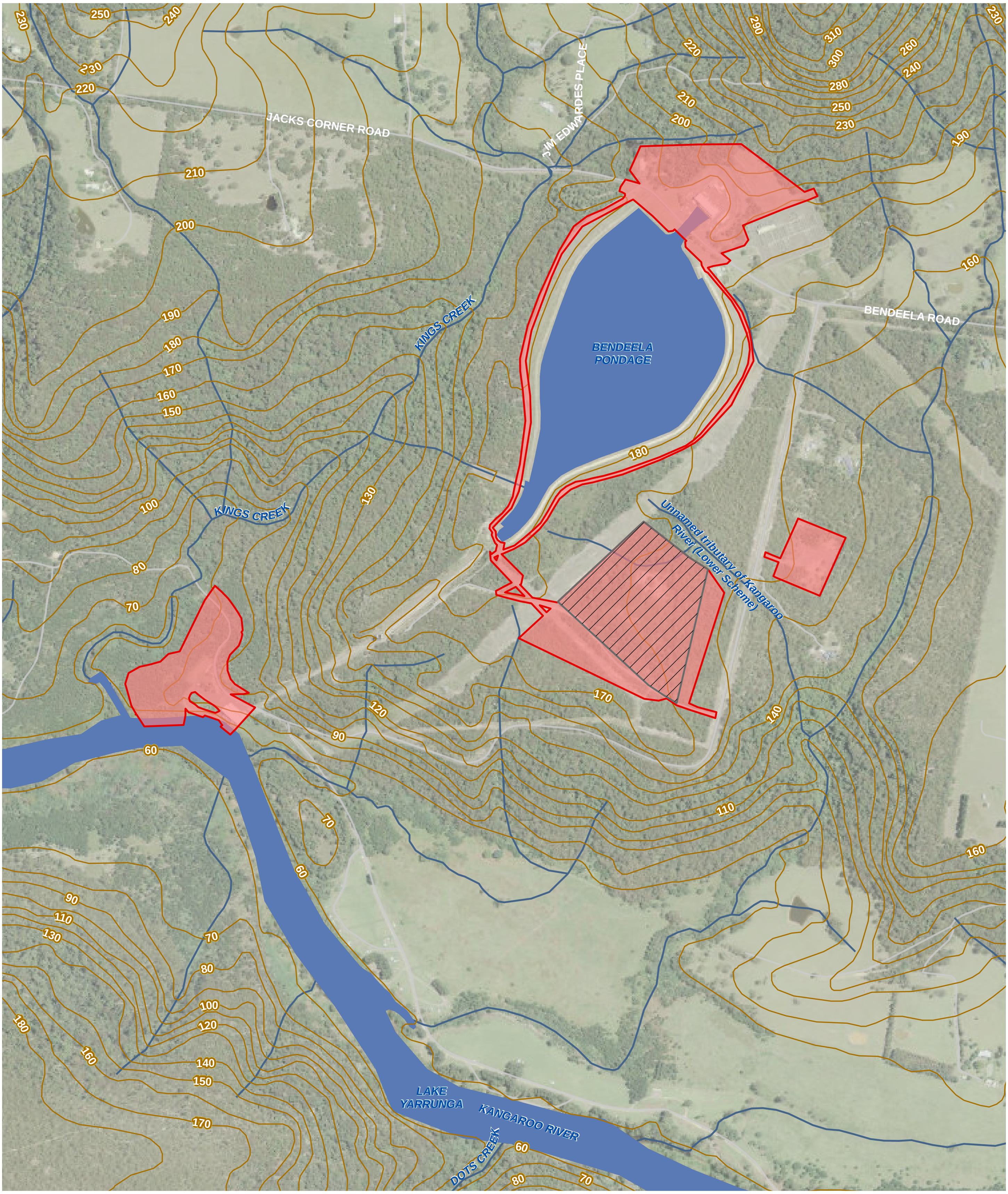
Figure 4-3a Topography of the study area - Upper Scheme (plateau)



Legend

- Contour 10m
- Waterway
- Road
- Construction disturbance area
- Spoil site

0 0.3 0.5 km

1:12,500 at A4

GDA2020 MGA Zone 56

Data sourcesb

Jacobs 2022
Department of Planning and Environment 2022
© Department of Customer Service 2020

Figure 4-3b Topography of the study area - Lower Scheme (Kangaroo Valley)

Date: 21/07/2022 Path: \\ausyd0vs01\gisproj\NSW_IS392600_ShoalhavenEIS\Apps\IS392600_SurfaceWater.aprx
Created by : JB | QA by : HK

4.1.4 Soils and geology

4.1.4.1 Geology

The geology of the Study Area is varied across distance and depth. The surface geology of the lower valley in the southern extent of the study area is comprised of the Broughton formation, while the elevated plateau is mainly comprised of the Hawkesbury Sandstone formation. Below the Broughton Formation, a number of geological units including the Budgong Sandstone, Berry Siltstone, Nowra Sandstone, Wandrawandian Siltstone, Snapper Point Formation and Yarrunga Coal Measures, are present in descending order.

A number of these geological units have potential for generating acid rock. These include the Snapper Point Formation, Wandrawandian Siltstone and Berry Siltstone.

4.1.4.2 Soil landscapes

According to the NSW soil and land information database "eSPADE" (DPE, 2022), the study area is situated on several soil landscapes, however the data for this section of the NSW mapping is incomplete therefore soil landscapes have been interpolated based on corresponding topography. **Table 4-2** describes the predicted soil landscapes in the study area and **Figure 4-4** shows the predicted landscapes across the study area.

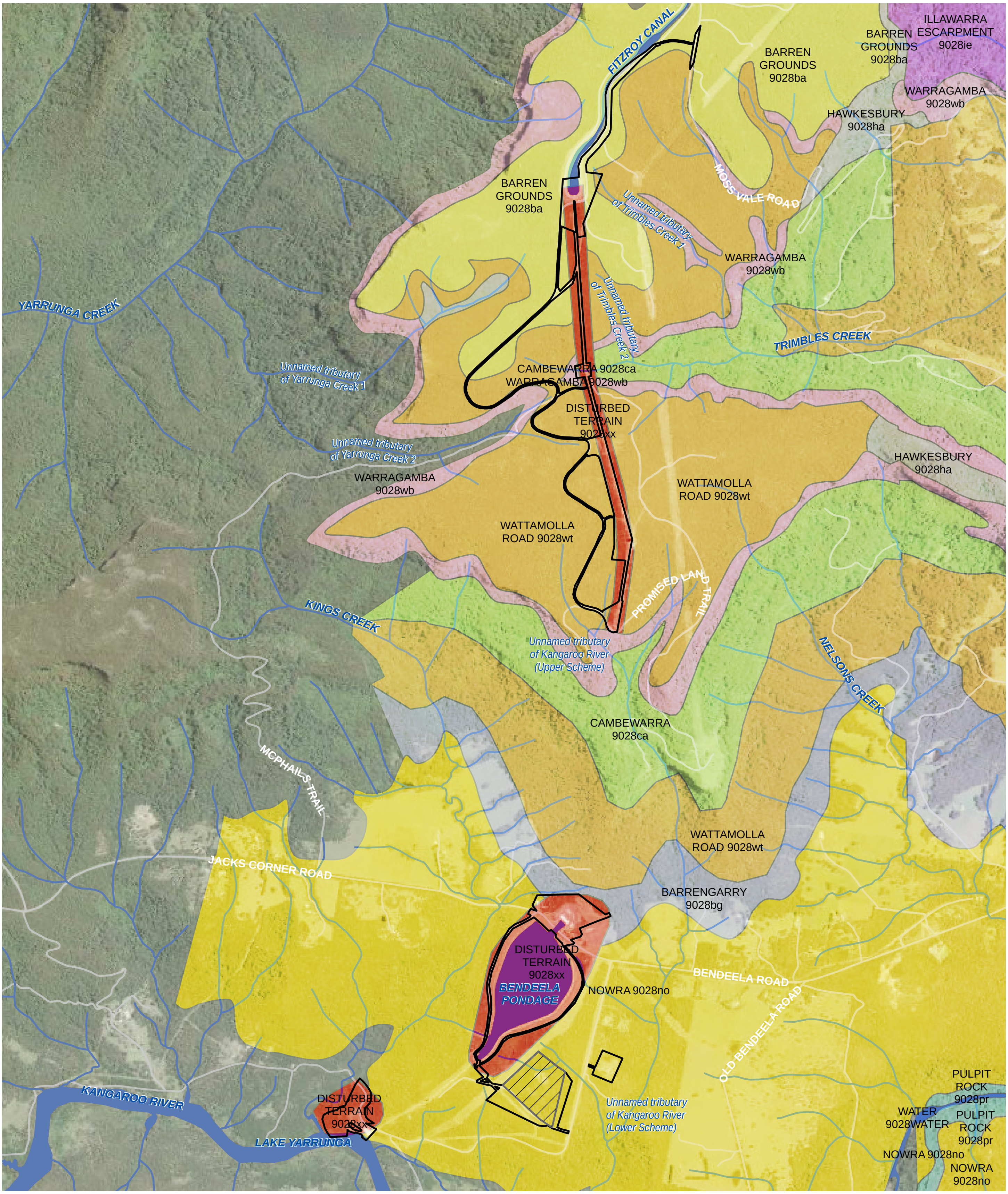
For the purpose of this assessment, however, Wattamolla Road, Barrengarry and Nowra soil landscapes characteristics have been used for developing erosion and sediment controls. Characteristics of these soil landscapes are summarised **Table 4-2** and further described in **Appendix H.**

Table 4-2 Soil landscapes within the study area

Soil Landscape	Description (DPE, 2022)
Hawkesbury – Colluvial	This soil landscape has three dominant soil materials. The first of which is loose brownish black coarse quartz sand (topsoil) which has a colour of brownish black to brownish grey, a texture of sand to sandy loam, dispersed <2 percent (%) 2-6mm stone fragments and abundant roots and a pH of 4.0. Soil limitations include high permeability, low available water-holding capacity, low fertility, high erodibility, strongly acidic, and high aluminium toxicity. The second dominant soil material is earthy, yellowish brown sandy clay loam. The colour is generally yellowish brown to yellow orange, it has a pH of 4.5-5.5, gravels are common and there are no roots. Limitations include stoniness (localised), high permeability (localised), very low fertility and high erodibility. The final type is Bright yellowish brown light clay, it has a colour of bright yellowish brown (10YR 6/6) to bright brown (5YR 5/6), a pH of 4.5, gravels are common and there no roots. Some limitations include very low fertility, strongly acidic, high erodibility.

Soil Landscape	Description (DPE, 2022)
Wattamolla Road – Depositional	This soil landscape is characterised by 2 topsoils and 3 subsoils. Hardsetting brownish black fine sandy loam (topsoil) has a colour of brownish black (5YR 3/1) to greyish brown (7.5YR 4/2) with occasional bleaching at depth, a pH of 6.0, <2% 2-6mm stones and roots are abundant. Friable brown silt loam (topsoil) has a colour of brown (7.5YR 4/3) to dull brown (7.5YR 4/6) with occasional bleach, a pH of 5.5, no stones and roots are common. Some limitations of the topsoils include hardsetting, strongly acidic, high organic matter, low wet bearing strength and sodicity. The subsoils include mottled brown light clay (subsoil) which has a colour of brown (7.5YR 4/3) yellowish brown (10YR 5/4) red mottles (50%), a pH of 5.5, no stones and a few roots. Dark reddish brown strongly pedal light clay (subsoil) has a colour of dark reddish brown (5YR 3/4), a pH of 5.5, no stones and roots are common. Mottled brown strongly pedal medium clay (subsoil) has a colour of brown (7.5YR 4/6) to yellowish brown (10YR5/8) with red and grey mottles (50%) at depth, a pH of 4.5, no stones and a few roots. Limitations of the subsoils include low wet bearing strength, sodicity, strongly acidic, high permeability and low permeability.
Cambewarra – Erosional	The dominant soil materials for this soil landscape include two topsoils and two subsoils. The first topsoil is friable very dark reddish brown sandy clay loam (topsoil) which has a colour of very dark reddish brown (5YR 2/3) (with occasional bleach), a pH of 5.5-6.0, 2–10% 2–6 mm rounded and subrounded dispersed stones and roots are common. Very dark reddish brown silty clay loam (topsoil) has a colour of very dark reddish brown (2.5YR 2/3), a pH of 5.5-6.0, 50–90% 2–6 mm angular dispersed stones and few roots. Topsoil limitations include stoniness, very low available water-holding capacity, sodicity and shallowness. The subsoils include bright brown strongly pedal light clay (subsoil) which has a colour of bright brown (7.5YR 5/8) to reddish brown (2.5YR 4/8), a pH of 4.5 and 2–10% 2–6 mm rounded and subrounded dispersed stones and few roots. Mottled bright reddish brown strongly pedal medium clay (subsoil) has a colour of bright reddish brown (5YR 5/8) with yellow (50%) and grey (40%) mottles, a pH of 3.5-5.5, nil to localised 10–20% 6–60 mm angular and sub-angular dispersed stones and no roots. Subsoil limitations include strongly acidic, stoniness, low permeability and low wet bearing strength.
Warragamba – Colluvial	This soil landscape consists of 1 topsoil and2 hybrid topsoil/subsoil. Friable brownish black loamy sand (topsoil) has a colour of brownish black (10YR 2/2) to yellowish brown (10YR 5/6), a pH of 3.5, 2–10% <2mm angular dispersed stones and roots are also abundant. Its limitations include stoniness, high permeability, very strongly acidic, low fertility and low available water-holding capacity. Very dark reddish brown clayey sand (topsoil and subsoil) is very dark reddish brown (5YR 2/3) to yellowish brown (10YR 5/6), has a pH of 3.5-5.0, common 60–200 mm angular and sub-angular dispersed stones and roots are common. Dull brown strongly pedal medium clay with faint mottles at depth (topsoil and subsoil) has a colour of dull brown (7.5YR 5/4) to reddish brown (5YR 4/6) yellow and red mottles 50%, a pH of 3.5-4.0, >10% 2–6 mm angular dispersed stones and no roots. Their limitations include stoniness, erodibility (localised), high permeability, very strongly acidic, high potential aluminium toxicity, low fertility and low available water-holding capacity.

Soil Landscape	Description (DPE, 2022)
Barrengarry – Depositional	This soil landscape is defined by 1 topsoil and 4 subsoils. Moderately pedal dull reddish brown sandy clay loam (topsoil) has a colour of dull reddish brown (5YR 4/3), a pH of 5.0, <2% 2-6mm angular dispersed stones and roots are common. Limitations of the topsoil include stoniness, high organic matter, high available water-holding capacity and shrink-swell. Dark reddish brown silty clay loam (subsoil) has a colour of dark reddish brown (5YR 3/3), a pH pf 5.0, no stones and roots are common. Reddish brown silty clay (subsoil) has a colour of reddish brown (2.5YR 4/6), a pH of 4.5 and no stones or roots. Mottled bright brown medium clay (subsoil) has a colour of bright brown (5YR 5/8) yellowish brown (10YR 5/6) red, yellow and grey mottles (25%), a pH of 3.5, 10–20% 6–60 mm sub-angular to angular dispersed stones and no roots. Limitations of the subsoils include high organic matter, high available water-holding capacity, shrink-swell, strongly acidic, stoniness, low permeability and low wet bearing strength.
Nowra – Depositional	This soil landscape can be characterized by 2 topsoils, 1 topsoil and subsoil and 4 subsoils. Loose yellowish-brown single-grained sand (topsoil) has a colour of greyish yellow brown (10YR 5/4) to yellowish brown (10YR 4/6), a pH of 4.0-6.5, no stones and roots are common. Hardsetting dark reddish-brown loam fine sandy (topsoil) has a colour of dark reddish brown (5YR 3/3), a pH of 4.5, no stones and roots are common. Hardsetting gravelly massive yellowish brown clayey sand (topsoil and subsoil) has a colour of yellowish brown (10YR 5/6), a pH of 5.5, 50–90% 6–20 mm sub-angular and stratified stones, and roots are common. Limitations of these three soil types include high organic matter, high permeability, low available water-holding capacity, sodicity, hardsetting, stoniness, low permeability and strongly acidic. Mottled light clay (subsoil) has a colour of dull yellow orange (10YR 7/3) red and grey mottles (50%), a pH of 3.5 and no stones or roots. Dark olive sandy clay (subsoil) has a colour of dark olive (5Y 4/4) to brown (10YR 4/6), a pH of 3.5-6.0, 20–50% 6–20 mm rounded and subangular dispersed stones and no roots. Bright brown moderately pedal light medium clay (subsoil) has a colour of bright brown (7.5YR 5/8) to dark olive (5Y 4/4), a pH of 3.5-5.0, 10–20% 6–20 mm sub-rounded and sub-angular dispersed stones and no roots. Brown sandy clay loam (subsoil) has a colour of brown (7.5YR 4/6), a pH of 6.5, no stones and few roots. Limitations of these subsoil layers include low permeability, strongly acidic, low wet bearing strength, very high aluminium toxicity, low available water-holding capacity, and stoniness.
Disturbed Terrain	Most of the original soil has either been removed, buried or greatly disturbed in this soil landscape. It may be artificially topsoiled or covered by concrete and bitumen. Soil is highly variable depending on site. There is high potential for contamination.



Legend

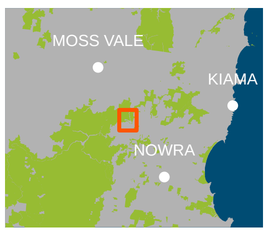
Soil Landscape

- Barren Grounds - 9028ba
- Barrengarry - 9028ba
- Cambewarra - 9028ca
- Disturbed Terrain - 9028xx
- Hawkesbury - 9028ha
- Illawarra Escalprment - 9028ie
- Nowra - 9028no
- Pulpit Rock - 9028pr
- Warragamba - 9028wb
- Water
- Wattamolla Road -09028wt
- Construction disturbance area
- Spoil site
- Road
- Waterway
- Waterbody

0 0.6 1.2 km

Disclaimer
The soil landscape shown is an interpretation only and not original data from DPIE.

1:30,000 at A4
GDA2020 MGA Zone 56



Data sources

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Figure 4-4 Soil landscapes (Adapted from DPE, 2022)

4.1.4.3 Soil erodibility

Soil erodibility is the susceptibility of the disturbed land surface area to erosion, it is defined in the blue book as: 'a measure of the susceptibility of individual soil particles to detachment and transport by rainfall and runoff'.

According to the soil landscape description for Wattamolla Road, soil erodibility is moderate for the topsoils and high for the sub-soils. For the Barrengarry soils, erodibility is low for the topsoils and moderate for the sub-soils, and for the Nowra soils, erodibility is low for the topsoils and high for the sub-soils.

4.2 Waterways and waterbodies

Key waterways and waterbodies within the study area have been described according to:

- The Strahler stream classification system where waterways are given an order according to the number of additional tributaries associated with each waterway (Strahler, 1952)
- Key hydrological characteristics including stream type, general direction of stream flow and discharge conditions
- Whether the waterway or waterbody is classified as KFH, based on published KFH mapping of NSW by NSW Fisheries (DPI, 2022)
- Other relevant features within, or in proximity to the waterway or waterbody
- Whether the watercourse or waterbody is predicted to support any threatened aquatic species under Commonwealth (EPBC Act) or state legislation (FM Act and/or BC Act).

A summary of important features for key waterways and waterbodies crossed by the alignment or with potential to be impacted by the Project is provided in **Table 4-3**. **Figure 4-5** presents the location of key waterways and waterbodies within the study area. Further description and details from field observations have been discussed in the sections below.

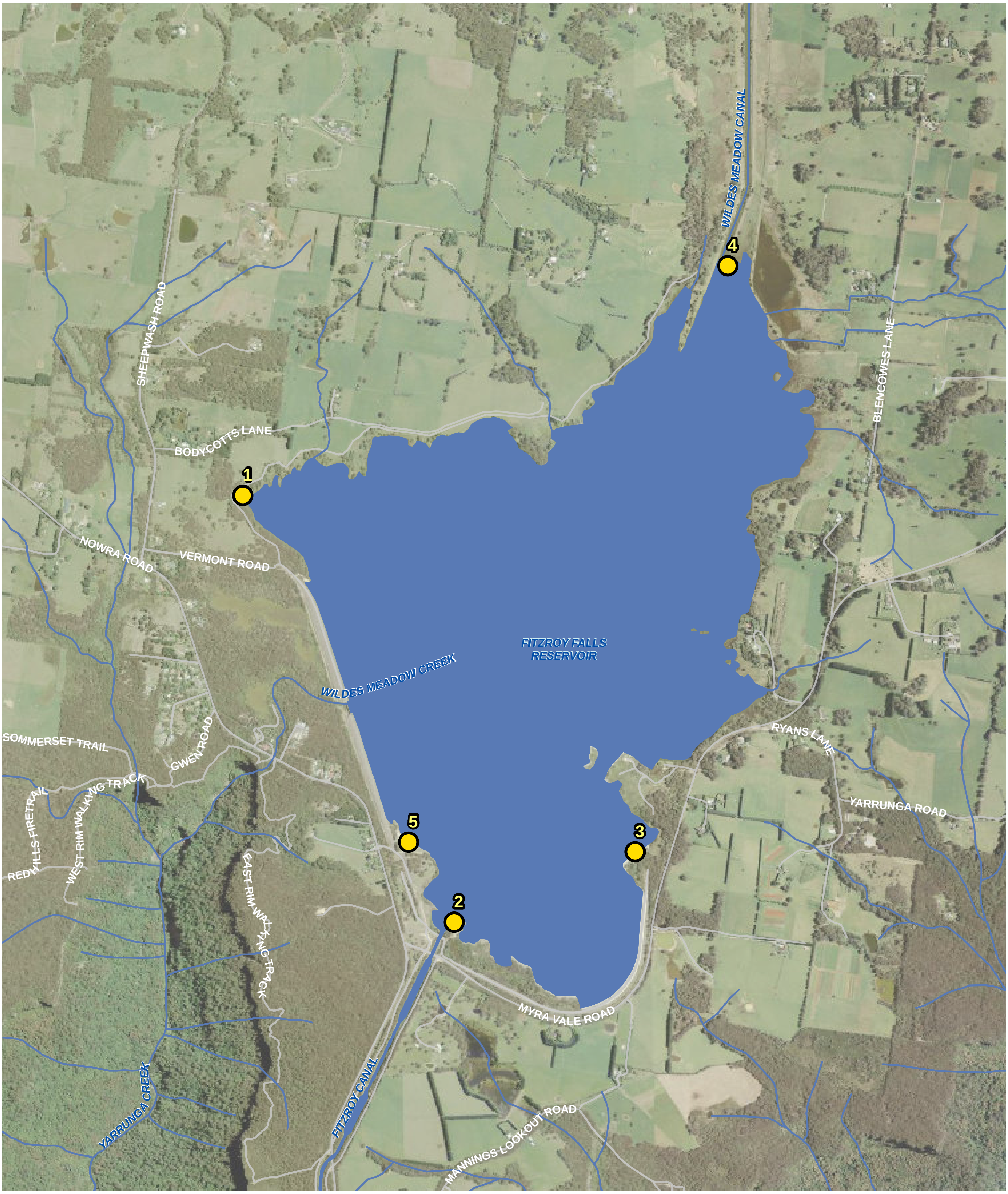
Table 4-3 Summary of key features of waterways and waterbodies identified as having potential to be impacted in study area

Waterway / waterbody	Stream order	KFH	Stream type	Visited in the field	Relevant features
Kangaroo River (upstream) / Lake Yarrunga (downstream)	6	Yes	Perennial (upstream) Permanent waterbody (downstream)	Yes	▪ Kangaroo River (upstream) experiences low-moderate flows in a westerly direction before reaching Lake Yarrunga ▪ Kangaroo River (upstream) is predicted habitat for the Macquarie Perch (DPI, 2022). ▪ Lake Yarrunga (downstream) generally has no-low flow, however experiences water level fluctuation from the existing pumped hydro scheme ▪ At full supply level (FSL), Lake Yarrunga extends approximately 2 km upstream of the Bendeela Power Station. Above this, the waterway is Kangaroo River.
Kings Creek	3	Yes	Perennial	Yes	▪ Generally flows south toward Lake Yarrunga ▪ The lower portion of the creek (below Lower Bendeela Road crossing) becomes inundated from Lake Yarrunga regularly. The upper portion is a series of interconnected pools and riffles

Waterway / waterbody	Stream order	KFH	Stream type	Visited in the field	Relevant features
					▪ A cliff-like topographic feature is present approximately 0.5 km upstream of the Lower Bendeela Road crossing, creating a barrier to fish passage ▪ Based on groundwater modelling (refer to *Technical Report 6 – Hydrogeology*), there is potential that the lower reaches of Kings Creek, above the influence of Lake Yarrunga and below the break in slope (approximately 60 m AHD) may be subject to groundwater baseflow from the regional water table.
Unnamed tributary of Kangaroo River	3	Yes	Ephemeral	No	▪ The unnamed tributary flows in a southerly direction toward Kangaroo River ▪ The lower portion forms a wetland environment, and the surrounding area has been cleared of vegetation apart for a small riparian corridor ▪ The upstream section flows through a mix of cleared rural properties and densely forested area, as well as under Bendeela Road approximately 800 m east of the Kangaroo Valley Power Station ▪ Predicted habitat for the Macquarie Perch (DPI, 2022) in the unnamed tributary of Kangaroo River.
Bendeela Pondage	-	Yes	Permanent waterbody	Yes	▪ An earth and rockfill embankment structure, connected by pipes to Fitzroy Falls Reservoir and Lake Yarrunga forms the central balancing storage for the existing SHPS ▪ Utilised for water supply for Kangaroo Valley township ▪ The pondage is approximately 250 m across at its widest point and narrows to approximately 50 m.
Unnamed tributaries of Trimbles Creek	1	No	Ephemeral	No	▪ Multiple drainage paths which flow for over 1 km toward Trimbles Creek in a south and south-easterly direction ▪ In proximity to the eastern perimeter of Laydown / Work Area 1 ▪ Flows only occur during or after rainfall.
Trimbles Creek	2	No	Ephemeral	Yes	▪ Trimbles Creek flows in an easterly direction toward Barrengarry Creek ▪ The Project traverses Trimbles Creek in the existing disturbance area of the existing surface pipeline / anchor block

Waterway / waterbody	Stream order	KFH	Stream type	Visited in the field	Relevant features
					▪ The creek is mapped as KFH 1.4 km downstream of the Project crossing.
Unnamed tributaries to Yarrunga Creek	1	No	Ephemeral	No	▪ Multiple drainage paths which flow for over 3 km toward Yarrunga Creek in a westerly direction ▪ In proximity to the western perimeter of Laydown / Work Area 1 and Laydown / Work Area 2 ▪ Flows only occur during or after rainfall.
Yarrunga Creek	4	Yes	Perennial	No	▪ The creek runs approximately parallel to Fitzroy Falls Upper Canal and the penstock before flowing south-west toward Lake Yarrunga ▪ The upper portion of Yarrunga Creek is disconnected from the lower portion by a large waterfall formation (Fitzroy Falls) ▪ The creek receives regulated environmental flows from Fitzroy Falls Reservoir as per the dam operational rules ▪ The creek flows through a densely forested gully entirely within the Morton National Park ▪ The lower 3.5 km of Yarrunga Creek is permanently inundated and forms part of Lake Yarrunga.
Fitzroy Falls Upper Canal	4	Yes	Permanent waterbody	Yes	▪ Fitzroy Falls Upper Canal is a large, permanent, artificial channel located in the upper portion of the study area which connects the main waterbody of the Fitzroy Falls Reservoir to the existing scheme penstock ▪ The canal is an earth and rockfill embankment structure in the lower portion near the penstock connection and has been incised into bedrock in the upper portion closer to the reservoir ▪ The canal is approximately 65 m across at its widest point (at the inlet/outlet works) and narrows to approximately 15 m along the length of the canal.
Fitzroy Falls Reservoir	4	Yes	Permanent waterbody	Yes	▪ Fitzroy Falls Reservoir consists of four separate earth and rockfill embankments damming Yarrunga Creek, upstream of Fitzroy Falls ▪ The reservoir has a catchment totalling 31 km^2

Waterway / waterbody	Stream order	KFH	Stream type	Visited in the field	Relevant features
					▪ The reservoir is a permanent waterbody and water level fluctuates up to 14 m ▪ Predicted habitat for the Fitzroy Falls Spiny Crayfish (DPI, 2022).



Legend

- Feild Assessment Site
- Waterway
- Road
- Waterbody

0 0.8 1.5 km

1:25,000 at A4

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Data sourcesa

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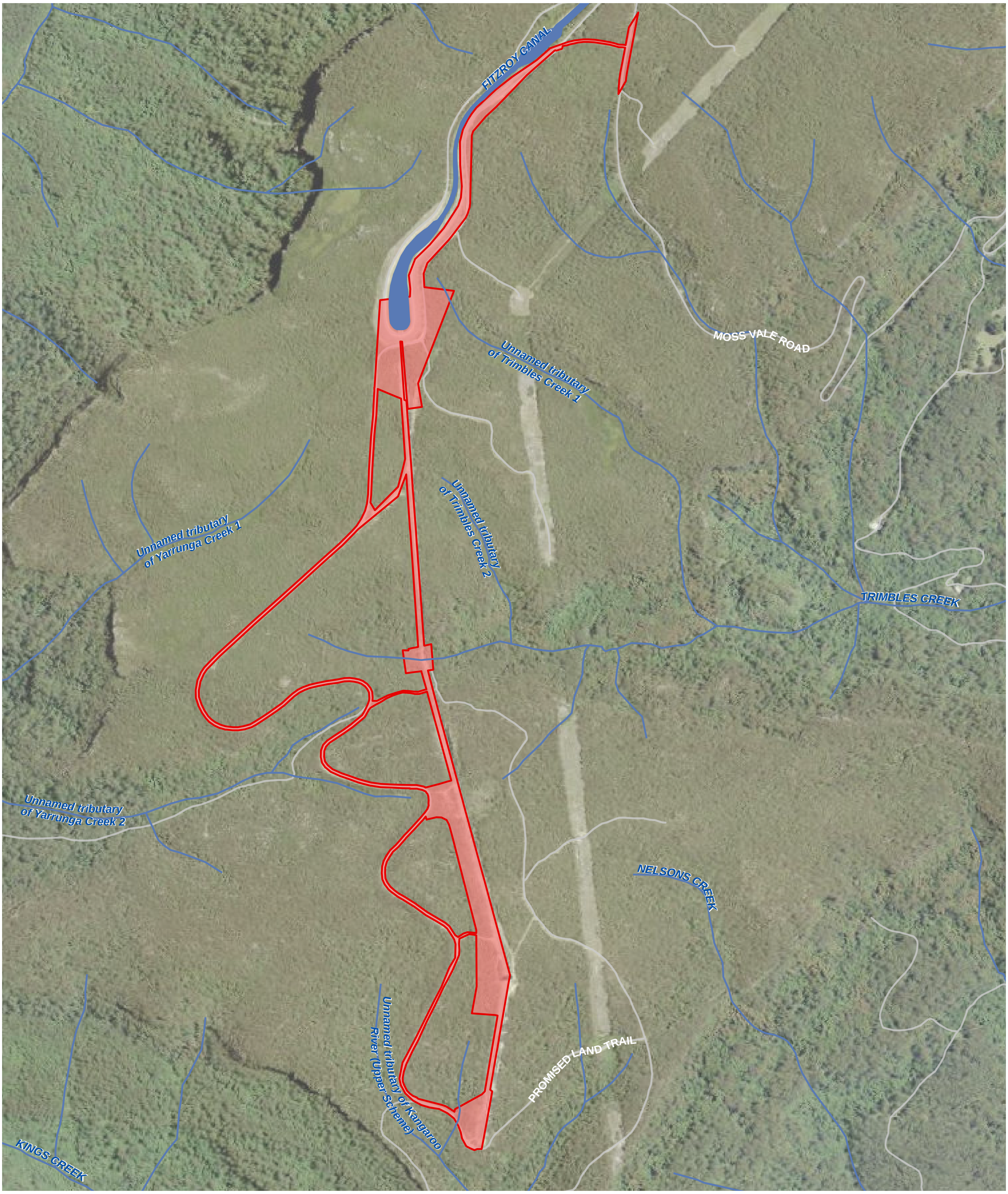
Figure 4-5a Key waterways and waterbodies - Fitzroy Falls Reservoir



Legend

- Waterway
- Road
- Construction disturbance area
- Waterbody

0 0.5 0.9 km

1:16,000 at A4

GDA2020 MGA Zone 56

Data sourcesb

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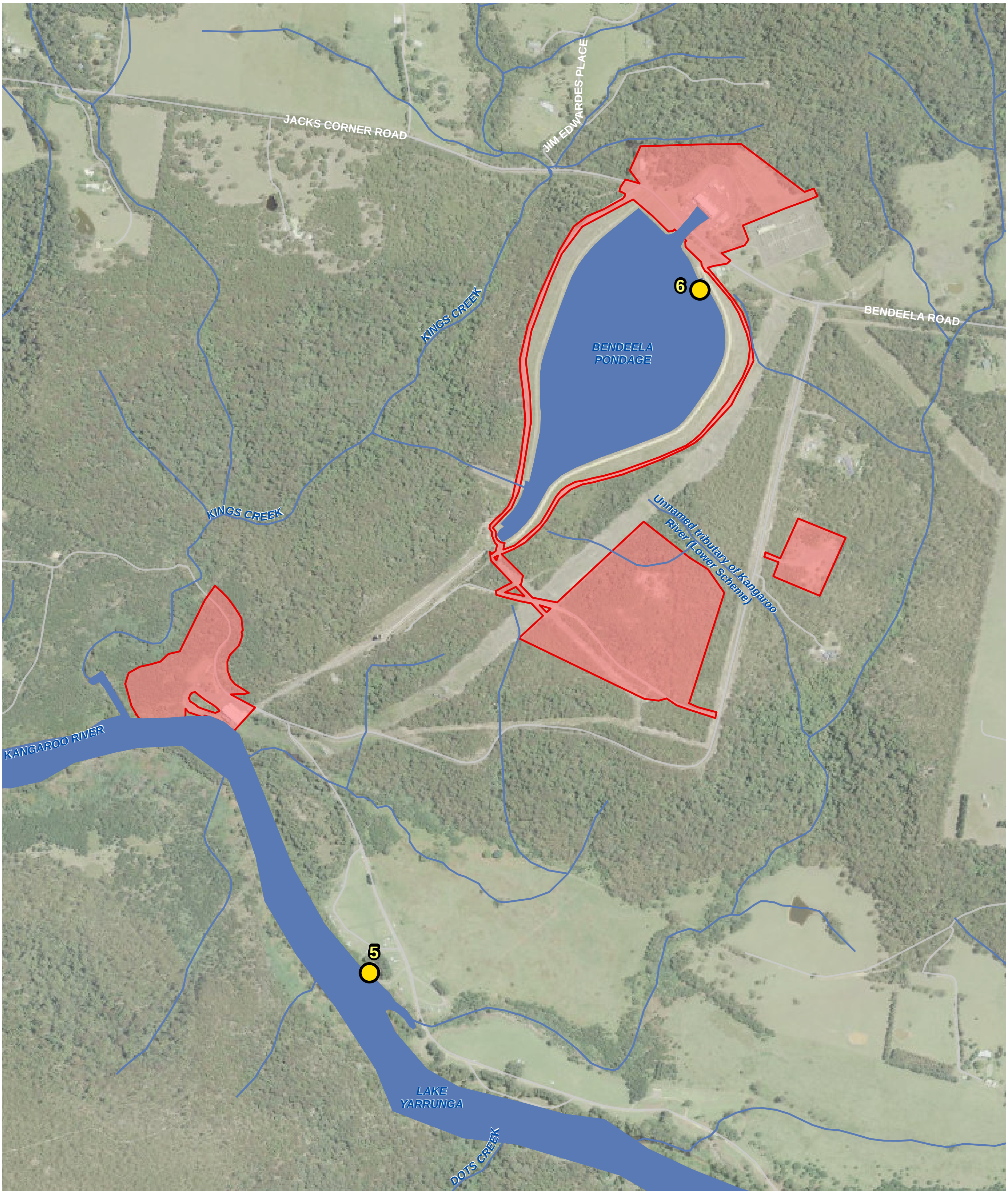
Figure 4-5b Key waterways and waterbodies - Upper Scheme (plateau)



Legend

- Feild Assessment Site
- Waterway
- Road
- Construction disturbance area
- Waterbody

0 0.3 0.7 km

1:12,500 at A4

GDA2020 MGA Zone 56

Data sourcesc

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Figure 4-5c Key waterways and waterbodies - Lower Scheme (Kangaroo Valley)

Date: 21/07/2022 Path: \\ausyd0vs01\gisproj\NSW_IS392600_ShoalhavenEIS\Apps\IS392600_SurfaceWater.aprx
Created by : NT | QA by : CC

4.2.1 Lake Yarrunga (Kangaroo River)

Kangaroo River is naturally a perennial, sixth order major waterway which flows in a westerly direction toward Shoalhaven River (refer to **Figure 4-5**). Since Tallowa Dam was built on the waterway at the confluence of Kangaroo River and Shoalhaven River in the 1970's, the downstream portion of Kangaroo River now forms part of a large, permanent waterbody known as Lake Yarrunga (refer **Figure 4-6**). From the existing Bendeela Power Station to approximately 20 river km downstream and 2 river km upstream, the waterway forms a large lake with little to no flow (Lake Yarrunga at FSL). Upstream of the FSL, it is a major waterway with moderate flow. At the Lower intake site, the lake is approximately 60 m wide and 10 m deep at its deepest point. The substrate is mostly silty sand. Evidence of erosion was observed during site inspection, particularly undercutting on the banks, this most likely being attributed to the regular level in which water is operated and associated wave action. Several sandbars are present in channel within proximity of the study area as can be seen in **Figure 4-7** when the Lake is at Minimum Operating Level (MOL).

Lake Yarrunga/Kangaroo River is mapped as KFH (DPI, 2022) and exhibited several aquatic habitat features including large woody debris, tree roots, overhanging vegetation and instream macrophytes. No threatened aquatic species have predicted habitat in the downstream portion (Lake Yarrunga) however the Macquarie Perch is mapped upstream (above the FSL) in Kangaroo River (DPI, 2022). Further, the water dependent EEC River Flat Eucalypt Forest River Flat Eucalypt Forest is likely to occur within the riparian vegetation near Lake Yarrunga.

Lake Yarrunga facing *upstream* from Bendeela Power Station.

Lake Yarrunga facing *downstream* from Bendeela Power Station.

Figure 4-6 Lake Yarrunga upstream and downstream

Lake Yarrunga at Minimum Operating Level, facing *upstream* toward the Bendeela Power Station (September 2004)

Lake Yarrunga at Minimum Operating Level, facing *downstream* from the Bendeela Power Station (September 2004)

Figure 4-7 Lake Yarrunga at MOL upstream and downstream

4.2.2 Kings Creek

Kings Creek is a perennial, third order stream located immediately west of the Bendeela Pondage, Kangaroo Valley and Bendeela Power Stations (refer to **Figure 4-5**). The creek flows in a southerly direction toward Lake Yarrunga/Kangaroo River from its headwaters on the escarpment in Morton National Park and has several unnamed, first order tributaries flowing into it. The creek is shallow and has a narrow channel, approximately one to three m wide. The substrate is mostly bedrock with some gravel beds and large boulders. No evidence of erosion was observed during site inspection. Erosion is not expected due to the bedrock substrate. Kings Creek is mapped as KFH (DPI, 2022) and exhibited aquatic habitat features in good condition including instream aquatic vegetation and large woody debris, significant rock pools and rock crevasses. The lower portion of the creek (below Lower Bendeela Road crossing) becomes inundated from Lake Yarrunga regularly. Above this road crossing, the creek consists of a series of interconnected rock pools and riffles (refer **Figure 4-8**). A large cliff-like topographic feature is present approximately 0.5 km upstream of the Lower Bendeela Road crossing. Based on groundwater modelling (refer to *Technical Report 6 – Hydrogeology*), there is potential that the lower reaches of Kings Creek, above the influence of Lake Yarrunga and below the break in slope (approximately 60 m AHD) to be subject to groundwater baseflow from the regional water table. It is assumed that above the break in slope the stratified nature of the formation would restrict vertical drawdown propagation. Threatened aquatic species are not mapped as having predicted distribution in Kings Creek (DPI, 2022), however the water dependent EEC River Flat Eucalypt Forest River Flat Eucalypt Forest is likely to occur within the riparian corridor in the lower portions of Kings Creek.

	
Kings Creek facing upstream from Lower Bendeela Road Crossing.	Kings Creek facing downstream from Jacks Corner Crossing.

Figure 4-8 Kings Creek upstream and downstream

4.2.3 Unnamed tributary of Kangaroo River

The unnamed tributary of Kangaroo River traverses much of the study area from its headwaters in the Upper Study Area on the plateau to the downstream reach in Kangaroo Valley, immediately upstream of the Project in the Lower Study Area.

The unnamed tributary of Kangaroo River (Upper Scheme) is a first order, ephemeral stream located to the west of the Project construction footprint area on the Plateau (refer to **Figure 4-5**). The unnamed tributary flows generally in a south-easterly direction for approximately 5.5 km before reaching Lake Yarrunga / Kangaroo River. The tributary only flows during and after rainfall. The unnamed tributary flows through the forested area of Morton National Park, however it is considered unlikely that it would support aquatic ecosystems. The upstream portion of the tributary is not mapped as KFH (DPI, 2022), however is mapped approximately 1 km downstream.

The unnamed tributary of Kangaroo River (Lower Scheme) is a third order, perennial stream located to the east of Bendeela Pondage, and Kangaroo and Bendeela Power Stations (refer to **Figure 4-5**). The unnamed tributary flows generally in a southerly direction toward Kangaroo River. The lower portion of the stream forms a wetland environment, and the surrounding area has been cleared of vegetation apart for a small riparian corridor. The upstream section flows through a mix of cleared farmland and densely forested area, as well as under Bendeela Road approximately 800 m east of the Kangaroo Valley Power Station. The unnamed tributary of Kangaroo River is mapped as KFH and the Macquarie Perch is mapped as have predicted habitat in this waterway (DPI, 2022). Further, the water dependent EEC River Flat Eucalypt Forest River Flat Eucalypt Forest is likely to occur within the riparian vegetation.

4.2.4 Bendeela Pondage

Bendeela Pondage is an earth and rockfill embankment dam structure connected by pipes to Fitzroy Falls Reservoir and Lake Yarrunga. Bendeela Pondage, forming the central balancing storage for the existing SHPS and also water supply to the Kangaroo Valley Water Treatment Plant for use as drinking water for the local township (refer to **Figure 4-5**). The pondage is approximately 250 m across at its widest point and narrows to approximately 50 m (refer **Figure 4-9**). The bottom substrate is a thin layer of silty clay in the central area of the pondage and small to large rock boulders (riprap) along the edges of the pondage. There was no evidence of erosion at the time of inspection. Water level in Bendeela Pondage fluctuates constantly with operation of either

Kangaroo Valley Power Station or Bendeela Power Station in pump or generation modes. The pondage is mapped as KFH (DPI, 2022) however there was no visible aquatic habitat features present within the waterbody during the inspection. Threatened aquatic species are not mapped as having predicted distribution in Bendeela Pondage.

Bendeela Pondage facing the south-eastern extent of the reservoir, downstream from Kangaroo Valley Power and Pumping Station

Bendeela Pondage facing the south-western extent of the reservoir, downstream from Kangaroo Valley Power and Pumping Station.

Figure 4-9 Bendeela Pondage

4.2.5 Unnamed tributaries of Trimbles Creek

There are several unnamed tributaries located on the eastern side of the plateau which flow to Trimbles Creek up to 1.4 km downstream of Laydown/ Work Area 1, these tributaries have been denoted as unnamed tributary of Trimbles Creek 1 and 2 on **Figure 4-5**. The tributaries are ephemeral, first order drainage lines and only flow during and after rainfall. The unnamed tributaries flow through the forested area of Morton National Park on the eastern side of the plateau, however are not mapped as KFH (DPI, 2022) and are considered unlikely to support aquatic ecosystems.

4.2.6 Trimbles Creek

Trimbles Creek is an ephemeral, first order stream located on the plateau (refer to **Figure 4-5**). The Project traverses the waterway in proximity of the existing penstock and anchor block (refer to **Appendix F** for site context). Trimbles Creek flows in an easterly direction toward Barrengarry Creek. The creek is shallow and has a narrow channel, approximately one to three m wide. The substrate is mostly sandstone bedrock with some gravel beds and large boulders at the site (refer **Figure 4-10**). No evidence of erosion was observed during site inspection, however due to the topography of the site the waterway receives runoff from the cleared corridor and disturbed area associated with the existing scheme.

The existing concrete anchor block is situated within Trimbles Creek, with flows directed under the anchor block via a culvert.

Trimbles Creek in the study area is not mapped as KFH (DPI, 2022) however exhibited several instream aquatic features including woody debris, rock pools and rock crevasses. The creek has been mapped as KFH approximately 1.4 km downstream of the anchor block. Threatened aquatic species are not predicted within Trimbles Creek.

Trimbles Creek facing upstream of the existing surface pipeline anchor block

Trimbles Creek facing downstream of the existing surface pipeline anchor block

Figure 4-10 Trimbles Creek upstream and downstream

4.2.7 Unnamed tributaries of Yarrunga Creek

There are several unnamed tributaries located on the western side of the plateau which flow to Yarrunga Creek up to 3 km downstream of the construction footprint area, these tributaries have been denoted as unnamed tributary of Trimbles Creek 1, 2 and 3 on **Figure 4-5**. The tributaries are ephemeral, first order drainage lines and only flow during and after significant rainfall. The unnamed tributaries in proximity of the Project form the headwaters of the drainage channels which flow to Yarrunga Creek via the forested area of Morton National Park on the western side of the plateau. The headwater drainages are not expected to support aquatic ecosystems and flows to Yarrunga Creek from these drainages are considered unlikely unless during a very large rainfall event.

4.2.8 Yarrunga Creek

Yarrunga Creek is a perennial, fourth order stream located in the western portion of the study area (refer to **Figure 4-5**). The creek runs approximately parallel to Fitzroy Falls Upper Canal and the penstock before flowing south-west toward Lake Yarrunga. The upper portion of Yarrunga Creek is disconnected from the lower portion by a large waterfall formation (Fitzroy Falls). The creek flows through a densely forested gully entirely within the Morton National Park. The lower 3.5 km of Yarrunga Creek is permanently inundated and forms part of Lake Yarrunga. Yarrunga Creek is mapped as KFH however is not predicted to support any threatened species (DPI, 2022). It is likely that the water dependent EEC River Flat Eucalypt Forest River Flat Eucalypt Forest occurs within the riparian corridor of Yarrunga Creek. Yarrunga Creek was not visited in the field due to access constraints, however the waterway is largely undisturbed therefore it is predicted that water quality and aquatic habitat would be in pristine condition.

4.2.9 Fitzroy Canal

Fitzroy Canal is a permanently inundated, artificial channel located in the upper portion of the study area which connects the main waterbody of the Fitzroy Falls Reservoir to the existing penstock (refer to **Figure 4-5**). The Fitzroy Canal receives flows in either direction depending on whether the pumped hydro scheme is in pumping or generation mode. The canal is an earth and rockfill embankment structure in the lower portion near the upper intake connection and has been incised into bedrock in the upper portion where the canal meets the reservoir (refer **Figure 4-11**). The canal is approximately 65 m across at its widest point (at the inlet/outlet connection) and narrows to approximately 15 m. The bottom substrate is a thin layer of silty clay in the central area of the canal and small to large rock boulders (riprap) or bedrock along the edges. There was no evidence of erosion at the time of inspection, indicating that the channel is unlikely to be susceptible to erosion. The canal is mapped as KFH (DPI, 2022) and there were no visible aquatic habitat features present during the inspection. Threatened species are not mapped as having predicted distribution in the canal, however the canal is connected to the reservoir therefore may be utilised by Fitzroy Falls Spiny Crayfish (DPI, 2022).

Fitzroy Canal facing upstream toward the Fitzroy Falls Reservoir

Fitzroy Canal facing downstream of the Fitzroy Falls Reservoir

Figure 4-11 Fitzroy Falls Upper Canal upstream and downstream

4.2.10 Fitzroy Falls Reservoir

Fitzroy Falls Reservoir, with a total operating capacity of 9.95GL, forms a key part of the Shoalhaven Scheme which has been designed as a dual-purpose water transfer and hydro-electric power generation scheme (refer **Figure 4-12**). Fitzroy Falls Reservoir is situated in the upper portion of the study area and consists of four separate earth and rockfill embankments damming Wildes Meadow Creek, upstream of Fitzroy Falls (refer to **Figure 4-5**). The reservoir has a relatively small catchment, totalling 31km^2. The reservoir is a permanent waterbody and water level fluctuates up to 14 m. The bottom substrate is silty clay and small to large rock boulders (riprap) along the dam walls. Some areas along the edges of the reservoir have sandy silt deposited on the banks and emergent aquatic vegetation including instream macrophytes. Other aquatic habitat features observed along the edges of the reservoir included large woody debris and overhanging vegetation. No evidence of erosion was observed around the perimeter during site inspection. The reservoir is mapped as KFH and the Fitzroy Falls Spiny Crayfish has predicted habitat within the reservoir (DPI, 2022).

Fitzroy Falls Reservoir facing upstream toward the Burrawang Pumping Station

Fitzroy Falls Reservoir facing downstream toward the Fitzroy Canal

Figure 4-12 Fitzroy Falls Reservoir upstream and downstream

4.3 Sensitive Receiving Environments

As described in **Section 3.4**, all waterways within the study area are considered SREs, however the level of sensitivity differs for each waterway based on site-specific conditions as well as the environmental and human uses for the waterways. **Table 4-4** classifies each potential receiving environment and key waterways / waterbodies described in **Section 4.2** based existing conditions and waterway-specific values.

Table 4-4 Sensitivity rating for waterways and waterbodies within the study area

Waterway / Waterbody	Considerations for sensitivity rating	Sensitivity rating
Kangaroo River (upstream) / Lake Yarrunga (downstream)	▪ Drinking water supply storage for Sydney Drinking Water Catchment ▪ Located within WaterNSW Sydney Special Area – restricted entry ▪ Predicted habitat for threatened aquatic species, Macquarie Perch, in Kangaroo River (upstream) ▪ Identified as KFH and a high-quality aquatic environment with good aquatic habitat features ▪ Utilised for primary and secondary recreational uses (ie. Swimming, kayaking, fishing) ▪ Perennial waterway upstream and inundated lake downstream ▪ River Flat Eucalypt Forest River Flat Eucalypt Forest is likely to occur within the riparian vegetation near Lake Yarrunga ▪ Instream works proposed and would receive discharges from sediment basins following water quality treatment via Kings Creek ▪ During operation, Lake Yarrunga would receive groundwater seepage discharges following water quality treatment.	High
Kings Creek	▪ Downstream portion of the waterway (area that becomes inundated by Lake Yarrunga) is located within WaterNSW Sydney Special Area – restricted entry ▪ Flows directly to Lake Yarrunga drinking water supply storage ▪ Identified as KFH and a high-quality aquatic environment with good aquatic habitat features ▪ Upstream portion of the waterway consists of a perennial waterway with potential groundwater baseflow ▪ The River Flat Eucalypt Forest River Flat Eucalypt Forest EEC is likely to occur within the riparian corridor in the lower portions of the creek ▪ Downstream portion of the Creek may receive discharges from sediment basins following water quality treatment.	High
Unnamed tributary of Kangaroo River (Lower Scheme)	▪ Downstream portion of the waterway is located within WaterNSW Sydney Special Area – restricted entry ▪ Flows directly to Kangaroo River which is immediately upstream of Lake Yarrunga drinking water supply storage ▪ Predicted habitat for threatened aquatic species, Macquarie Perch, in the downstream portion of the waterway ▪ Identified as KFH and downstream portion of the waterway is considered a high-quality wetland environment with good aquatic and wetland habitat features	High

Waterway / Waterbody	Considerations for sensitivity rating	Sensitivity rating
	▪ River Flat Eucalypt Forest River Flat Eucalypt Forest EEC is likely to occur within the riparian vegetation ▪ The upstream portion of the tributary would receive discharges from sediment basins following water quality treatment	
Bendeela Pondage	▪ Provides water to Kangaroo Valley Water Treatment Plant for town drinking water supply ▪ The pondage is connected to Lake Yarrunga and Fitzroy Falls Reservoir via the existing scheme ▪ Not considered KFH and does not exhibit aquatic habitat features ▪ During construction, Bendeela Pondage may receive tunnel dewatering discharges following water quality treatment.	High
Unnamed tributary of Kangaroo River (Upper Scheme)	▪ Ephemeral drainage channel which receives flows during rainfall ▪ Flows to Kangaroo River approximately 5.5 km downstream ▪ Not considered KFH and does not exhibit aquatic habitat features. The drainage channel is considered unlikely to support aquatic ecosystems ▪ The tributary would receive discharges from a sediment basin via overland flow.	Very Low
Unnamed tributary of Trimbles Creek 1	▪ Ephemeral drainage channel which receives flows during rainfall ▪ Flows to Trimbles Creek approximately 600 m downstream ▪ The tributary is located within Morton National Park, however, is not considered KFH and does not exhibit aquatic habitat features. The drainage channel is considered unlikely to support aquatic ecosystems ▪ The tributary would receive discharges from a sediment sump via overland flow.	Very Low
Unnamed tributary of Trimbles Creek 2	▪ Ephemeral drainage channel which receives flows during rainfall ▪ Flows to Trimbles Creek approximately 1.2 km downstream ▪ The tributary is located within Morton National Park, however, is not considered KFH and does not exhibit aquatic habitat features. The drainage channel is considered unlikely to support aquatic ecosystems ▪ The tributary would receive discharges from a sediment sump via overland flow.	Very Low
Trimbles Creek	▪ Ephemeral creek which receives flows during rainfall ▪ Trimbles Creek also receives runoff from the disturbed area of the existing scheme on the plateau	Low

Waterway / Waterbody	Considerations for sensitivity rating	Sensitivity rating
	▪ The existing concrete anchor block is situated within the stream channel, flows are directed underneath the anchor block through a culvert ▪ Trimbles Creek is located within Morton National Park but is not considered KFH in the study area. The creek exhibits some aquatic habitat features and is mapped as KFH downstream.	
Unnamed tributary of Yarrunga Creek 1	▪ Ephemeral drainage channel which receives flows during rainfall ▪ Flows to Yarrunga Creek approximately 3 km downstream ▪ Not considered KFH and does not exhibit aquatic habitat features ▪ The tributary would receive discharges from a sediment sump via overland flow.	Very Low
Unnamed tributary of Yarrunga Creek 2	▪ Ephemeral drainage channel which receives flows during rainfall ▪ Flows to Trimbles Creek approximately 1.4 km downstream ▪ The tributary is located within Morton National Park, however, is not considered KFH and does not exhibit aquatic habitat features. The drainage channel is considered unlikely to support aquatic ecosystems ▪ The tributary would receive discharges from a sediment sump via overland flow.	Very Low
Yarrunga Creek	▪ The lower 3.5 km of Yarrunga Creek is permanently inundated and forms part of Lake Yarrunga, therefore the waterway is located within WaterNSW Sydney Special Area – restricted entry ▪ Identified as KFH. Yarrunga Creek was not visited in the field due to access constraints, however the waterway is located entirely within Morton National Park and is largely undisturbed therefore it is predicted that water quality and aquatic habitat would be in pristine condition ▪ River Flat Eucalypt Forest River Flat Eucalypt Forest ECC is likely to occur within the riparian corridor of Yarrunga Creek ▪ Despite its environmental sensitivity, Yarrunga Creek is not expected to be impacted by the Project due to distance from Project activities.	Very Low
Fitzroy Falls Upper Canal	▪ Drinking water supply storage for Sydney Drinking Water Catchment ▪ Located within WaterNSW Sydney Special Area – restricted entry	Medium

Waterway / Waterbody	Considerations for sensitivity rating	Sensitivity rating
	▪ Permanently inundated, artificial channel connecting the main waterbody of the Fitzroy Falls Reservoir to the existing penstock ▪ The canal is mapped as KFH but there were no visible aquatic habitat features present along the edges of the canal during the inspection. Threatened species are not mapped as having predicted distribution in the canal, however the canal is connected to the reservoir therefore may be utilised by Fitzroy Falls Spiny Crayfish.	
Fitzroy Falls Reservoir	▪ Drinking water supply storage for Sydney Drinking Water Catchment ▪ Located within WaterNSW Sydney Special Area – restricted entry ▪ Utilised for primary and secondary recreational uses (ie. Swimming, kayaking, fishing) ▪ Permanently inundated lake, constructed from four separate earth and rockfill embankments damming Wildes Meadow Creek, upstream of Fitzroy Falls ▪ The reservoir is mapped as KFH and the Fitzroy Falls Spiny Crayfish is mapped has having predicted habitat within the reservoir.	High

4.4 Existing surface water quality

4.4.1 Lake Yarrunga at Kangaroo River at Bendeela Pondage Station (DTA8)

The water quality of Lake Yarrunga is monitored at numerous locations, including in the Kangaroo River Arm at Bendeela Pumping Station (DTA8) (refer to **Figure 3-1**). Monitoring data collected since July 2018 indicates that the water quality at this location is variable with median levels for only seven of the 16 indicators meeting the relevant guidelines for protection of Lake aquatic ecosystems (refer to **Appendix A**).

Indicators that complied with the respective DGVs for protection of Lake aquatic ecosystems included turbidity, pH, filtered aluminium (Al), filtered iron (Fe) and total and filtered manganese (Mn). Indicators which exceeded the recommended DGVs included total phosphorus (TP) and chlorophyll-a (Chl-a), nitrogen in all its forms (TN, NO_x and NH_3), electrical conductivity (EC), dissolved oxygen (DO), total Al and Fe. More specifically, chl-a which is recommended to be less than 5µg/L had median concentrations of 9.4µg/L and similarly TP which is recommended to remain below 0.01mg/L had median concentrations of more than double at 0.025mg/L. EC and DO concentrations fell outside their respective recommended DGV ranges, with median EC of 105µS/cm exceeding the upper recommended limit of 30µS/cm, and median DO of 87 percent saturation (% Sat) falling below the lower limit of 90 % Sat. NH_3, NO_x and TN levels failed to comply with recommended DGVs, with median levels of 0.018mg/L, 0.011mg/L and 0.41mg/L exceeding the respective DGVs of 0.01mg/L, 0.01mg/L and 0.35mg/L. Total Al failed to comply with the recommended DGV with median levels of 0.5mg/L exceeding the DGV of 0.055 mg/L. Finally, total Fe values failed to comply with the DGV of 0.3mg/L recording a median concentration of 0.57mg/L over the monitoring period.

As highlighted above, the water quality at DTA8 over the monitoring period was variable, and whilst only seven indicators had median concentrations that complied with the respective DGVs for protection of aquatic ecosystems, it should be noted that all but two indicators; manganese (total and filterable) and turbidity exceeded the recommended guideline on at least one occasion as indicated by the maximum value (or minimum for DO) displayed in **Table 4-5**.

Visual amenity of Lake Yarrunga is also a nominated environmental value. Protection of this value requires water to be free from surface films and debris, free from nuisance organisms and median turbidity of less than 20NTU. This assessment uses quantitative values to determine compliance, as such only turbidity has been applied which had a median of 5NTU and a maximum of 9NTU. Therefore, visual amenity of Lake Yarrunga at DTA8 is currently being achieved.

Table 4-5 Summary water quality results for Kangaroo River at Bendeela Power Stations (DTA8) (July 2017 – March 2022). Bolded values indicate exceedance with the recommended DGVs.

Indicator	Minimum	Maximum	20th percentile	80th percentile	Median	ANZG (2018) guideline for aquatic ecosystems - Lakes
Aluminium Filtered (mg/L)	0	**0.19**	0.0005	0.050	0.025	<0.055
Aluminium Total (mg/L)	0.0005	**0.50**	0.025	**0.50**	**0.5**	<0.055
Chlorophyll-a (µg/L)	0.7	**109.4**	3.8	**15.18**	**9.4**	<5
Conductivity (µS/cm)	**81**	**112**	**87**	**108**	**105**	20 – 30
Dissolved Oxygen (%Sat)	**84**	91	**86**	90	**87**	90 – 110
Iron Filtered (mg/L)	0.010	**0.54**	0.16	**0.36**	0.26	<0.3
Iron Total (mg/L)	0.22	**0.98**	**0.43**	**0.66**	**0.57**	0.3

Indicator	Minimum	Maximum	20th percentile	80th percentile	Median	ANZG (2018) guideline for aquatic ecosystems - Lakes
Manganese Filtered (mg/L)	0.001	0.048	0.004	0.028	0.011	<1.9
Manganese Total (mg/L)	0.02	0.140	0.030	0.061	0.041	<1.9
Ammoniacal Nitrogen (mg/L)	0.005	**0.130**	**0.011**	**0.043**	**0.018**	<0.01
Oxidised Nitrogen (mg/L)	0.002	**0.54**	**0.032**	**0.19**	**0.11**	<0.01
Total Nitrogen (mg/L)	0.20	**0.71**	0.33	**0.48**	**0.41**	<0.35
Soluble Reactive Phosphorus (mg/L)	0.001	**0.019**	0.001	**0.007**	0.004	<0.005
Total Phosphorus (mg/L)	**0.011**	**0.063**	**0.019**	**0.034**	**0.025**	<0.01
pH	6.7	**8.5**	6.7	7.9	7.5	6.5 – 8
Suspended solids (mg/L)	2	12	4	7	6	No guideline
Turbidity (NTU)	2	9	3	7	5	<20
True Colour @ 400nm (CU)	7	46	13	30	20	70[1]

[1] as per the raw water supply agreement to the Kangaroo Valley WFP

[2] as per the visual amenity guidelines

4.4.2 Kangaroo River at Hampden Bridge (E706)

The water quality of Kangaroo River is monitored at several locations, including at Hampden Bridge (E706) (refer to **Figure 3-1**). Monitoring data collected since July 2018 indicates that the water quality of Kangaroo River is variable with median levels of only seven of the 16 indicators meeting the relevant guidelines for protection of lowland river aquatic ecosystems (refer to **Table 4-6**).

Indicators that complied with recommended DGVs included turbidity, pH, DO, soluble reactive phosphorus (SRP), filtered Al, and total and filtered Mn. Indicators that exceeded the recommended DGVs included TP, chl-a, TN, NO_x, NH_3, EC and total Al and Fe. Filterable Fe, whilst compliant in Lake Yarrunga, had median concentrations of 0.34mg/L which was slightly above the DGV of 0.3mg/L. Chl-a was slightly elevated above the DGV of 3µg/L with median concentrations of 3.1µg/L and similarly TP was slightly above the DGV of 0.025mg/L with median concentrations of 0.031mg/L. EC was outside the recommended DGV range, with median levels of 113µS/cm falling below the lower recommended limit of 200µS/cm. NH_3, NO_x, and TN, with median concentrations of 0.03mg/L, 0.1mg/L and 0.4mg/L, failed to comply with the respective DGVs of 0.02mg/L, 0.04 mg/L and 0.35mg/L. Total Al also failed to comply with the recommended DGV, with median levels of 0.5 mg/L exceeding the DGV of 0.055 mg/L. Finally, total and filterable Fe concentrations failed to comply with the DGV of 0.3mg/L, with median concentrations of 0.65mg/L and 0.35mg/L, respectively.

Whilst only seven indicators had median concentrations that complied with respective DGVs for protection aquatic ecosystems throughout monitoring period, some of these indicators such as DO, pH, turbidity and filterable reactive phosphorus were recorded in levels that did not comply at least once during the same monitoring timeframe.

The environmental value of visual amenity is currently protected in Kangaroo River at Hampden Bridge as indicated by median turbidity of 4NTU which complies with the recommended DGV of 20NTU. It should be noted that on one occasion over the monitoring period (March 2022), a turbidity of 123NTU was recorded following a significant rainfall event and as such impacted on the visual amenity of the Kangaroo River during that time.

Table 4-6 Summary water quality results for Kangaroo River at Hampden Bridge (E706) (January 2017-March 2022). Bolded values indicate exceedance with the recommended DGVs.

Indicator	Minimum	Maximum	20th percentile	80th percentile	Median	ANZG (2018) guideline for aquatic ecosystems – Lowland River
Aluminium Filtered (mg/L)	0	**0.41**	0.0005	0.035	0.005	<0.055
Aluminium Total (mg/L)	0.0005	**0.50**	0.025	**0.50**	**0.50**	<0.055
Chlorophyll-a (µg/L)	0.7	**51.6**	1.5	**9.7**	**3.1**	<3
Conductivity (µS/cm)	68	204	**97**	**130**	**112**	200 – 300
Dissolved Oxygen (%Sat)	**45**	**120**	87	101	96	85 – 110
Iron Filtered (mg/L)	0.17	**0.69**	0.26	**0.44**	**0.34**	0.3
Iron Total (mg/L)	**0.34**	**4.13**	**0.48**	**0.78**	**0.65**	0.3
Manganese Filtered (mg/L)	0.009	0.065	0.015	0.031	0.020	<1.9
Manganese Total (mg/L)	0.012	0.130	0.020	0.045	0.027	<1.9
Ammoniacal Nitrogen (mg/L)	0.005	**1.330**	0.014	**0.118**	**0.032**	<0.02
Oxidised Nitrogen (mg/L)	0.002	**0.420**	**0.052**	**0.203**	**0.102**	<0.04
Total Nitrogen (mg/L)	0.07	**1.85**	0.26	**0.52**	**0.36**	<0.35
Soluble Reactive Phosphorus (mg/L)	0.001	**0.172**	0.007	**0.026**	0.011	<0.02
Total Phosphorus (mg/L)	0.005	**0.209**	0.0206	**0.0734**	**0.031**	<0.025
pH	**6.4**	8.2	6.9	7.3	7.1	6.5 – 8.5
Suspended solids (mg/L)	1	159	2	7	3	No guideline

Indicator	Minimum	Maximum	20th percentile	80th percentile	Median	ANZG (2018) guideline for aquatic ecosystems – Lowland River
Turbidity (NTU)	1	**123**	2	6	4	<50 or <20[2]
True Colour @ 400nm	8	50	15	33	25	70[1]

[1] as per the raw water supply agreement to the Kangaroo Valley WFP

[2] as per the visual amenity guidelines

4.4.3 Kangaroo River at Oakdale (E7061)

The water quality of Kangaroo River is also monitored at Oakdale (E7061) (refer to **Figure 3-1**). Monitoring data collected since July 2018 indicates that the water quality of Kangaroo River at this location is generally very good with median levels of 13 of the 16 indicators meeting the relevant guidelines for protection of lowland river aquatic ecosystems (refer to **Table 4-7**).

All indicators except for total Al, total Fe and EC compiled with the respective DGVs. Total Al and total Fe levels failed to comply with their DGVs of 0.055mg/L and 0.3mg/L, with median levels of 0.5mg/L and 0.61mg/L respectively. EC fell below the lower recommended DGV of 200µS/cm with median levels of 93µS/cm.

Despite the very good water quality, many indicators exceeded the recommended guideline limits on at least one occasion as indicated by the maximum values or minimum for (DO and pH) provided in **Table 4-7.**

Similar to the Kangaroo River at Hampden Bridge, the environmental value of visual amenity is currently protected in Kangaroo River at Oakdale as indicated by median turbidity of 3NTU which is below the recommended DGV of 20NTU. There was also one occasion over the monitoring period (March 2022), a turbidity of 157TU was recorded following a significant rainfall event and as such impacted on the visual amenity of the Kangaroo River during that time.

Table 4-7 Summary water quality results for Kangaroo River at Oakdale (E7061) (January 2017 - March 2022). Bolded values indicate exceedance with the recommended DGVs.

Indicator	Minimum	Maximum	20th percentile	80th percentile	Median	ANZG (2018) guideline for aquatic ecosystems – Lowland River
Aluminium Filtered (mg/L)	0	**0.38**	0.0002	0.025	0.0025	<0.055
Aluminium Total (mg/L)	0.0005	**0.5**	0.0025	**0.5**	**0.5**	<0.055
Chlorophyll-a (µg/L)	0.3	**20.5**	0.5	**3.3**	0.8	<3
Conductivity (µS/cm)	**61**	**161**	**82**	**108**	**93**	200 – 300
Dissolved Oxygen (%Sat)	**45**	103	**83**	97	93	85 – 110

Indicator	Minimum	Maximum	20th percentile	80th percentile	Median	ANZG (2018) guideline for aquatic ecosystems – Lowland River
Iron Filtered (mg/L)	0.08	**0.64**	0.17	**0.34**	0.24	0.3
Iron Total (mg/L)	0.21	**10.2**	**0.40**	**1.40**	**0.61**	0.3
Manganese Filtered (mg/L)	0.006	0.079	0.012	0.024	0.016	<1.9
Manganese Total (mg/L)	0.012	0.23	0.019	0.075	0.028	<1.9
Ammoniacal Nitrogen (mg/L)	0.005	**0.072**	0.005	0.014	0.007	<0.02
Oxidised Nitrogen (mg/L)	0.002	**0.190**	0.011	**0.067**	0.035	<0.04
Total Nitrogen (mg/L)	0.04	**1.45**	0.13	**0.60**	0.33	<0.35
Soluble Reactive Phosphorus (mg/L)	0.001	**0.030**	0.002	0.007	0.003	<0.02
Total Phosphorus (mg/L)	0.005	**0.182**	0.011	**0.040**	0.017	<0.025
pH	**6.2**	7.8	6.7	7.1	6.8	6.5-8.5
Suspended solids (mg/L)	1	232	2	67	13	No guideline
Turbidity (NTU)	1	**157**	2	6	3	<50 or <20[2]
True Colour @ 400nm	6	55	10	20	16	70[1]

[1] as per the raw water supply agreement to the Kangaroo Valley and Wingecarribee WFP

[2] as per the visual amenity guidelines

4.4.4 Bendeela Pondage (DBP1)

The water quality of the Bendeela Pondage has been monitored at point DBP1 (refer to **Figure 3-1**). Monitoring data collected since January 2018 indicates that the water quality of the Bendeela Pondage is variable with median levels for only half of the indicators complying with the relevant guidelines for protection of lake aquatic ecosystems (refer to **Table 4-8**).

Indicators which complied with recommended DGVs included turbidity, pH, SRP, DO, filtered Al and Fe, and total and filtered Mn. Indicators which did not comply included total Fe, total Al, Chl-a, EC, NH_3, NO_x, TN and TP. Total Fe and total Al failed to comply with their respective DGVs of 0.3mg/L and 0.055mg/L, with median concentrations of 0.41mg/L and 0.5mg/L. NH_3, NO_x and TN failed to comply with DGVs of 0.01mg/L for NH_3 and NO_x and 0.35mg/L for TN, with median concentrations of 0.013mg/L, 0.12mg/L and 0.41mg/L respectively. Chl-a exceeded the DGV of 5µg/L with median concentrations of 11.1µg/L. Additionally, EC exceeded the upper recommended limit of 30µS/cm with median concentrations 102µS/cm. Finally, TP also failed to comply with the DGV of 0.01mg/L, with median concentrations of 0.02mg/L.

Whilst eight indicators had median concentrations that complied with respective DGVs for protection aquatic ecosystems throughout monitoring period, all indicators except Mn (total and filtered), filtered aluminium and turbidity were recorded in levels that did not comply at least once during the same monitoring timeframe.

Visual amenity of Bendeela Pondage is also a nominated environmental value. Protection of this value requires water to be free from surface films and debris, free from nuisance organisms and median turbidity of less than 20NTU. This assessment uses quantitative values to determine compliance, as such only turbidity has been applied which had a median of 4NTU and a maximum of 7NTU. Therefore visual amenity of Bendeela Pondage at DBP1 is currently being achieved.

As Bendeela Pondage supplies water for drinking to Kangaroo Valley WFP, water quality data has also been compared to criteria outlined in the raw water supply agreement to the Kangaroo Valley WFP (refer **Appendix A**). All indicators had medians that met the respective criteria including true colour, Fe, Mn, pH, hardness, alkalinity and algae.

Table 4-8 Summary water quality results Bendeela Pondage (DBP1) (January 2017 - March 2022). Bolded values indicate exceedance with the recommended DGVs.

Indicator	Minimum	Maximum	20th percentile	80th percentile	Median	ANZG (2018) guideline for aquatic ecosystems - Lakes
Aluminium Filtered (mg/L)	0	**0.15**	0	0.025	0.0005	<0.055
Aluminium Total (mg/L)	0.0005	**0.50**	0.0005	**0.50**	**0.50**	<0.055
Chlorophyll-a (µg/L)	0.6	**42.3**	**6.8**	**15.6**	**11.1**	<5
Conductivity (µS/cm)	**85**	**124**	**99**	**107**	**102**	20 – 30
Dissolved Oxygen (%Sat)	**82**	108	**87**	99	96	90 – 110
Iron Filtered (mg/L)	0.03	**0.43**	0.11	**0.32**	0.20	<0.3
Iron Total (mg/L)	0.15	**0.86**	0.28	**0.63**	**0.41**	<0.3
Manganese Filtered (mg/L)	0.001	0.031	0.002	0.012	0.004	<1.9
Manganese Total (mg/L)	0.016	0.079	0.022	0.054	0.038	<1.9
Ammoniacal Nitrogen (mg/L)	0.005	**0.077**	0.0094	**0.036**	**0.013**	<0.01
Oxidised Nitrogen (mg/L)	0.002	**0.38**	**0.08**	**0.24**	**0.12**	<0.01
Total Nitrogen (mg/L)	0.25	**0.60**	0.35	**0.51**	**0.41**	<0.35

Indicator	Minimum	Maximum	20th percentile	80th percentile	Median	ANZG (2018) guideline for aquatic ecosystems - Lakes
Soluble Reactive Phosphorus (mg/L)	0.001	**0.006**	0.001	0.0026	0.002	<0.005
Total Phosphorus (mg/L)	0.01	**0.037**	**0.012**	**0.024**	**0.02**	<0.01
pH	6.5	**8.2**	7.3	7.4	7.4	6.5 – 8
Suspended solids (mg/L)	2	10	4	9	8	No guideline
Turbidity (NTU)	0.2	7	3	6	4	<25 or <20[2]
True Colour @ 400nm	10	25	10	21	16	70[1]

[1] as per the raw water supply agreement to the Kangaroo Valley WFP

[2] as per the visual amenity guidelines

4.4.5 Wildes Meadow Creek (E300)

Wildes Meadow Creek (E300) was monitored approximately 2.5 km upstream of the inflow to Fitzroy Falls Reservoir (refer to **Figure 3-1**). Monitoring data collected since July 2018 indicates that the water quality of Wildes Meadow Creek is generally good with median levels of nine of the 16 indicators meeting the relevant guidelines for protection of upland river aquatic ecosystems (refer to **Table 4-9**).

Indicators which complied with recommended DGVs included turbidity, pH, SRP, filtered Al, Chl-a, EC, filtered Fe, and total and filtered Mn. Indicators which did not comply included Total Al and Fe, NH_3, NO_x and TN, TP and DO. Total Fe levels failed to comply with the recommended DGV of 0.3mg/L, with median concentrations of 1.1mg/L. Additionally, total Al was also recorded in high concentrations with median levels of 0.5mg/L, nine times the recommended limit of 0.055mg/L. DO levels were outside the recommended DGV range, with median concentrations of 81 % Sat falling below the lower recommended limit of 90 % Sat. NH_3, NO_x and TN concentrations with median values of 0.019mg/L, 1.13mg/L and 1.15mg/L exceeded the DGVs of 0.013mg/L, 0.015mg/L and 0.25mg/L respectively. TP also failed to comply with the recommended DGV, with a median value of 0.033mg/L. Despite the generally good water quality, most indicators exceeded the recommended DGVs on occasion, including filtered and total AL, filtered Fe, turbidity and pH as indicated by the maximum value recorded.

The environmental value of visual amenity is currently protected at Wildes Meadow Creek as indicated by median turbidity of 5NTU which is below the recommended DGV of 20NTU. It should be noted that on one occasion over the monitoring period (October 2017), a turbidity of 29NTU was recorded, as such visual amenity of Wildes Meadow Creek was not met at that time.

Table 4-9 Summary water quality results for Yarrunga Creek at Wildes Meadow (E300) (January 2017 - March 2022). Bolded values indicate exceedance with the recommended DGVs.

Indicator	Minimum	Maximum	20th percentile	80th percentile	Median	ANZG (2018) guideline for aquatic ecosystems – Upland River
Aluminium Filtered (mg/L)	0	**0.15**	0.001	0.046	0.01	<0.055
Aluminium Total (mg/L)	0.0005	**0.50**	0.0025	**0.50**	**0.50**	<0.055
Chlorophyll-a (µg/L)	0.7	**36.6**	1.8	4.9	2.8	<5
Conductivity (µS/cm)	30	99	77	88	82	30 – 350
Dissolved Oxygen (%Sat)	**36**	104	68	88	**81**	90 – 110
Iron Filtered (mg/L)	0.05	**0.61**	0.10	0.29	0.14	0.3
Iron Total (mg/L)	0.22	**8.23**	0.52	**2.57**	**1.05**	0.3
Manganese Filtered (mg/L)	0.012	0.340	0.026	0.076	0.043	<1.9
Manganese Total (mg/L)	0.015	0.538	0.045	0.240	0.086	<1.9
Ammoniacal Nitrogen (mg/L)	0.005	**0.499**	0.013	**0.038**	**0.019**	<0.013
Oxidised Nitrogen (mg/L)	0.002	**2.44**	**0.59**	**1.44**	**1.13**	<0.015
Total Nitrogen (mg/L)	**0.31**	**5.20**	**0.92**	**2.32**	**1.51**	<0.25
Soluble Reactive Phosphorus (mg/L)	0.001	**0.041**	0.0014	0.004	0.002	<0.015
Total Phosphorus (mg/L)	0.005	0.527	0.012	0.161	**0.033**	<0.02
pH	**6.1**	**12.2**	**6.4**	7.0	6.6	6.5 – 8
Suspended solids (mg/L)	1	207	2	51	7	No guideline
Turbidity (NTU)	2	**29**	3	7	5	<25 or <20[2]
True Colour @ 400nm	3	29	5	15	8	70[1]

[1] as per the raw water supply agreement to the Wingecaribee WFP

[2] as per the visual amenity guidelines

4.4.6 Lake Fitzroy Falls at Midlake (DFF6)

The water quality of Fitzroy Falls Reservoir was monitored at Midlake from point DFF6 (refer to **Figure 3-1**). Monitoring data collected since July 2018 indicates that the water quality of Lake Fitzroy Falls is variable with median levels of nine of the 16 indicators meeting the relevant guidelines for protection of Lake aquatic ecosystems (refer to **Table 4-10**).

Indictors which complied with recommended DGVs included turbidity, pH, SRP, DO, total and filtered Mn and Fe, filtered Al. Indicators which did not comply included filtered Al, Chl-a, EC, NH_3, NO_x, TN and TP. Similarly to Wildes Meadow Creek upstream, total Al concentrations were elevated in Fitzroy Falls Reservoir with median concentrations of 0.5mg/L nine times the recommended DGV of 0.055mg/L. TP failed to comply with median concentrations of 0.014mg/L exceeding the DGV of 0.01mg/L. Additionally, EC levels failed to comply with the recommended DGV range, with median concentrations of 102.5µS/cm exceeding the upper recommended limit for lakes of 30µS/cm. It should be noted that the conductivity of Fitzroy Falls Reservoir over the monitoring period never fell within the recommended limits of 30-50µS/cm. NH_3, NO_x, and TN levels failed to comply with their respective recommended DGVs of 0.01mg/L, 0.01mg/L and 0.35mg/L, with median concentrations of 0.036mg/L for NH_3, 0.161mg/L for NO_x and 0.57mg/L for TN. Chl-a concentrations also failed to comply with the recommended DGV of 5µg/L, with a median concentration of 9.7µg/L.

Despite the generally good water quality, most maximum values for each indicator exceeded the recommended guideline DGVs, including filtered Al, total Fe, NO_x, TP, and pH.

Visual amenity of Fitzroy Falls is also a nominated environmental value. Protection of this value requires water to be free from surface films and debris, free from nuisance organisms and median turbidity of less than 20NTU. This assessment uses quantitative values to determine compliance, as such only turbidity has been applied which had a median of 6NTU and a maximum of 10NTU. Therefore visual amenity of Fitzroy Falls Reservoir at DFF6 is currently being achieved.

Table 4-10 Summary water quality results for Fitzroy Falls Reservoir (DFF6) (January 2017 - March 2022). Bolded values indicate exceedance with the recommended DGVs.

Indicator	Minimum	Maximum	20th percentile	80th percentile	Median	ANZG (2018) guideline for aquatic ecosystems - Lakes
Aluminium Filtered (mg/L)	0	**0.15**	0.0005	0.025	0.005	<0.055
Aluminium Total (mg/L)	0.0005	**0.50**	0.0201	**0.50**	**0.50**	<0.055
Chlorophyll-a (µg/L)	4.1	**31.4**	**7.2**	**15.4**	**9.7**	<5
Conductivity (µS/cm)	**60**	**105**	**82**	**104**	**103**	20 – 30
Dissolved Oxygen (%Sat)	**87**	99	**89**	96	93	90 – 110
Iron Filtered (mg/L)	0.01	0.25	0.03	0.09	0.05	<0.3
Iron Total (mg/L)	0.06	**0.75**	0.14	**0.33**	0.2	0.3
Manganese Filtered (mg/L)	0.001	0.012	0.001	0.002	0.001	<1.9

Indicator	Minimum	Maximum	20th percentile	80th percentile	Median	ANZG (2018) guideline for aquatic ecosystems - Lakes
Manganese Total (mg/L)	0.007	0.035	0.012	0.026	0.019	<1.9
Ammoniacal Nitrogen (mg/L)	0.005	**0.196**	**0.012**	**0.102**	**0.036**	<0.01
Oxidised Nitrogen (mg/L)	0.002	**0.368**	**0.044**	**0.252**	**0.161**	<0.01
Total Nitrogen (mg/L)	0.32	**0.81**	**0.46**	**0.65**	**0.57**	<0.35
Soluble Reactive Phosphorus (mg/L)	0.001	0.003	0.001	0.001	0.001	<0.005
Total Phosphorus (mg/L)	0.006	**0.046**	**0.011**	**0.019**	**0.014**	<0.01
pH	7.1	**8.3**	7.4	**8.1**	7.6	6.5-8
Suspended solids (mg/L)	1	12	5	8	6	No guideline
Turbidity (NTU)	2	10	3	7	5	<25 or <20[2]
True Colour @ 400nm	6	30	7	14	10	70[1]

[1] as per the raw water supply agreement to the Wingecarribee WFP

[2] as per the visual amenity guidelines

4.4.7 Calaang Creek at Old Kangaloon Road (E301)

The water quality of Calaang Creek was monitored at Old Kangaloon Road (E301) (refer to **Figure 3-1**). Monitoring data collected since July 2018 indicates that the water quality of Calaang Creek is good with median concentrations of 12 indicators complying with the respective DGV for protection of Upland River aquatic ecosystems (refer to **Table 4-11**).

All indicators except for total Al, total Fe, NO_x and TN compiled with the respective DGVs. Total Al concentrations failed to comply with recommended the DGV of 0.055mg/L, with median levels of 0.5mg/L. Total Fe concentrations also failed to comply with the DGV of 0.3mg/L, with a median value of 0.49mg/L. NO_x and TN were both elevated in Calaang Creek, failing to comply with the respective DGVs of 0.01mg/L and 0.35mg/L, with median levels of 0.662mg.L and 0.74mg/L.

Despite the good water quality, many indicators exceeded the recommended guideline limits on occasion, including filtered and total Al, filtered FE, DO, TP and NH_3 as indicated by the maximum value recorded.

The environmental value of visual amenity is currently protected at Calaang Creek as indicated by median turbidity of 3.34NTU which is below the recommended DGV of 20NTU and at no times during the monitoring period did turbidity ever exceed the recommended limit for protection of visual amenity.

Table 4-11 Summary water quality results for Calaang Creek at Old Kangaloon Rd (E301) (January 2017 - March 2022). Bolded values indicate exceedance with the recommended DGVs.

Indicator	Minimum	Maximum	20th percentile	80th percentile	Median	ANZG (2018) guideline for aquatic ecosystems – Upland River
Aluminium Filtered (mg/L)	0	**0.15**	0.0005	0.025	0.005	<0.055
Aluminium Total (mg/L)	0.0005	**0.50**	**0.025**	**0.50**	**0.50**	<0.055
Chlorophyll-a (µg/L)	0.5	**24.1**	0.9	3.6	1.6	<5
Conductivity (µS/cm)	75	113	78	91	82	30 – 350
Dissolved Oxygen (%Sat)	**76**	**122**	**84**	95	92	90 – 110
Iron Filtered (mg/L)	0.07	**0.60**	0.10	0.23	0.15	0.3
Iron Total (mg/L)	0.18	**11.4**	**0.32**	**0.74**	**0.49**	0.3
Manganese Filtered (mg/L)	0.011	0.143	0.018	0.040	0.028	<1.9
Manganese Total (mg/L)	0.01	0.244	0.021	0.059	0.033	<1.9
Ammoniacal Nitrogen (mg/L)	0.005	**0.070**	0.005	**0.016**	0.009	<0.013
Oxidised Nitrogen (mg/L)	0.003	**1.950**	**0.410**	**0.856**	**0.662**	<0.015
Total Nitrogen (mg/L)	0.18	**2.28**	**0.50**	**0.98**	**0.74**	<0.25
Soluble Reactive Phosphorus (mg/L)	0.001	0.011	0.002	0.005	0.003	<0.015
Total Phosphorus (mg/L)	0.005	**0.49**	0.008	**0.022**	0.014	<0.02
pH	6.6	**9.3**	6.7	7.4	7.0	6.5 – 8
Suspended solids (mg/L)	1	213	1	4	2	No guideline
Turbidity (NTU)	1	16	2	6	3	<25 or <20[2]
True Colour @ 400nm	3	21	4	12	6	70[1]

[1] as per the raw water supply agreement to the Wingecaribee WFP

[2] as per the visual amenity guidelines

4.5 Flows and water levels

Fitzroy Falls Reservoir is located on Yarrunga Creek upstream of Fitzroy Falls and has a total operating capacity of 9,950ML (at FSL). Yarrunga Creek which flows into Fitzroy Falls is estimated to have a 90th percentile flow of 1.3ML/day as measured at Wildes Meadow gauge.

Tallowa Dam is located on the Shoalhaven River immediately downstream of its confluence with the Kangaroo River. Lake Yarrunga is the storage created from the impoundment of Tallowa Dam and is the largest of the three storages with a total volume of 90,000ML (FSL at 56.34mRL) but due to dead storage an operating volume of approximately 36,000ML at FSL. Kangaroo River which flows into Lake Yarrunga is estimated to have a 90th percentile flow of 7ML/day as measured at Hampden Bridge gauge.

Bendeela Pondage is a dam located between Fitzroy Falls and Tallowa Dam on the Kangaroo River arm of Lake Yarrunga, which has a full capacity of 1,200ML

As part of the WAL, a maximum of 4021ML can be transferred between Yarrunga and Fitzroy Falls at any one time, 880ML between Bendeela Pondage. Under unusually high power demand, up to 10,000ML can be transferred between Lake Yarrunga and Fitzroy Falls. The current operating regime and storage volumes are provided in **Table 4-12** and **Table 4-13**.

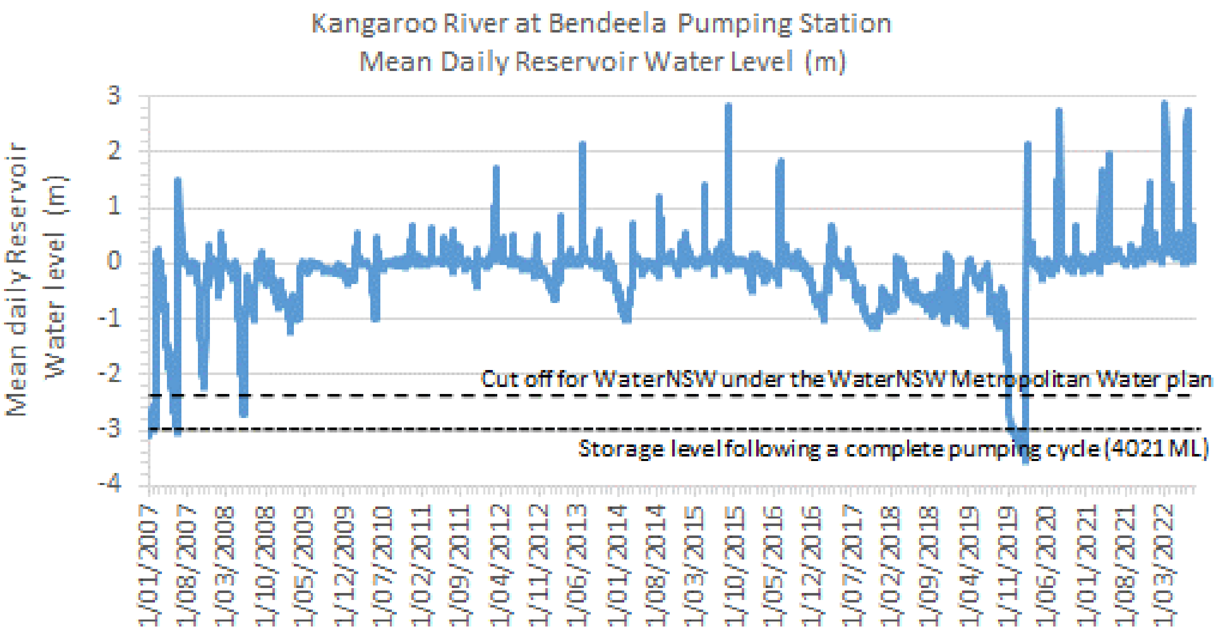
Table 4-12 Current operating regime and storage volumes Fitzroy Falls (source: Origin Energy, 2018)

Level (mRL)	Total Volume (ML)	Volume (ML) below 663.35m	Comments
663.55	10054	-1038	This is the level of the Fitzroy Falls spillway
663.55	9016	0	This is the normal operating level when Fitzroy Falls is at FSL (ie Top Operating Level (TOL))
662.54	4995	4021	This is the storage level following a complete pumping cycle (4021ML) of licenced water if operating to TOL.
661.72	1271	7745	This is the current bottom operating limit (BOL)
661.42	0	9016	This is the current MOL

Table 4-13 Current operating regime and storage volumes Lake Yarrunga (source: Origin Energy 2018)

Level (mRL)	Total Volume (ML)	Volume (ML) below 56.39m	Comments
56.39	36072	0	This is the level of the Lake Yarrunga spillway
55.39	28047	8025	This is the cut off for WaterNSW under the WaterNSW Metropolitan Water plan
54.862	24025	12047	This is the storage level following a complete pumping cycle (4021ML) of licenced water if operating below 1m WaterNSW cut off level
51.81	3512	32650	This is the current BOL
51.21	0	36072	This is the current MOL

Further, **Figure 4-13** shows variation in water levels for Kangaroo River at Bendeela Pumping Station. Also shown is the level for the cut off for WaterNSW and the storage level following a complete pumping cycle, which generally is below the level of stream flow for the plotted period.


Kangaroo River at Bendeela Pumping Station
Mean Daily Reservoir Water Level (m)
Mean daily Reservoir Water level (m)
3
2
1
0
-1
-2
-3
-4
Cut off for WaterNSW under the WaterNSW Metropolitan Water plan
Storage level following a complete pumping cycle (4021 ML)
1/01/2007
1/08/2007
1/03/2008
1/10/2008
1/05/2009
1/12/2009
1/07/2010
1/02/2011
1/09/2011
1/04/2012
1/11/2012
1/06/2013
1/01/2014
1/08/2014
1/03/2015
1/10/2015
1/05/2016
1/12/2016
1/07/2017
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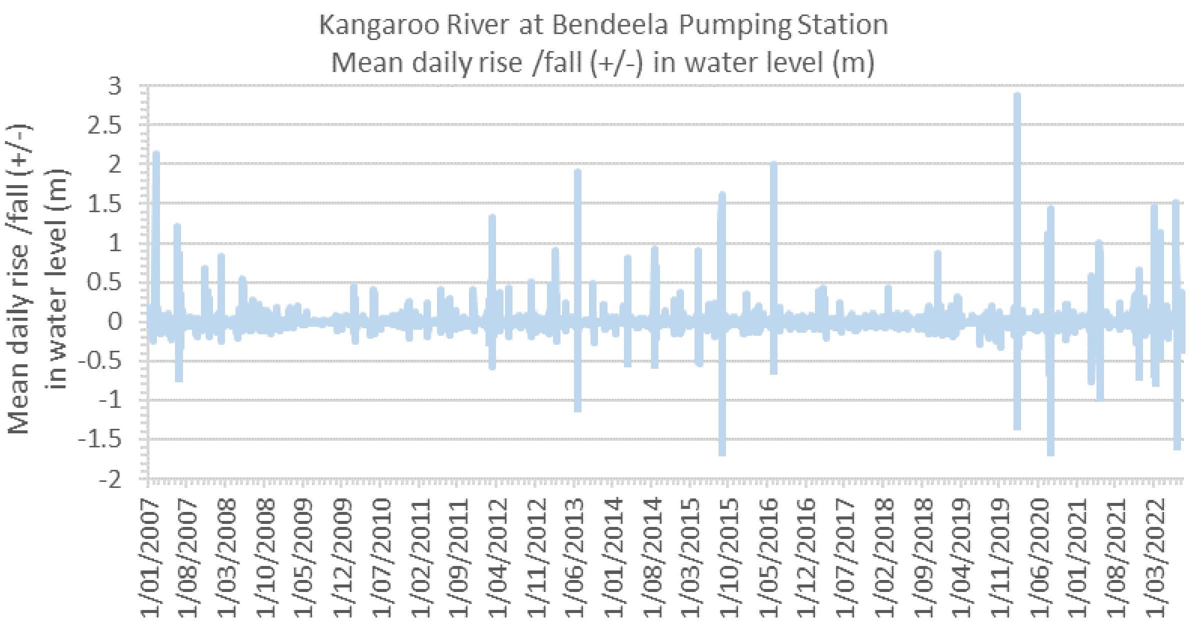
1/04/2019
1/11/2019
1/06/2020
1/01/2021
1/08/2021
1/03/2022


Kangaroo River at Bendeela Pumping Station
Mean daily rise /fall (+/-) in water level (m)
Mean daily rise /fall (+/-) in water level (m)
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
1/01/2007
1/08/2007
1/03/2008
1/10/2008
1/05/2009
1/12/2009
1/07/2010
1/02/2011
1/09/2011
1/04/2012
1/11/2012
1/06/2013
1/01/2014
1/08/2014
1/03/2015
1/10/2015
1/05/2016
1/12/2016
1/07/2017
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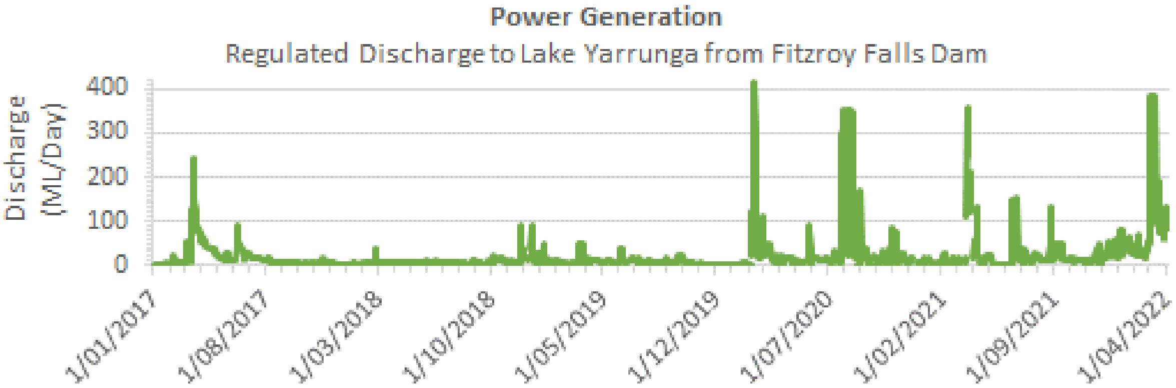
1/08/2021
1/03/2022



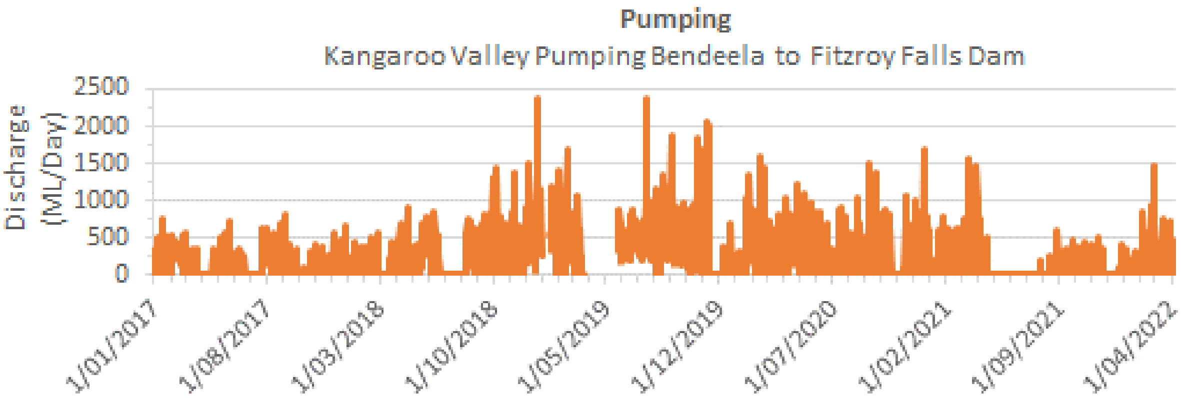


Figure 4-13 Series of plots showing variation in mean daily reservoir levels at Kangaroo River (at Bendeela Pumping Station, dashed lines show upper and lower limits for pumping under current operation), mean daily rise/fall in water levels, regulated discharges to Lake Yarrunga and pumping over the period of record (2017 to 2022).

5. Water quality controls

A strategy for erosion and sediment control measures and an assessment of the risks, constraints and mitigation measures has been developed for the construction phase of the Project. The proposed erosion and sediment control strategy is preliminary and indicative only. The strategy has been developed for the purpose of providing a basis to assess the impacts of the Project on water quality.

The contractor will be able to expand this erosion and sediment control strategy into more comprehensive and progressive erosion and sediment control plans (ESCP), which would be based on detailed design and construction staging of the Project where efficiencies (i.e. reduced disturbance footprint) may allow for changes to the plan. The contractor would then need to progressively revise ESCPs as the construction is completed. These proposed water quality controls are based on the proposed works and assumptions outlined in **Table 1-1**.

5.1 Water Quality Objectives

The water quality objective of the Project during the construction phase is to minimise the potential impacts on downstream receiving waters, so that the Project changes the existing water regime by the smallest amount practicable. This objective is to be achieved using adequate erosion and sediment controls measures and water quality monitoring.

The water quality objective of the Project during the operational phase is to ensure that the post-construction operational stages do not generate any additional pollutant loads when compared to existing pre-construction conditions.

5.2 Sediment basins

On a site where land disturbance occurs due to construction activities which may include clearing or earthworks, soil particles consisting of coarse and fine sediments will be mobilised with surface runoff that is generated by rainfall events. Local erosion and sediment controls can trap some of the sediments, for instance a sediment fence can trap coarse sediment but would not be able to trap most of the fine sediments which would require a sediment basin.

Sediment basins receive 'dirty' surface runoff from the areas where soil and land disturbance occurs during the construction stages. In some cases, they also receive some 'clean' surface runoff from undisturbed areas where the 'clean' runoff cannot be diverted away and therefore would mix with the 'dirty' runoff.

In order to minimise the number of sediment basins, and the impact of the construction of these basins on the local natural environment, the Blue Book criteria of 'minimum 150m^3' is recommended to be adopted. This criterion indicates that if the estimated annual soil losses from a disturbed catchment is less than 150m^3, then a sediment basin may not be required subject to other localised erosion and sediment controls being implemented. This is described in the following Blue Book extract:

- Reference: Blue Book Section 6.3.2, Clause (d): "*.... the average annual soil loss from the total area of land disturbance can be estimated (Appendix A). Where this is less than 150 cubic m per year, the building of a sediment retention basin can be considered unnecessary. In such circumstances, alternate measures may be employed to protect the receiving waters*".

The annual soil loss is dependent on several parameters; however, the most sensitive parameter is the steepness or slope of the terrain. As the slopes will vary on site from some relatively flat areas to some localised very steep areas of up to 33%, the maximum catchment area that can be disturbed before a sediment basin is needed will also vary.

A range of this site-specific maximum area has been estimated from the Blue Book criteria which indicates that if the estimated annual soil losses from a disturbed catchment is more than 150m^3, then a sediment basin is required.

This maximum area that can be disturbed has been estimated to be between 0.3ha for the steeper areas, to 1.5ha for the flatter areas on site. Therefore, temporary sediment basins will be required to capture and treat runoff from disturbed areas before discharging into the receiving waterways for all areas that exceed their maximum permissible area depending on the slopes in its catchment.

At locations upstream of an outlet point from the construction site where the maximum disturbed area does not require a sediment basin, sediment sump of approximately 20m^3 are recommended in addition to the local sediment controls, such as sediment fences, filters, logs etc.

5.2.1 Design Criteria

The design criteria for the sizing of temporary sediment basins used during the construction phase are aimed at achieving the Project water quality objectives. They are based on the requirements of:

- Managing Urban Stormwater, Soils and Construction guidelines, Volume 1 (Landcom, 2004) and Volume 2 (2008) (known as the Blue Book)
- Managing Urban Stormwater, Volume 2D: Main Road Construction (DECC, 2008).

The NSW EPA typically issues an EPL for each construction phase temporary sediment basin and requires the basins to be designed to a nominated percentile for the 5-day and the 85th percentile rainfall depth for sensitive receivers such as waterways and waterbodies in the Sydney Drinking Water Catchment. As such, temporary sediment basins will be provided for the construction phase and sized to satisfy the anticipated EPL conditions. All sediment basins on this Project will need to be sized using the 85th percentile 5-day rainfall depth and the other critical design input parameters that are provided in **Table 5-3** in **Section 5.3.5.1**.

5.2.2 Sediment basin locations

Sediment basins have been located where they will collect a high proportion of sediment laden runoff from disturbed areas of the construction site, and where they are accessible for maintenance. The ideal location of the sediment basins is on the downstream side of the proposed construction area and immediately upstream of proposed waterway crossings. However, in determining locations, consideration was also given to minimising impacts upon existing or proposed utilities, designated heritage and environmental exclusion zones or existing trees and vegetation.

5.2.3 Sediment basin sizing methodology

Sediment basins were sized to provide sufficient volume for settling and storage of sediments. The settling zone volume was estimated using catchment areas and the appropriate design rainfall depth. The storage zone was estimated using the Revised Universal Soil Loss Equation (RUSLE).

The sediment basins were designed as Type D or F, as per the Blue Book classifications and assumed soil parameters. Some localised pockets of Type C soils exist; however, these are small and isolated, therefore Type D soils have been adopted for the design.

The two key design elements that were used in the individual sizing of each sediment basin are:

- Catchment areas contributing to the sediment basins (disturbed and undisturbed areas). The required volume of each sediment basin was determined according to an estimate of the maximum disturbed catchment area that drains to the basin during various stages of the construction. The entire disturbed land area was included in the calculation
- The percentage of the total contributing sub-catchment area that is either “cut” or “fill”. These are batters/embankment areas that will generally be in the order of less than 25% for this Project. These sub-catchments generate greater soil losses due to the steeper gradients.

Other design input parameters include soil type, rainfall erosivity (which is a function of local rainfall intensity), soil hydrologic group, volumetric runoff coefficients and soil erodibility. The key site-specific design parameters that were used to size the sediment basins are listed in **Table 5-2** The sediment basin volumes were derived from these key elements and the Blue Book design methodology.

The proposed sediment basin locations and sizes are given on **Table 5-3**.

5.3 Erosion and sediment control strategy

5.3.1 Design approach

Whilst the installation of appropriate erosion control measures would greatly reduce the quantity of soil eroded from a construction site, some erosion would inevitably occur, and measures are therefore required to ensure that eroded material is trapped and retained. Such measures include catch and diversion drains, check dams, level spreaders, sediment fences and sediment basins.

The proposed detailed erosion and sediment control measures to be implemented during each construction stage of the Project should be based on five principles:

- Controlling the occurrence of erosion
- Controlling the movement of sediment
- Diverting offsite "clean" water away from construction areas
- Diverting onsite "dirty" water towards a sediment basin
- Capturing sediments that are transported through diversion drains in adequately sized sediment basins.

Erosion and sediment controls need to be designed for the construction phase, including the provision of temporary sediment basins where they are needed to intercept construction runoff before discharging into the receiving waterways.

Water quality would be managed within the area bounded by the Project construction site area, including, but not limited to:

- Access and haulage tracks
- Earthworks stockpile and storage areas
- Vegetation stockpile areas
- Compound areas, such as the Contractor's and the Principal's facilities
- Wash-down facilities
- Temporary sediment basins.

During construction, temporary sediment basins would be the primary mechanism to capture and treat all runoff from all disturbed areas within construction footprint before discharging into the receiving waterways. Where construction does not result in a high potential for erosion, such as resurfacing existing roads, only local sediment controls, for example sediment fences or filter logs, would be required.

The proposed erosion and sediment controls (ESCs) for the various site areas listed below include two components:

- The site-specific controls described in **Table 5-1** and in **Section 5.3.5.3** for the proposed sediment basins on the site
- The standard controls that are described in **Sections 5.3.3** to **Section 5.3.4**, **Appendix B**, and the sediment basins that are described in **Section 5.3.5**.

Table 5-1. Area specific erosion and sediment controls

Area	Specific controls
Nowra Road site access upgrade area	This area which includes the access road to the Upper Intake and Laydown / Work Area 1 where localised clearing will be undertaken requires standard ESCs that include a stabilised access structure, sediment fences and barrier fences.
Upper Intake and Laydown / Work Area 1	This area where clearing will be undertaken requires standard ESCs that include diversion drains, sediment fences, barrier fences. A sediment basin would not be required; however, smaller (20 m^3) sediment sumps will be required at the locations shown in **Appendix C.**
Pipeline corridor (between the Upper Intake and the low	This area where clearing will be undertaken requires standard ESCs that include 'clean' and 'dirty' diversion drains, sediment fences, barrier fences and a sediment basin (No 1) (subject to level of clearing actually required

Area	Specific controls
point near the Penstock Anchor Block)	within the maximum disturbance area) at the location shown in **Appendix C.**
Pipeline corridor (between Laydown / Work Area 2 and the low point near the Penstock Anchor Block)	This area where clearing will be undertaken requires standard ESCs that include 'clean' and 'dirty' diversion drains, sediment fences, barrier fences and a sediment basin (No 2) (subject to level of clearing actually required within the maximum disturbance area) at the location shown in **Appendix C.**
Laydown / Work Area 2 and Surge Tank area	This area where clearing will be undertaken requires standard ESCs that include diversion drains, sediment fences, barrier fences and two sediment basins (No 3 and 4) at the locations shown in **Appendix C.**
Laydown / Work Area 3 and Vertical Shaft area	This area where clearing will be undertaken requires standard ESCs that include sediment fences and barrier fences.
Tunnel Portal and Spoil Haulage track around Bendeela Pondage	This area where localised clearing and excavation cutting will be undertaken requires standard ESCs that include sediment fences and barrier fences. Depending on the extent of additional land disturbance that is identified at detailed design, sediment sumps or a basin may also be required.
Spoil emplacement area	This area where clearing and spoil emplacement potentially including acid rock treatment or encapsulation may occur requires standard ESCs that include 'clean' and 'dirty' diversion drains, sediment fences, barrier fences and a sediment basin (No 5) at the location shown in **Appendix C**. The detailed design of spoil emplacement and potential acid generating material management would determine the need for separate treatment for pH adjustment of runoff
Laydown / Work Area 7	This area where some localised clearing will be undertaken requires standard ESCs that include sediment fences and barrier fences
Laydown / Work Area 6 (Intake outlet area)	This area where clearing will be undertaken requires standard ESCs that include 'clean' and 'dirty' diversion drains, sediment fences, barrier fences and two sediment basin (No 6 and 7) at the locations shown in **Appendix C**.
Promised Land Trail	This track where localised widening and clearing will be undertaken to restore its previous width of approximately up to 8m requires standard ESCs that include sediment fences and barrier fences.
Laydown/Work Area 5	Where clearing will be undertaken requires standard ESCs that include sediment fences and barrier fences.

5.3.1.1 Erosion hazard along the pipeline corridor

Proposed pipeline corridor

The gradients on site where land disturbance will occur vary significantly; however, portions of the proposed pipeline corridor are located in the steepest areas and carry the highest erosion hazard risk. As such these areas require careful risk and mitigation assessment. The remaining areas will also be assessed but they may only require standard erosion and sediment controls including basins.

The Blue Book (Landcom, 2004) appraises the erosion hazard via the calculation of the predicted annual average soil loss using the Revised Universal Soil Loss Equation (RUSLE): A = R x K x LS x P x C, where:

A = computed soil loss (t/ha/yr)

R = rainfall erosivity factor

K = soil erodibility factor

LS = slope length/gradient factor

P = erosion control practice factor

C = ground cover and management factor.

The unmitigated erosion hazard on site as defined in Table 4.2 of the blue book ranges from low-moderate to extremely high as shown on **Figure 5-1.** The Erosion hazard will vary across the site as it is very dependent on the LS steepness parameter of the location.

Table 4.2 The Soil Loss Classes (adapted from Morse and Rosewell, 1996)

Soil Loss Class	Calculated soil loss (tonnes/ha/yr)	Erosion hazard
1	0 to 150	very low
2	151 to 225	low
3	226 to 350	low-moderate
4	351 to 500	moderate
5	501 to 750	high
6	751 to 1,500	very high
7	>1,500	extremely high

Figure 5-1 Soil loss classes (extract from Landcom, 2004)

The pipeline corridor along which some soil disturbance is proposed is shown on **Figure 5-2** and **Figure 5-3.** The varying gradients are also indicated as well as the High points (H) and Low points (L).

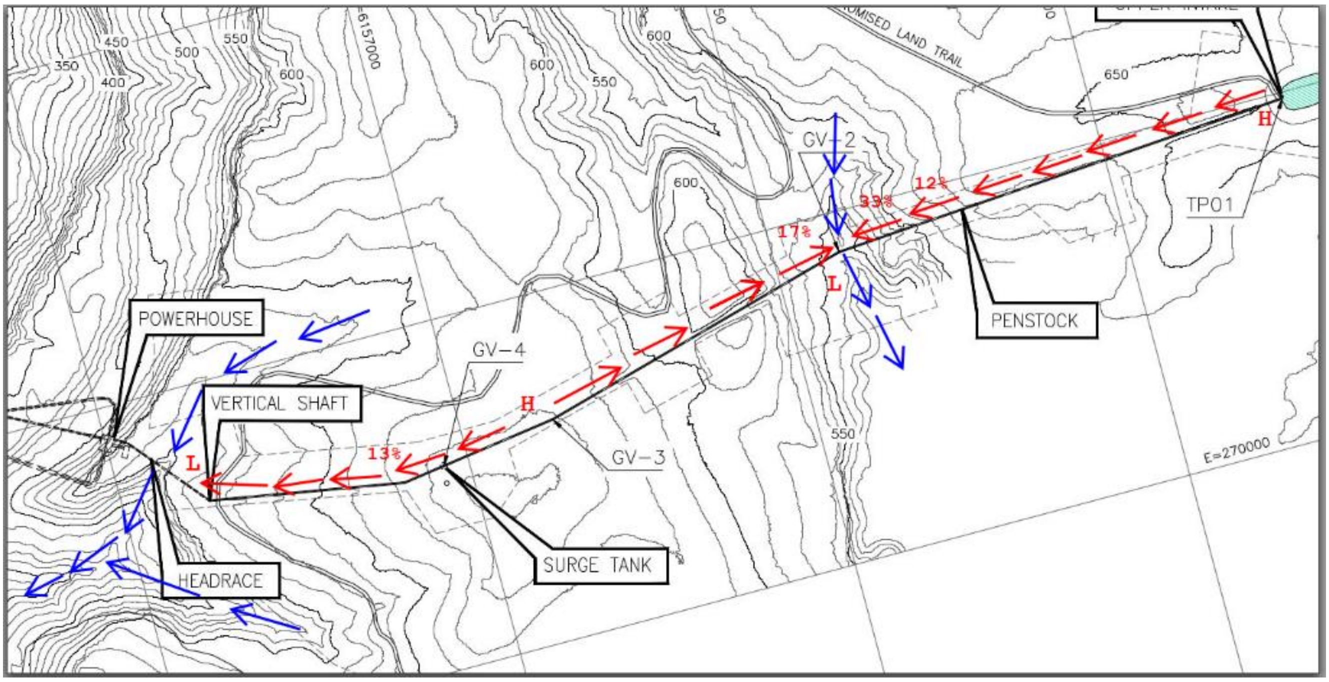


Figure 5-2 Layout of the proposed pipeline area

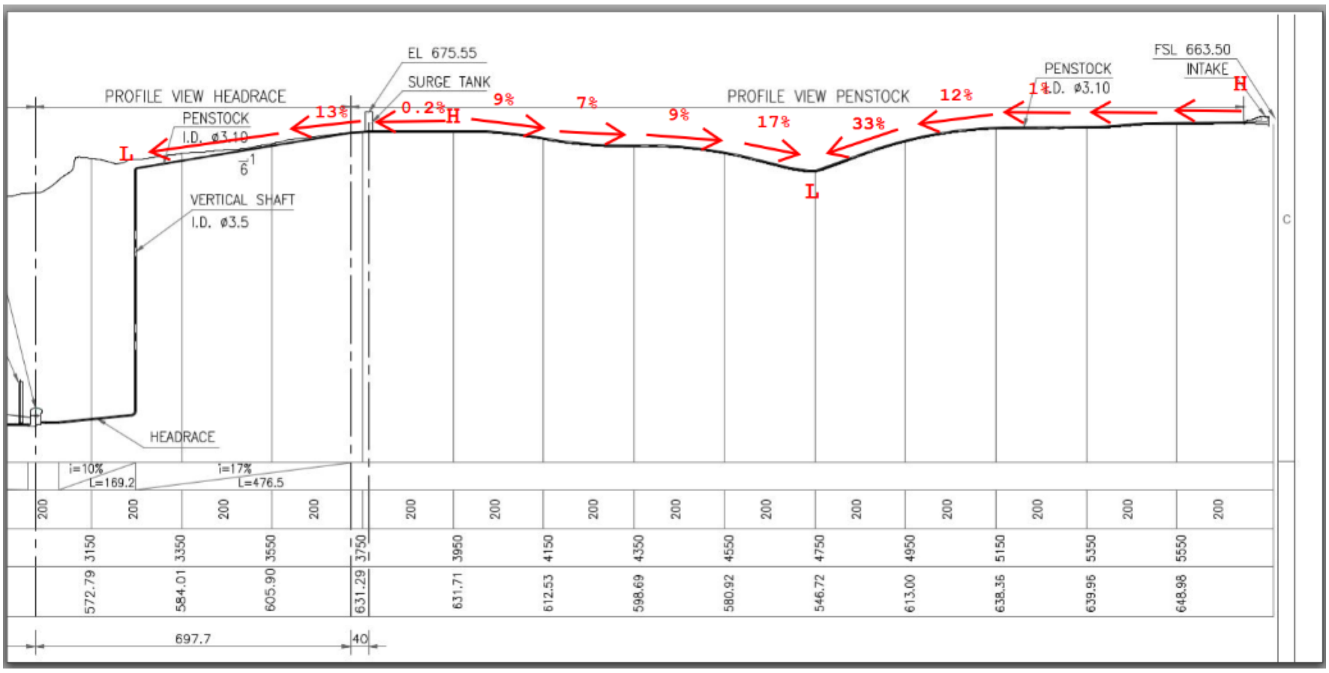


Figure 5-3 **Vertical profiles of the proposed pipeline area**

The gradients shown on **Figure 5-2** and **Figure 5-3** indicate that they vary from less than 5%, up to 33%. The erosion hazards for the standard 80m spacing requirement of sediment fences along the contours on a disturbed area of the site is shown on **Table 5-2**. The predicted annual soil losses (t/ha) and hazards vary from *low-moderate* for areas of less than 5% gradient, to *extremely high* for areas with higher than 15% gradient. For the steepest area on site the estimated soil loss rates are approximately 2 to 3 times higher than *extremely high* hazard.

To mitigate the erosion hazard risk from areas that carry very high to extreme risk, the sediment fence spacing would need to be reduced such that the resultant risk is reduced to *low-moderate*. For the steepest area, this risk can only be reduced to *moderate* using sediment fencing; however, the estimated annual soil loss would have been significantly reduced from 4,487 t/ha to 470 t/ha. Additional consideration of this area is as such warranted and include overall minimisation of disturbance footprint, application of soil stabilisers including shotcrete or an alternative material on trafficked areas, progressive disturbance and rapid stabilisation and rehabilitation.

Table 5-2 Erosion hazard risk assessment and proposed mitigation for the pipeline corridor area

Longitudinal slope in %	Estimated soil loss in t/ha per year	Erosion hazard with standard 80m Length for LS estimate	Improved non-standard LS Length in m	Reduced soil loss in t/ha per year	Improved erosion hazard
<5%	350	Low-moderate	80m	350	Low-moderate
10%	825	Very high	15m	320	Low-moderate
>15%	1615	Extremely high	10m	350	Low-moderate
33%	4487	Outside range, higher than extremely high	5m	470	Moderate

5.3.2 Erosion and sediment control strategy

The overall erosion and sediment control design strategy for the Project is to prevent or reduce erosion and sediment impacts during construction. Where erosion does occur, the aim is to capture it as close to this source as practicable.

To achieve the principles outlined in **Section 5.3.1**, water quality during construction would be managed using:

- Site managed erosion controls measures
- Physical sediment control measures
- Treatment with sediment basins
- Monitoring and maintenance.

5.3.3 Site managed erosion control measures

Construction activities would be sequenced and managed by the construction contractor to minimise potential water quality degradation due to erosion. Management would include:

- Minimising the extent and duration of exposed topsoil by retaining topsoil cover, grassed drainage lines and shrub cover on the soil surface for as long as possible
- Minimising the lengths of slopes through limiting the extent of excavations and the use of diversion drains to reduce water velocity over disturbed areas
- Application of soil stabilisers and shotcrete on high risk area
- Designation of 'no go' zones for construction plant and equipment
- Shaping of land to minimise slope lengths and gradients and improve drainage, e.g. benching
- Employment of appropriate measures to prevent wind-blown dust entering waterways
- Creation of diversion banks at the upstream boundary of construction activities to divert upstream runoff around exposed areas
- Creation of catch drains at the downstream boundary of construction activities where practicable to contain sediment-laden runoff and diversion toward treatment areas to prevent flow of runoff to downstream undisturbed areas
- Specification of construction procedures that minimise water flow velocities and avoid excess velocities such as implementation/construction of level spreaders, check dams, bank and channel linings
- Where possible, cleared native vegetation and native mulch would be used to reduce erosion and contain sediment during construction through use of small vegetation filter windrows placed across the contour in drainage lines, below fill batters, below cutting works at the head of cleared minor drainage lines and before the inlet to sediment basins and waterways. Mulch should not be used for surface cover or sedimentation controls in any low-lying areas of the site that remain consistently wet. Alternative controls such as Geofabric (for surface protection), hydro mulching or sediment fences will be required in these areas. Unprotected mulch sediment controls should not be placed in concentrated flow lines where the

mulch may be washed away. Mulch may be protected by wrapping it with Geofabric or other materials to provide a stable control. All temporary catch dams constructed from mulch must have a stable outlet to minimise the washing away of mulch in high rainfall events, and the possible failure of the control
- Where possible, constructing working platforms from rock fill so that bare earth is not exposed
- Installing stabilised vehicle exit points to remove sediments from vehicles leaving site areas
- In addition to these general erosion control measures, specific mitigation measures are required for site compounds, stockpiles, works near waterways and spills.

5.3.3.1 Site compound management

In general, mitigation would be similar to general construction site mitigation, with additional factors, such as:

- Restricting vehicle movements to designated pathways where feasible
- Paving areas that would be exposed for extended periods where feasible
- Diverting offsite runoff around stockpiles sites where required
- Designation of areas for plant and construction material storage within the site compound
- If the above local controls are not implemented, and where required, treating onsite runoff with a construction or compound-specific sediment basin. Monitoring the sediment basin for parameters such as dissolved oxygen levels and organics would be required to determine suitable discharge to the environment. Such basins would be considered once compound locations have been finalised.

5.3.3.2 Stockpile management

The maintenance of established stockpile sites during construction is to be in accordance with the requirements of the Blue Book (Soils and Construction), in order to prevent erosion of the stockpile flowing into downstream waterways. These, and additional recommendations include:

- Diverting runoff around stockpiles sites where required
- Minimising the number and size of stockpiles
- Lining the base of stockpiles if they are located over shallow water tables
- Treating stockpiles at the source by covering with plastic sheets
- Establishing effective sediment control works to contain any runoff including cut-off drains, vegetation and silt fences to minimise risk of sediments entering waterways
- If the above local controls are not implemented, and where required, treating onsite runoff with a construction or compound-specific sediment basin. Monitoring the sediment basin for parameters such as turbidity, pH and organics would be required to determine suitable discharge to the environment. Such basins would be considered once compound locations have been finalised
- Any material found to be unsuitable for reuse would be disposed of in accordance with the Waste Classification Guidelines (DECCW, 2008).

5.3.3.3 Managing spills

Sediment basins must be designed to include provision for spill containment. Spill management procedures during construction, including an Emergency Spill Response Plan, would be developed, and incorporated into the CEMP prior to construction. This would include measures to avoid spillages of fuels, chemicals, and fluids into any waterways or waterbodies. The storage, handling and use of the materials would be undertaken in accordance with the *Occupational Health and Safety Act 2000* and Workcover's Storage and Handling of Dangerous Goods Code of Practice (Workcover, 2005).

Procedures would include (but not be limited too):

- All fuels, chemicals, and liquids would be stored at least 50m away from any waterways or drainage lines and would be stored in an impervious bunded area within the compound site
- Bunded areas for refuelling and wash-down
- Spill kits
- Training of staff.

5.3.3.4 Maintenance of erosion and sediment controls

Regular maintenance of all erosion and sediment controls on site is required after each storm event (more than 2mm of rainfall) to remove trapped sediments and repair eroded areas. Accumulated sediments in the basins need to be checked every 2 months and removed when the sediment depth reaches 300mm.

5.3.4 Physical sediment control measures

Whilst the installation of appropriate erosion control measures would greatly reduce the quantity of soil eroded from a construction site, some erosion would inevitably occur, and measures are therefore required to ensure that eroded material is trapped and retained. Such measures include catch and diversion drains, check dams, level spreaders, sediment fences, constructed drainage and sediment basins.

5.3.4.1 Catch and diversion drains

Either individually or in combination, these structures are used to intercept and direct runoff water to a desired location. By doing so, sheet flow is converted to concentrated flow, and the time of concentration for runoff is decreased. There are two types of drains for clean and dirty runoff used during the construction phase, and they are often used in conjunction with level spreaders and check dams:

Upslope runoff diversion drain (catch drain)

- This diversion drain is an earth channel with lining designed to intercept and direct clean runoff from the undisturbed upstream catchment and divert it to an existing waterway, so that it does not enter the construction site. Drains would be lined with biodegradable organic fibre mesh hydro seeding and anionic bitumen emulsion spray at a rate of 3 L/m2. Other suitable linings can also be used.

Onsite runoff diversion drains

- A temporary earth bank installed at the downstream end of disturbed areas to convey contaminated runoff to sediment basins.

All temporary drains would be constructed to avoid trees and other permanent infrastructure, where feasible.

5.3.4.2 Check dams

A check dam is a small, temporary dam built across a swale or diversion drain. Its primary function is to reduce the velocity of flow in the channel and thus reduce erosion of the channel bed. The entrapment of sediment behind these structures is a secondary function. Check dams can be used:

- To protect a grass lined channel during initial establishment of vegetation
- As a substitute for channel lining in a temporary channel.

Check dams can be constructed by using any materials on the site that can withstand the flow of water. Rock, logs and sandbag check dams can be the sturdiest if these materials are correctly placed in position. Wire netting, woven brush and straw bales can also be used.

Although check dams are not primarily intended as sediment trapping devices, larger-sized particles would inevitably accumulate behind them. This sediment should be removed before it accumulates to one-half of the original height of the dam and placed where it would not be washed back into the drainage system.

5.3.4.3 Level spreaders

A level spreader is an excavated outlet constructed with zero grade. It converts an erosive, concentrated flow of runoff into sheet flow, and discharges it at a non-erosive velocity onto an undisturbed area stabilised by vegetation.

Level spreaders may be used as outlets for diversion or perimeter banks or channels, where storm runoff has been intercepted and diverted to stable areas. They should be used only where the spreader can be constructed on undisturbed soil. The area directly below the spreader sill should be uniform in slope and well vegetated, allowing water to spread out as sheet flow.

The cross-sectional area and length of the level spreader would be designed by the contractor to be sufficient to discharge the design flow from the selected frequency rainfall event.

5.3.4.4 Sediment fencing and filters

Sediment fences / filters act as sediment mitigation measures for small, disturbed areas where it is impracticable to direct the runoff to sediment basins by diversion drains. Sediment fences / filters function by intercepting and filtering small volumes of runoff, which mainly occur as sheet flow.

Sediment fences would be selected that use woven polypropylene and cotton / geotextile thread with a flow rate greater than 110 L/m^2/s to Australian standards AS3706.9.

If straw bales are used in conjunction and in addition to sediment fencing, the straw bales should be weed free to ensure that weeds are managed appropriately and not spread.

5.3.4.5 Airborne dust and sediments

During construction, air quality issues may arise from temporary increases in local dust (including total deposited dust, total suspended solids and fine particulate matter) emissions associated with vegetation clearing, excavation and demolition works and the handling, storage and disturbance of soils and materials; and other emissions such as exhaust fumes associated with the operation of construction machinery. This might cause direct impacts on the residential and commercial properties adjacent to the Project.

Although all phases of construction have the potential to adversely impact upon local ambient air quality, the following activities present the greatest risk:

- Excavation activities
- Materials handling and storage operations
- Demolition works
- Compound, laydown and storage area operations.

The primary issues which need to be managed associated with these phases of construction are identified below:

- Site preparation and clearing: Increased risk of windborne erosion arising from disturbed and exposed surfaces
- Earthwork and excavations: Temporary increases in local dust and exhaust emissions associated with:
  - Windborne dust emanating from disturbed/exposed surfaces
  - Dust and debris arising from haulage of materials
- Revegetation work: Increased risk of windborne erosion arising from non-vegetated surfaces.

5.3.5 Sediment basins

5.3.5.1 Design criteria for sediment basin sizing

The design criteria for the temporary water quality treatment controls used during the construction phase are aimed at achieving the water quality objectives and meeting the performance objectives described in **Section 5.2.**

The storage zone has been estimated using the Revised Universal Soil Loss Equation (RUSLE). The parameters that have been used to size the sediment basins are outlined in **Table 5-3.**

Table 5-3 Design criteria for sizing sediment basins for the Shoalhaven pumped hydro expansion Project

Parameter	Value	Comments
Rainfall Parameters		
Rainfall depth duration (days)	5	5 day adopted as standard duration for the NSW EPA EPL requirements.

Parameter	Value	Comments
Rainfall percentile	85^{th}	85^{th} percentile adopted for sensitive receiving environments in a drinking water supply catchment with construction duration between 6 months and 3 years.
Rainfall Depth (mm) – 5 Day	45.7 mm	85^{th} for **Kangaroo Valley** (Table 6-3a Blue Book).
Volumetric Runoff Coefficient, C_v	0.64	0.42 to 0.64 range. 0.64 adopted (conservative design) for expected type of activities on site and compacted surfaces.
Rainfall intensity for 2 year ARI, 6 hr duration	~14 mm/hr	Obtained from the 2016 BoM site for site location near the Penstock: S-34˚ 41' 41.65" and E-150 ˚28' 53.84". Approximated to be 14mm/hr, conservative estimate. Refer to **Appendix D** for the approximate interpolation between 11mm/hr and 15.2mm/hr. Refer to Rainfall Erosivity below.
RUSLE Parameters		
Soil/sediment Type	C, D or F	Varies along the pipeline route. Mainly type F, type D, and small localised pockets of type C. Type D has been adopted for the design of all sediment basins.
Erodibility, k	0.045	K range = 0.03 to 0.06. K=0.045 was adopted based on site soil data. Refer to **Appendix G** and **Appendix H.**
Rainfall Erosivity, R	5000	4285 for **Kangaroo Valley** based on estimated site-specific rainfall intensity above 5000 for **Kangaroo Valley** based on the Blue Book map 11 Vol1, refer to **Appendix E** 5000 has been adopted as the conservative value.
Hydrologic Soil Group	D	For high runoff potential, Ref: Appendix F of Blue Book.
Soil Cover, C	1	Corresponding to expected type of activities on site.
Soil Conservation Practices, P	1.3	Corresponding to expected type of activities on site.
Length Slope Factors, LS	Variable	Determined separately for the various sections that differ in slope steepness.
Sediment Yield Time Period (months)	1	Default duration in Blue Book is 2 months; however, 1 month has been adopted to reduce the footprint of the basins due to space constraints. This is acceptable provided the inspection and maintenance frequency is also adjusted to 1 month.

5.3.5.2 Methodology for sediment basin sizing

The design methodology and the relevant equations used in the sizing of sediment basins are described in the following sections of the Blue Book:

1) Revised Universal Soil Loss Equation (RUSLE) which estimates annual soil loss amount: pages A1 to A11 of Appendix A of the Blue Book
2) Settling zone volumetric requirements: pages 6-22 to 6-25 of Chapter 6
3) Rainfall erosivity estimation: Appendix B - Blue Book
4) Volumetric runoff coefficient (Type D): pages F1 to F4 of Appendix D - Blue Book.

The required volume of each sediment basin was determined according to the maximum catchment area that would drain to the basin during the various stages of construction assuming that all external catchment areas would divert away from the basins, and the parameters listed in **Table 5-3**. The required basin volume includes the volume for both the settling zone and the sediment storage zone.

5.3.5.3 Proposed sediment basins for the Shoalhaven pumped hydro expansion Project

The locations of the sediment basins were selected to provide for the maximum runoff captured from catchments throughout the construction process using gravity diversion drains to divert runoff to the sediment basins. The results of the sediment basin sizing and locations are listed below and summarised in **Table 5-4.**

Seven temporary sediment basins are identified as required during the construction phase of the Project in the event complete clearing of the maximum disturbance footprint is required. The need for, location and sizing would be confirmed as part of detailed design subject to actual clearing required and other means of risk reduction available. Any required basins should be built before any work or land disturbance occurs within their applicable catchment.

The approximate cleaning frequency of the captured sediments is roughly once every 4 weeks or longer depending on the actual rainfall conditions during the construction phase and therefore the rate of soil transport and capture rates in the basin. This frequency which was adopted for all proposed basins on the Project has been reduced to minimise the overall volume of the basin, reducing the need to clear more land for the basin construction.

The need for sediment basins is dependent on key factors such as the catchment area, the steepness of the disturbed terrain and the local rainfall conditions. For this site, the minimum catchment area that requires a sediment basin ranges from 0.3ha for the steeper areas of more than 30%, and 0.6 ha for the areas with less than 5% slope

At locations where a sediment basin is not warranted, smaller sediment sumps with a total water volume of 20m^3 are proposed. The locations of these proposed sediment sumps are shown on the Erosion and Sediment Control Plans (ESCPs) in **Appendix C**.

Penstock Anchor Block North – Basin No 1

Sediment basin number 1 is proposed at the low point near the Penstock Anchor Block at the northern end of the Trimbles Creek. The location of this proposed sediment basin is shown on the ESCPs in **Appendix C**. The total construction phase catchment of this basin is approximately 0.64ha, half of which is assumed to be disturbed during construction along the new pipeline corridor. The estimated basin water volume is 200m^3 and the estimated dimensions of the basin at the waterline are: Length=14m, width=9m with a max depth of 2.6m.

Detailed design and construction methodology development in this area would prioritise the avoidance of clearing and staging of excavations with the objective of reducing erosion potential to the extent reasonable and feasible.

Penstock Anchor Block South – Basin No 2

Sediment basin number 2 is required at the low point near the penstock anchor at the southern end of the natural creek. The location of this proposed sediment basin is shown on the ESCPs in **Appendix C**. The total construction phase catchment of this basin is approximately 0.5ha, half of which is assumed to be disturbed during construction along the new pipeline corridor. The estimated basin water volume is 160m^3 and the estimated dimensions of the basin at the waterline are: Length=12m, width=9m with a max depth of 2.5m.

Detailed design and construction methodology development in this area would prioritise the avoidance of clearing and staging of excavations with the objective of reducing erosion potential to the extent reasonable and feasible.

Laydown / Work Area 2, northern end – Basin No 3

Sediment basin number 3 is required at the northern end of the Laydown / Work Area 2. The location of this proposed sediment basin is shown on the ESCPs in **Appendix C**. The total construction phase catchment of this basin is approximately 2.25ha, 75% of which is assumed to be disturbed during construction along laydown area 2. The estimated basin water volume is 690m3 and the estimated dimensions of the basin at the waterline are: Length=49m, width=13m with a max depth of 2.2m.

Laydown / Work Area 2, southern end – Basin No 4

Sediment basin number 4 is required at the southern end of the Laydown / Work Area 2. The location of this proposed sediment basin is shown on the ESCPs in **Appendix C**. The total construction phase catchment of this basin is approximately 1.9ha, 50% of which is assumed to be disturbed during construction at laydown area 2. The estimated basin water volume is 550m3 and the indicative estimated dimensions of the basin at the waterline are: Length=40m, width=11m with a max depth of 2.5m.

Spoil Emplacement Area – Basin No 5

Sediment basin number 5 is required at the spoil emplacement area. The location of this proposed sediment basin is shown on the ESCPs in **Appendix C**. The total construction phase catchment of this basin is large at approximately 12ha, half of which is assumed to be contributing sediment exports. The estimated basin water volume is 3560m^3 and the indicative estimated dimensions of the basin at the waterline are: Length=70m, width=28m with a max depth of 2.5m.

Laydown / Work Area 6 – Basin No 6

Sediment basin number 6 is required at the southern end of Laydown / Work Area 6. The location of this proposed sediment basin is shown on the ESCPs in **Appendix C**. The total construction phase catchment of this basin is approximately 2.2ha, 75% of which is assumed to be disturbed during construction at the southern end of the outlet area. The estimated basin water volume is 730m^3 and the indicative estimated dimensions of the basin at the waterline are: Length=40m, width=14m with a max depth of 2.0m

Laydown / Work Area 6 – Basin No 7

Sediment basin number 7 is required at the northern end of Laydown / Work Area 6. The location of this proposed sediment basin is shown on the ESCPs in **Appendix C**. The total construction phase catchment of this basin is approximately 1.9 ha, 75% of which is assumed to be disturbed during construction at the southern end of the outlet area. The estimated basin water volume is 630 m^3 and the indicative estimated dimensions of the basin at the waterline are: Length=38 m, width=13 m with a max depth of 2.0 m.

Table 5-4 Indicative size of temporary sediment basins for the construction phase

Basin number	Sediment basin volume (m^3)
1	200
2	160
3	690
4	550
5	3560
6	730
7	630

5.3.5.4 Treatment requirements for all sediment basins

The use of flocculation at the proposed sediment basins is likely to be required subject to discharge criteria. Flocculants will attract and trap finer soil particles in the water column and sink them to the bottom of the sediment basin. The extent and type of flocculation that is required will depend on several factors, with the following of most importance:

- **NSW EPA requirements -**The NSW EPA has requirements for discharges from sediment basins. For instance, the EPL licence of the basins may require that the concentration of the discharges should not exceed a certain nominated value, or that it should not exceed the existing concentrations for parameters such as TSS, turbidity and pH and other parameters. This means that each basin may have slightly different requirements as existing conditions may change from one basin location to another. The existing concentration conditions will need to be established before construction commences - refer to the Water Quality monitoring in **Section 5.3.5.6**
- **Soil characteristics, flocculant type and jar test -** The characteristics of the soils on site for the negatively charged colloids need to be assessed as these repel each other in the water column and do not easily settle to the bottom of the basin. Some soils are more dispersible than others and therefore require more flocculation and sometimes stronger flocculants. The type of flocculant to be selected will depend on the EPL requirements and the soils. The preferred flocculant is super fine gypsum; however, if gypsum cannot meet the required concentration reductions of TSS and turbidity, then other flocculants such as Ferric Chloride ($FeCl_3$) or Aluminium sulphate (Al_2SO_4) known as Alum may be utilised. A laboratory jar test needs to be undertaken for each of the proposed flocculants to determine if the required concentrations can be achieved and to identify the required dosage, for instance for gypsum, this dosage rate could be 30kg/100m^3 for example. Other flocculants such as Ferric Chloride coagulant or Alum can only be used under a special licence from the NSW EPA and will require the measurement of residual heavy metals in the discharge such as iron or aluminium so that they can be compared to acceptable levels of discharge. Auto injection system can be used at the inlet of basins at a rate that is proportional to the inflows. pH adjustments may also be required for certain flocculants.

5.3.5.5 Sediment basin characteristics

The sediment basins are likely to consist of:

- Compacted earth embankments with a nominal slope of 2:1 (H:V) and a minimum crest width of one m, or up to three m where space is available
- An excavated storage area that allows a maximum water depth of typically two m
- One or more inflow points
- A primary outlet spillway and protection to reduce erosion downstream
- A basin dewatering device and provision for gypsum or other flocculation
- Access to the basin for maintenance so that sediment build-up can be retrieved
- Freeboard of 500mm.

5.3.5.6 Water quality monitoring for the sediment basins sediment and sumps

Monitoring at site runoff discharge points should be undertaken before and during the construction phase to detect any environmental degradation as a result of the construction works. The monitoring would also be required to ensure that any NSW EPA licence conditions for discharges from the basins are met. The monitoring parameters and requirements would be those that are provided in the EPL held for construction. There are seven locations where water quality monitoring is proposed at the outlets of the seven proposed temporary sediment basins. When pre-construction monitoring will be undertaken to represent existing conditions at these seven locations, a correlation relationship should also be established between TSS and turbidity to provide the option of obtaining on-site results during the construction phase. The reason for this is because the EPL may nominate TSS as the requirement, and unlike turbidity, TSS values require laboratory analysis and cannot be provided instantaneously when measuring on site. This procedure will enable additional flocculation to be applied (if required) without any delay which will provide an improved environmental outcome. Monitoring is also required at the downstream end of sediment sumps.

5.4 Summary of water quality control strategy

A strategy for erosion and sediment control measures and an assessment of the risks, constraints and mitigation measures has been developed for the construction phase of the Project. The proposed erosion and sediment control strategy is preliminary and indicative only. The strategy has been developed for the purpose of providing a basis for the construction contractor to expand into a more comprehensive ESCP, which would be based on detailed design and construction staging of the Project. The contractor would then need to progressively develop ESCPs as the construction is undertaken.

The erosion and sediment controls investigation identified the potential need for seven sediment basins throughout the construction phase of the Project based on reference design assumptions of maximum disturbance area. The implementation of the erosion and sediment controls identified in this report are important to protect the downstream sensitive environment.

Assuming that the strategy in this report is fully adopted during the construction phases, and the required water quality monitoring and management is undertaken prior and during the construction phase, the risk of causing environmental impacts within the study area from erosion and sediment runoff can be minimised and adequately managed.

For the operational phase of the Project, the NorBE water quality objective can be achieved through complete rehabilitation of any disturbed areas to reinstate them to their existing conditions as there are no proposed changes to the operational phase land use following the construction phase.

6. Potential construction impacts

Construction of the Project has potential to result in changes to surface water hydrology, degradation of downstream water quality and changes to geomorphology if mitigation measures are not implemented, monitored and maintained throughout the construction phase. Potential impacts to surface water hydrology, water quality and geomorphology could occur due to the construction activities outlined in **Table 6-1**. The waterways at risk of being impacted by these construction activities are provided in **Table 6-2**.

Potential impacts and their associated risk to water quality, hydrology and geomorphology during construction are identified in **Section 6.1**, **Section 6.2** and **Section 6.3**, respectively. With the implementation of recommended mitigation measures, a risk assessment of impacts to waterways and waterbodies in the study area is provided in **Section 6.4**.

Table 6-1 Construction activities to be carried out in work areas

	Site access upgrade	Laydown / Work Area 1	Promised land trail	Penstock Anchor block	Laydown / Work Area 2	Laydown / Work Area 3	Underground works	Laydown / Work Area 5	Laydown / Work Area 6	Laydown / Work Area 7	Spoil haulage route	Spoil emplacement area
Road works	✓ (minor)		✓ (minor)									
Vegetation clearing	✓ (minor)	✓	✓ (minor)	✓ (minor)	✓	✓		✓	✓	✓ (minor)	✓ (minor)	✓
Earthworks	✓ (minor)	✓	✓ (minor)	✓	✓	✓	✓	✓	✓		✓ (minor)	
Concrete works / batching		✓			✓	✓	✓	✓	✓	✓		
Site facilities / material laydown	✓ (minor)	✓			✓	✓		✓	✓	✓		
Spoil movement			✓			✓		✓			✓	
Spoil stock piling and emplacement						✓		✓				✓
Dewatering / discharges		✓		✓	✓	✓	✓	✓	✓			✓
Rock blasting									✓			
Steel works					✓		✓					
Instream works				✓				✓				
Tunnelling and underground works							✓					

Table 6-2 Waterways with the potential to be impacted by construction activities at work areas

	Site access upgrade	Laydown / Work Area 1	Promised land trail	Penstock Anchor block	Laydown / Work Area 2	Laydown / Work Area 3	Laydown / Work Area 5	Laydown / Work Area 6	Laydown / Work Area 7	Spoil haulage route	Spoil emplacement area
Fitzroy Falls Upper Canal	✓	✓	✓								
Unnamed tributary of Trimbles Creek 1		✓									
Unnamed tributary of Trimbles Creek 2		✓	✓								
Unnamed tributary of Yarrunga Creek 1		✓									
Trimbles Creek		✓		✓							
Unnamed tributary of Yarrunga Creek 2					✓						
Unnamed tributary of Kangaroo River (upstream)						✓			✓	✓	
Kings Creek							✓				
Bendeela Pondage							✓			✓	
Unnamed tributary of Kangaroo River (downstream)										✓	✓
Lake Yarrunga								✓			

6.1 Impacts to water quality from construction activities

6.1.1 Road works

Road works are required at the intersection of the Promised Land Trail with Moss Vale Road to improve access and turning. This will be achieved by widening the intersection and resurfacing it as per its original condition (sealed road). Road works are also required along the existing Promised Land Trail to reinstate the road to its original width, as well as along the spoil haulage route around Bendeela Pondage.

Road works along the Promised Lands Trail will occur from the intersection with Moss Vale Road through to the start of the Headrace Shaft. The road works will require some excavation (including vegetation removal), grading and levelling as well as improvements to drainage and potentially sealing the road in steep sections. Road works along the spoil haulage route around Bendeela Pondage will also require earthworks, levelling and placing road material (i.e. imported gravel).

Soils in the road corridor and the road material (compacted in situ material and imported gravel) are at risk of being washed via stormwater runoff into the downstream aquatic environments. Once sediments enter the waterways they have the potential to temporarily reduce downstream water quality by increasing turbidity and smothering aquatic organisms.

Waterways at risk in the Upper Scheme include the unnamed ephemeral tributaries of Trimbles Creek 1 and 2, unnamed tributary of Yarrunga Creek 1 and 2 and the unnamed tributary of Kangaroo River (Upper Scheme). Waterways at risk in the Lower Scheme area are Kings Creek and the unnamed tributary of Kangaroo River (Lower Scheme).

Site erosion and sediment controls, as described in **Chapter 5**, would be established as soon as possible after commencement of construction works to avoid and/or manage potential impacts. In addition, other mitigation measures outlined in **Chapter 11**, will be established and adopted during the construction phase to manage potential impacts.

6.1.2 Vegetation clearing

Establishment of all work areas would require removal of vegetation, although the amount of clearing varies. Work areas where the most vegetation would be removed include the Spoil emplacement area, and Laydown / Work Areas 1, 2 and 6. Overall, construction of the Project would require removal of up to 29.5 hectares (ha) of vegetation. Vegetation clearance exposes soils to weathering processes, thereby increasing the risk of erosion and sedimentation.

Removal of vegetation can impact on water quality during the construction phase if runoff is allowed to mobilise exposed soils or tannin leachate. This can result in increased turbidity, suspended solids, nutrients and contaminants in downstream waterways. Clearing and trimming of vegetation will be done to avoid tannin leachate entering downstream waterways.

It is expected that there is low risk of impacts to water quality from vegetation clearing for most areas except for in areas with steep gradient slope where runoff may transport sediment or tannin leachate if able to mobilise downstream. Runoff in these higher risk areas would be managed primarily through erosion and sediment controls provided in **Chapter 5**, in addition to mitigation measures outlined in **Chapter 11**. These would be established on-site prior to any vegetation clearance work being carried out.

6.1.3 Earthworks

Construction of most Project elements would require excavation or earthworks thereby disturbing and exposing soils. Earthworks are required at all work areas, which as a minimum will involve clearing and preparing sites for works. Sedimentation can occur when rain or runoff comes into contact with these exposed areas, transporting sediment to downstream receiving waterways. Once sediments enter waterways, they can directly and indirectly impact the aquatic environment as detailed below:

- Increased sedimentation and deposition which can alter the geomorphology of waterways if large amounts of sediment are mobilised downstream. Sedimentation can also increase turbidity and reduce water clarity, impacting visual amenity and lead to smothering of aquatic organisms (i.e. by clogging fish gills or smothering aquatic plants), or decreasing trophic interactions due to reduced visibility
- Sediments may also contain high concentrations of nutrients which can lead to algal blooms and subsequently result in reduced light penetration and limited growth of aquatic vegetation. If large volumes of organic sediment are mobilised to downstream receivers, algal blooms may occur which can subsequently cause a reduction in dissolved oxygen within the waterway leading to anoxic conditions resulting in fish-kills
- Mobilised sediments may contain elevated concentrations of metals and other contaminants, which can negatively impact aquatic life, as well as reduce the suitability of the water for other beneficial uses (i.e. drinking, irrigation and recreation).

All waterways in the study area have the potential to be impacted, however the waterways at most risk are those located in close proximity to the work areas and where more significant earthworks would be occurring, including at Trimbles Creek and Lake Yarrunga. Without management, there would be potential for Trimbles Creek, and Lake Yarrunga to receive direct runoff from work areas and major earthwork sites.

Whilst disturbance from earthworks can result in sediment-laden runoff and pollutants temporarily reducing downstream water quality, impacts to surrounding waterways are considered unlikely to occur as construction runoff would be managed with the implementation of site erosion and sediment controls and water quality control measures as outlined in **Chapter 5**, as well as other mitigation measures outlined in **Chapter 11**. Measures to manage and divert runoff at construction sites would be established as the first step in commencement of construction activities to minimise erosion and sedimentation impacts associated with earthworks.

6.1.4 Concrete works

Concrete works will be required at work areas and comprise use of premixed concrete and onsite concrete batching plant.

In the Upper Scheme, premixed concrete will be transported to site via concrete agitator trucks and is required for the anchor block, penstock support structures, foundation of the surge tank and the secondary lining of the vertical shaft. In the Lower Scheme, a concrete batching plant will be required to produce sufficient concrete to line tunnels and in the underground power station structure. Precast concrete may also be used for other Project elements such as the penstock supports transported to site and installed by crane.

Concrete by-products are alkaline, with a pH of around 12 and therefore have the potential to alter the pH of water which can be harmful to aquatic life that are sensitive to changes in water quality. Water from concrete curing can be high in chromium and can accumulate in the gills of fish affecting the health of aquatic organisms. The appropriate management of concrete works to prevent concrete dust, concrete slurries or washout water being discharged to downstream waterways is required.

The main areas at risk from potential mobilisation of concrete waste are waterways which are in proximity to concrete works including Trimbles Creek, Bendeela Pondage, Kings Creek and its ephemeral tributary which are located in close proximity to Laydown / Work Areas and some unnamed ephemeral drainage lines which are located in the vicinity of Project elements requiring concrete works.

While there is potential for concrete works to impact water quality of downstream receivers, the risk of transportation of concrete waste is considered low as erosion and sediment controls, water quality controls and other mitigation measures detailed in **Chapter 5** and **Chapter 11** would be implemented to ensure no runoff is mobilised off-site prior to treatment and controlled discharge downstream.

6.1.5 Site facilities and material laydown

Site facilities and laydown areas will be located at each work area and may comprise of office and cribbing facilities, amenities, storage containers for tools and equipment, car parking and laydown areas, and material storage. Potential pollution pathways to surface water quality could arise from the establishment and use of site facilities and laydowns areas, including:

- Potential for litter and debris to be transported off the laydown area by wind, runoff and/or floods
- Sewage and wastewater spills entering a downstream receiver
- Spills and leaks from construction plant and equipment
- Transportation of soils and sediment associated with vegetation clearing and vehicle movements across exposed earth.

The subsequent impact to surface water quality could therefore be elevated turbidity, nutrients, toxicants and, elevated levels of enterococci or bacteria.

All watercourses in close proximity to site facilities and Laydown / Work Areas are at risk of being impacted without the implementation of appropriate mitigation measures. In particular, these waterways at risk include Trimbles Creek and the unnamed tributaries of Trimbles Creek 1 and 2, the unnamed tributary of Kangaroo River (Upper Scheme and Lower Scheme), Kings Creek, Bendeela Pondage and Lake Yarrunga.

Impacts to surrounding waterways are considered unlikely to occur as construction and site compound runoff would be managed with the implementation of erosion and sediment controls and water quality control measures as outlined in **Chapter 5**, as well as other mitigation measures outlined in **Chapter 11**. Measures to manage and divert runoff at construction sites would be established as early as possible at the commencement of construction activities to avoid and/or manage water quality impacts.

6.1.6 Spoil movement

A large amount of spoil will be generated from tunnelling works associated with underground works and limited excavations within the upper scheme. The spoil from underground works will be removed through the access portal near Kangaroo Valley Power Station and the tailrace portal near Bendeela Power Station. This spoil will then be transported to the spoil emplacement area. A small amount of spoil will also be generated from surface excavation works and from blind boring the headrace shaft.

The keys risks to water quality comes from temporarily stockpiling the excavated material prior to being transported and the transport of excavated material to the spoil emplacement area. Without management, this can result in sedimentation of downstream waterways if high rainfall events and high winds result in exposed materials and soils being mobilised downstream from temporary stockpiles or loss of excavated materials from vehicles moving between sites if not appropriately secured. Material/spoil transport poses the highest risk to waterways adjacent haulage routes and waterways in proximity to ancillary facilities or construction sites, in particular Kings Creek and Bendeela Pondage.

Impacts to surrounding waterways are considered unlikely to occur as construction runoff would be managed with the implementation of site erosion and sediment controls and water quality control measures as outlined in **Chapter 5**, as well as other mitigation measures outlined in **Chapter 11**. Measures to manage and divert runoff at construction sites and in spoil stockpiling areas would be established as the first step in commencement of construction activities to avoid and/or manage water quality impacts from site runoff.

6.1.7 Spoil stockpiling and emplacement

Stockpiles will be located at the separate areas during construction. Smaller stockpiles will be located at Laydown / Work Area 3 and 5 which may present a risk to the water quality of unnamed tributary of Kangaroo River and Bendeela Pondage due to the proximity of stockpiles to these waterways. Spoil from these areas and others will be progressively moved to the main spoil emplacement facility which is anticipated to stockpile 420,000m^3 of spoil. This facility, due to its location, presents a risk to the water quality of the unnamed tributary of Kangaroo River which is the nearest downstream receiver.

It is anticipated that spoil could comprise of NAF and low risk PAF. The re-use of NAF would be prioritised while spoil identified as PAF will require management or encapsulation. Materials identified as PAF present the greatest risk to water quality once exposed to oxygen and water which without appropriate management can result in acid drainage and contamination of downstream surface waters, as well as groundwater.

Stockpiles that are not adequately stabilised or managed can result in material eroding away during high rainfall events. This can introduce sediments, nutrients, acid leachate, hydrocarbons, metals, contaminants and gross pollutants into downstream waterways. Sedimentation can result in increased turbidity which could lead to fish kills and can also reduce light penetration which can limit the growth of aquatic vegetation.

Stockpile management during Project construction would be detailed in the Construction Soil and Water Management Plan (CSWMP). A spoil management strategy has been developed identifying available options for appropriate management spoil including PAF materials to eliminate risk of acid drainage. Options include real time sampling, minimisation of temporary stockpiling, treatment with lime prior to emplacement or complete encapsulation.

Other stockpile mitigation measures will include locating temporary stockpiles away from overland flow paths and providing stabilisation, watering and covering of stockpiles where necessary.

6.1.8 Dewatering and construction discharges

Tunnelling process water

The construction of the vertical shaft, tunnels and other underground works would generate tunnel process water constituting a mix of collected groundwater and water used in the tunnelling process. Tunnel process water would be captured within underground workings and require dewatering with excess water that needs to be discharged if it cannot be reused. An estimated 251.9ML of controlled discharge is anticipated, averaging approximately 4.9ML/month over the period of construction.

As a result of the tunnelling process, tunnel process water is likely to contain elevated levels of suspended solids, potential acid rock drainage and hydrocarbons, plus any known contaminants associated with groundwater in the area which may include elevated salinity and some heavy metals. If water is discharged untreated or poorly treated there is potential to impact the receiving waterways by introducing contaminants into downstream waterways.

Waterways at risk are those where discharge is proposed or downgradient areas where tunnel process water is stored and treated. To minimise the amount of groundwater seepage and potential for oxidation of materials leading to acid rock drainage the tunnels will be lined as soon as practical behind tunnel advancement.

The quality of groundwater in the area is largely unknown with the exception of data from two boreholes KPS 11 and KPS 12 located 280m north and 320m north-east of the Kangaroo Valley Power Station respectively (refer *Technical Report 6 - Hydrogeology*). **Table 6-3** summarises the expected concentrations of sampled contaminants that are likely to be present in groundwater and may require treatment prior to discharge, together the with existing water quality of Bendeela Pondage and Lake Yarrunga (and relevant guideline values) where water is expected to be discharged to one of these storages. Interim SSTVs for Lake Yarrunga are provided in **Appendix A**.

Table 6-3 Summary of groundwater contaminants, existing water quality of Bendeela Pondage (BP) and Lake Yarrunga (LY) and ADWG (2011) guideline values

Analyte	KPS11	KPS12	BP 20th %ile	BP 80th %ile	BP median	LY 20th %ile	LY 80th %ile	LY median	ADWG Guideline values
pH	7.4	7.5	7.3	7.4	7.4	6.8	8	7.6	6.5-8.5[2]
TDS (mg/L)	420	500	63.7[1]	68.4[1]	65.3[1]	55.4[1]	69.1[1]	67.2[1]	<600mg/L[4]
Sodium (mg/L)	34	32	9	10	10	9	11	10	<180mg/L[2]
Potassium (mg/L)	2	4	1	1	1	1	1	1	No guideline
Calcium (mg/L)	34	55	4	5	4.5	4	5	4	No guideline
Magnesium (mg/L)	15	28	3	3	3	2	3	3	No guideline
Chloride (mg/L)	70	95	15.4	17.6	16	15.6	18.4	17	<250mg/L
Sulphate (mg/L)	135	70	2	3	2	2	4	3	<250[2] <500[3]

[1]TDS calculated using formula EC (µs/cm)*0.64 (source: Lenntech, 2022)

[2]ADWG Aesthetic Guideline value

[3]ADWG Healthy Guideline value

[4]ADWG recommend <600mg/L for good palatability

Based on existing groundwater information it appears that almost all indicators are noticeably higher in groundwater when compared to Bendeela Pondage and Lake Yarrunga, although do still meet the recommended ADWG limits. To minimise the potential impacts, it is proposed to treat tunnel process water via a water treatment plant so that it meets the background water quality (SSTVs) of the discharge location and the water quality targets set out in the Kangaroo Valley Raw Water Supply Agreement and the ANZG (2018) guidelines. It is also recommended to undertake further groundwater monitoring to gain a greater appreciation of other key contaminants (i.e. metals and nutrients) that may be present in groundwater in elevated concentrations.

Sediment basin discharges

Controlled discharges: Project construction would result in the controlled discharge of water from temporary sediment basins. By capturing sediments (and subsequently nutrients and toxicants) via temporary sediment basins, the risk to downstream water quality would be reduced. To meet NorBE, controlled discharge of basins would occur following treatment, in accordance with the Blue Book (within 5 days of a rainfall event), when turbidity and pH concentration in the discharge are similar to existing water quality of the receiving waterways.

If after all reasonable and practicable measures have been implemented to avoid the discharge of water (including re-use options) unsuitably high levels of sediment remain in the runoff collected in the basin, the use of fine gypsum naturally occurring or flocculation to improve the settlement of dispersible soil particles in the sediment basins will be considered. Application of gypsum will be in accordance with relevant guidelines and the pH and electrical conductivity will be monitored to achieve compliance with ANZG (2018) and/or the water quality of downstream receivers prior to discharge to minimise any impact to aquatic ecosystems.

Uncontrolled discharges: With respect to basin discharges, the main risk to water quality of downstream receivers is during and following a significant rainfall event when the design capacity of the basin is exceeded, resulting in an uncontrolled discharge. Uncontrolled discharges are likely to result in high turbidity and subsequently elevated levels of nutrients and/or heavy metals which are bound to the sediment. Waterways at risk of sediment basin discharges are Trimbles Creek, the unnamed tributary of Yarrunga Creek 2, unnamed tributary of Kangaroo River (Lower Scheme) and Kings Creek as they are located downstream of likely sediment basin locations.

Basins that discharge directly or very close to a waterway present a greater risk to downstream water quality compared to those that discharge via overland flow. For this Project there are two potential basins that discharge into Trimbles Creek with minimal overland flow path which, if not treated appropriately, could impact the water quality of Trimbles Creek. Currently, there is no existing water quality information for Trimbles Creek, which is ephemeral and in a disturbed state at the proposed basin discharge locations due to previous instream works to install the existing scheme.

Given the proximity to Trimbles Creek, its ephemeral nature and there being only a small catchment area above the Project location, Trimbles Creek is unlikely to provide any dilution or assimilation of basin discharges that have elevated TSS. However, by also considering that the waterway is ephemeral and high in the catchment, it is expected that any water that flows via uncontrolled discharges to this waterway is unlikely to mobilise any significant distance to downstream. Importantly, the consequence of an uncontrolled discharge mobilising to Trimbles Creek would be minor as it is not considered to be a highly sensitive aquatic ecosystem, with the nearest highly sensitive SRE being several km downstream. Higher sediment concentrations in uncontrolled discharges is therefore expected to assimilate into the water within Trimbles Creek within a reasonable distance of the discharge point and would not impact on the environmental values of the water way. In addition, large rainfall events which would result in an uncontrolled discharge would be rare, therefore the risk is considered low. Nevertheless, Trimbles Creek has been identified as a priority area for erosion and sediment control development as part of detailed design.

6.1.9 Rock blasting

Blasting of rock is required as part of the construction of the Lower Intake / Outlet which requires the use of chemicals that can be harmful to aquatic ecosystems should they enter nearby waterways. Kings Creek and Lake Yarrunga are the surface water bodies at most risk of being impacted from rock blasting. The key risk to water quality is from leakage or spills of petroleum, oils, and other chemical contaminants from construction machinery, plant equipment, refuelling and vehicles traveling to and from site. This may result in the release of heavy metals, potentially hazardous substances such as ammonia and nitrate, and hydrocarbons which can be toxic to aquatic species. Additionally, blasted rockpiles that are not appropriately managed prior to being transported off site have the potential to contaminate surface water during rainfall events.

Rock blasting may take place within an enclosed instream work area (dry site) which may be constructed via a cofferdam that would be built into Lake Yarrunga at the Lower intake / outlet works area. The dry site will ensure no contaminants are released off-site or into Lake Yarrunga. Erosion and sediment controls, as described in **Chapter 5,** would be established around Laydown / Work Area 6 to ensure no contaminants from blasted rockpiles are able to mobilise from surface water runoff. Other mitigation measures outlined in **Chapter 11** will additionally be implemented to ensure contaminants are not mobilised to downstream receivers.

6.1.10 Steelworks

Approximately 7500 tonnes (t) of steel will be required during construction for a number of components including pipe and shaft lining, transformers, turbines, generators and other incidentals. Additionally, laydown areas will also contain areas for storage of pipe and surge tank steel. Steel cuttings may be mobilised to downstream waterways during steelworks which can result in increased toxicity of the waterway from leaching of heavy metal constituents (i.e. Iron, aluminium or chromium).

Contamination from steel works would be captured on site via water quality controls as described in **Chapter 5**. Other mitigation measures outlined in **Chapter 11** will additionally be implemented to ensure contaminants are not mobilised to downstream receivers.

6.1.11 Instream works

Temporary instream works would be required for the installation of the Penstock Anchor Block in Trimbles Creek and for the establishment of a cofferdam in Lake Yarrunga if required.

The installation of the anchor block at the penstock low point would involve works within Trimbles Creek largely limited to the disturbed existing scheme creek crossing. Instream works may result in the disturbance of sediment during excavation activities (including vegetation clearing) which may in turn increase sedimentation to the downstream receiver. Vegetation clearing within and near waterways may result in mobilisation of instream sediments, destabilisation of riverbanks and/or erosion of exposed topsoils via wind or runoff. Mobilised sediment may result in increased turbidity that can be detrimental to aquatic life, result in algal blooms and can reduce visual amenity.

Installation of a sediment curtain, coffer dam or alternate measure to manage water quality in Lake Yarrunga would be required at the inlet/outlet structure to minimise impacts to water quality from the rock blasting at the earthen block bank. While a cofferdam is a water quality control to minimise movement of sediment and other contaminants downstream, construction of the cofferdam will require dewatering around the construction area and surface water that seeps into the cofferdam will require extraction. If a coffer dam were adopted, dewatering from within the temporary cofferdam would be discharged into a sediment basin for treatment prior to be discharge back into Lake Yarrunga.

All works in the bank and bed of Lake Yarrunga would occur within a sediment curtain, coffer dam or alternate measure to manage water quality.

6.1.12 Tunnelling and underground works

Construction of the Project will involve approximately 6.8 km of tunnelling and 530 m of vertical boring. The primary tunnelling method is via roadheader, following which shotcrete is applied to the excavated tunnel walls. During construction, tunnelling activities would generate wastewater from groundwater ingress, which would need to be discharged if it can’t be reused. If water is discharged untreated or poorly treated there is potential to impact the receiving waterways (refer **Section 6.1.8**).

Tunnelling requires the excavation of shafts, which together with the tunnel will create a considerable amount of excavated material. This excavated material would require stockpiling and transport of site which is discussed in **Sections 6.1.6** and **Section 6.1.7**. Excavation of the shafts also requires a considerable work area which may require clearing of vegetation and topsoil. As discussed in **Section 6.1.2,** the disturbance of soil could increase the potential for soil erosion causing sediments, nutrients and other contaminants bound to the soil being transported to downstream waterways resulting in increased turbidity, lower dissolved oxygen and increased concentrations of nutrients due to increased sediment. This may lead to algal blooms, aquatic weed growth and reduced visual amenity.

Additionally during tunnelling there is risk of acid formation and subsequent acid leachate should excavation occur through acid forming rock. To minimise the risk to the quality of water during dewatering, rapid application of tunnel lining will occur.

6.2 Impacts on hydrology from construction activities

Water extraction from surface waters is not proposed during construction of the Project with the exception of water captured in sediment basins that may be re-used. As such, the only potential impacts to hydrology may result from groundwater drawdown from tunnelling and underground excavation works, as well as increased impervious surfaces from site works and surface hardening use of heavy machinery. These are discussed in the sections below.

6.2.1 Tunnelling and underground works

Surface environmental water availability and flows have the potential to be reduced as a result of groundwater drawdown during tunnelling and excavation of the underground caverns.

In particular, the groundwater assessment (refer to *Technical Report 6 – Hydrogeology*) calculates the pre-excavation baseflow contribution to the lower reaches of Kings Creek to be of the order of 18.1 m^3/day (0.21 L/s), reducing to 5.95 m^3/day (0.07 L/s) following excavation (in the absence of mitigation), a reduction of 12.12 m^3/day (0.14 L/s). Given the observed bedrock substrate, this is considered to be a very conservative assessment.

While this represents a potentially significant reduction in the estimated baseflow contribution to this lower reach of Kings Creek (approximately 67%), the section of the creek which is considered likely to have a groundwater baseflow component corresponds with the section of the creek in the lower lying area adjacent to Lake Yarrunga (sitting between approximately 56 mAHD and 60 mAHD), parts of which are influenced by short-term inundation by Lake Yarrunga. As such, any reduction in baseflows is unlikely to result in long-term or significant impacts to the hydrological function of Kings Creek. Moreover, baseflow reductions to the lower portion of Kings Creek are expected to be temporary, as full water level recovery is expected following the completion of construction.

6.2.2 Site works and impervious surfaces

Due to the scale of the Project, construction works would result in an increased hardening of ground surfaces across the Project disturbance area, for instance, from temporary buildings and roofs in Laydown / Work Areas, and along access roads which would be levelled and covered with compacted road base, or sealed with concrete / asphalt. This will result in reduced infiltration and increased surface water runoff on site. This could result in an increase in the quantity of water reaching local catchment streams and potential erosion and scour.

Whilst it is expected that there would be more impervious surfaces within the disturbance area during construction, the risk of increased surface water runoff resulting in significant hydrological changes is considered negligible as the Laydown / Work Areas, access roads and haulage routes would be maintained throughout the duration of the construction phase, and any runoff would be captured on-site in temporary sediment basins therefore would not flow off-site uncontrolled. Further, any changes to hydrology would be temporary and sites would be progressively stabilised and rehabilitated to their original states as far as practicable as works are completed.

6.3 Impacts on geomorphology from construction activities

6.3.1 Instream works

Proposed instream works have the potential to impact on the geomorphological condition of Lake Yarrunga and Trimbles Creek from erosion and sedimentation. In particular, the key risk to geomorphology of these waterways from temporary instream works is downstream deposition of sediment within the channel, potentially leading to alteration of flow and subsequent changes in the channel bed and banks.

While there is potential for minor geomorphological impacts to occur, they are considered unlikely with the implementation of erosion and sediment control measures outlined in **Chapter 5** and other mitigation measures outlined in **Chapter 11**. As such, the risk of changes to geomorphology are considered very low.

6.3.2 Dewatering and construction discharges

Dewatering and construction discharges have the potential to impact on the geomorphological condition of waterways. The nature of the pathways via which an impact can occur from these construction activities and mitigation measures is the same as that previously described in the section for instream works (refer to **Section 6.3.1**).

6.4 Risk assessment

Identified impacts largely relate to potential construction activities mobilising sediments or other contaminants to downstream waterways via stormwater, as well as discharge of sediment basins and reductions in groundwater contribution. A risk assessment for residual impacts to downstream waterways following implementation of recommended controls is provided in **Table 6-4,** with the rationale for the risk assessment outcome provided based on works required, existing conditions and mitigation measures that will be implemented.

Table 6-4 Determination of overall potential impact risk per waterway

Waterway	Consequence	Likelihood	Risk	Rationale
Fitzroy Falls Upper Canal	Minor	Unlikely	Very Low	▪ Fitzroy Falls Upper Canal largely runs in parallel with the Promised Land Trail and is therefore at risk from earthworks and vegetation removal associated with widening of this trail. With the implementation of mitigation measures, downstream water quality may be impacted if sediments are mobilised via wind only. There is no risk of surface water runoff reaching the Canal due to the significant embankment which separates the Promised Land Trail from the Canal ▪ Establishment of Laydown / Work Area 1 and work associated with the Upper Intake could result in a disturbance of up to 55,000m2 largely from earthworks and vegetation removal. Given the proximity to the Upper Canal, earthworks and removal of vegetation could present a minor risk to water quality during the construction phase if exposed soils are mobilised by wind. Erosion and sediment controls, as well as other mitigation measures, particularly dust suppression, will be implemented to ensure transport of sediments via wind would be unlikely ▪ Once established, Laydown / Work Area 1 would allow for various construction works on site such as site office, concrete batching and cranes which could present a minor risk to water quality if runoff from the work area resulted in transport of contaminants, particularly concrete dust, to the Fitzroy Falls Upper Canal ▪ With the implementation of proposed water quality controls outlined in **Chapter 5** and other mitigation measures outlined in **Chapter 11** the risk to the water quality of Fitzroy Falls Upper Canal from the above-mentioned works is very low.
Unnamed tributary of Trimbles Creek 1	Negligible	Unlikely	Very Low	▪ Unnamed tributary to Trimbles Creek 1 traverses Laydown / Work Area 1 in its upstream reaches. The tributary is at risk from earthworks and vegetation clearing to establish the worksite if surface runoff were to mobilise sediment and contaminants to this downstream receiver. Additionally, the tributary will receive discharges from a sediment sump located on the south-eastern side of the Laydown / Work Area 1 footprint ▪ The Laydown / Work Area will involve establishment of hardstand areas where there could be increased runoff and transport of contaminants to the unnamed tributary of Trimbles Creek 1.

Waterway	Consequence	Likelihood	Risk	Rationale
				▪ The tributary itself has very low environmental sensitivity and is unlikely to support aquatic ecosystems. Trimbles Creek downstream is not considered to be a highly sensitive waterway. Given the ephemeral nature of the tributary, water quality impacts from earthworks and removal of vegetation would be negligible. Discharges from sediment sumps to this drainage channel would similarly result in negligible water quality impacts. No impacts to downstream Trimbles Creek are anticipated from transport of surface runoff to the unnamed tributary of Trimbles Creek 1 ▪ With the implementation water quality controls outlined in **Chapter 5** and other mitigation measures outlined in **Chapter 11**, transport of sediments and other contaminants to the Unnamed tributary of Trimbles Creek 1 via surface runoff would be unlikely.
Unnamed tributary of Trimbles Creek 2	Negligible	Unlikely	Very Low	▪ Unnamed tributary to Trimbles Creek 2 traverses Laydown / Work Area 1 in its upstream reaches. The tributary is at risk from earthworks and vegetation clearing to establish the worksite if surface runoff were to mobilise sediment and contaminants to this downstream receiver. Additionally, the tributary will receive discharges from two sediment sumps located on the eastern side of the Laydown / Work Area 1 footprint ▪ The Laydown / Work Area will also involve establishment of hardstand areas where there could be increased runoff and transport of contaminants to the unnamed tributary of Trimbles Creek 2 ▪ The tributary itself has very low environmental sensitivity and is unlikely to support aquatic ecosystems. Trimbles Creek downstream is not considered to be a highly sensitive waterway. Given the ephemeral nature of the tributary, water quality impacts from earthworks and removal of vegetation would be negligible. Discharges from sediment sumps to this drainage channel would similarly result in negligible water quality impacts. No impacts to downstream Trimbles Creek are anticipated from transport of surface runoff to the unnamed tributary of Trimbles Creek 2 ▪ With the implementation of water quality controls outlined in **Chapter 5** and other mitigation measures outlined in **Chapter 11**, transport of sediments and other contaminants to the Unnamed tributary of Trimbles Creek 2 via surface runoff would be unlikely.

Waterway	Consequence	Likelihood	Risk	Rationale
Unnamed tributary of Yarrunga Creek 1	Negligible	Unlikely	Very Low	▪ The upstream extent of the Unnamed tributary to Yarrunga Creek 1 is in close proximity to works associated with the Promised Land Trail. There would be some minor earthworks and vegetation clearing in this area and the tributary will receive discharges from a sediment sump located on the western side of the Laydown / Work Area 1 footprint ▪ The tributary itself has very low environmental sensitivity and is unlikely to support aquatic ecosystems. The nearest highly sensitive receiver is Yarrunga Creek. Given the ephemeral nature of the tributary and distance from Yarrunga Creek, any runoff resulting in poor water quality runoff is highly unlikely to reach Yarrunga Creek. Potential impacts to downstream water quality are therefore considered negligible ▪ With the implementation of water quality controls outlined in **Chapter 5** and other mitigation measures outlined in **Chapter 11**, transport of sediments and other contaminants to the unnamed tributary of Yarrunga Creek via surface runoff would be unlikely.
Trimbles Creek	Minor	Possible	Low	▪ Instream works are proposed at Trimbles Creek for the installation of the Penstock Anchor Block. Instream works will involve vegetation removal, excavation and concrete works. Potential impacts from these activities present moderate risk to water quality of Trimbles Creek downstream if flows mobilise sediment and contaminants. Erosion and sediment control, as well as other mitigation measures will be implemented to minimise changes to downstream water quality ▪ Temporary instream works also have the potential to result in minor downstream impacts to geomorphology from deposition of sediment ▪ Runoff is proposed to be managed by progressive erosion and sediment controls which may include capture via temporary sediment basins. Controlled discharge of water from the sediment basins would be treated to meet existing water quality at the time of discharge (or pre-construction water quality if available). In the event of a significant rain event, however, sediment basin overflows may result in uncontrolled discharges to Trimbles Creek which may have a minor but temporary impact on water quality ▪ Importantly, given the ephemeral nature and existing disturbed conditions of Trimbles Creek, it is considered likely that any change in water quality would be temporary and contained to the study area, except during a major flood event.

Waterway	Consequence	Likelihood	Risk	Rationale
Unnamed tributary of Yarrunga Creek 2	Negligible	Unlikely	Very Low	▪ The upstream extent of the unnamed tributary to Yarrunga Creek 2 is in close proximity to works associated with Laydown / Work Area 2. There would be earthworks and vegetation clearing in this area to establish the worksite and the tributary will receive discharges from a sediment basin located on the western side of the Laydown / Work Area 2 footprint ▪ The tributary itself has very low environmental sensitivity and is unlikely to support aquatic ecosystems. The nearest highly sensitive receiver is Yarrunga Creek. Given the ephemeral nature of the tributary and distance from Yarrunga Creek, any runoff resulting in poor water is highly unlikely to reach Yarrunga Creek. Potential impacts to downstream water quality are therefore considered negligible ▪ As Laydown / Work Area 2 will involve establishment of hardstand areas, there could be increased runoff and transport of contaminants associated with proposed uses of Laydown / Work Area 2 to the unnamed tributary of Yarrunga Creek 2 ▪ Runoff is proposed to be captured via temporary sediment basins which would capture and treat water. Controlled discharge of water from the sediment basins would be treated to meet existing water quality at the time of discharge and therefore presents a low risk to downstream water quality ▪ With the implementation of water quality controls outlined in **Chapter 5** and other mitigation measures outlined in **Chapter 11**, transport of sediments and other contaminants to the Unnamed tributary of Yarrunga Creek via wind or surface runoff would be unlikely.
Kings Creek	Minor	Likely	Low	▪ Establishment of Laydown / Work Area 6 will involve earthworks and vegetation clearing to establish hardstand areas, which, due to the proximity to and perennial nature of Kings Creek, may have minor water quality impacts if surface water runoff mobilise sediment and contaminants during works ▪ At Laydown / Work Area 6, there could be increased runoff and transport of contaminants associated with excavation, placement of spoil and concrete waste/dust from the concrete batching plant which could present a moderate risk to water quality of Kings Creek.

Waterway	Consequence	Likelihood	Risk	Rationale
				▪ Runoff is proposed to be captured via temporary sediment basins which would capture and treat water. Controlled discharge of water from the sediment basin would be treated to meet NoRBE and therefore the risk to downstream water quality is low ▪ With the implementation of water quality controls outlined in **Chapter 5** and other mitigation measures outlined in **Chapter 11**, transport of sediments and other contaminants to Kings Creek via wind or surface runoff would be unlikely ▪ Groundwater baseflows in Kings Creek are predicted to be reduced by approximately 12.12 m^3/day (0.14 L/s). While this represents a potentially significant reduction in the estimated baseflow contribution to this lower reach of Kings Creek (approximately 67%), the section of the creek which is considered likely to have a groundwater baseflow component corresponds with the section of the creek in the lower lying area adjacent to Lake Yarrunga (sitting between approximately 56 mAHD and 60 mAHD), parts of which are influenced by short-term inundation by Lake Yarrunga. As such, a reduction in baseflows is unlikely to result in long-term or major impacts to the hydrological function of Kings Creek. Moreover, baseflow reductions to the lower portion of Kings Creek are expected to be temporary, as full water level recovery is expected following the completion of construction.
Bendeela Pondage	Minor	Unlikely	Low	▪ Establishment of Laydown / Work Area 5 will involve earthworks and vegetation clearing to establish hardstand areas. Additionally, proposed uses of Laydown / Work Area 5 can result in leaks and spills, rubbish and debris and sediment being transported downstream. Due to the proximity to Bendeela Pondage, this presents a minor risk to water quality without any management controls ▪ Bendeela Pondage is in close proximity to the temporary stockpiling of spoil at Laydown / Work Area 5. Additionally, the proposed haulage route for transport of spoil to the spoil emplacement area is via access roads that traverse around the base of the embankment walls of Bendeela Pondage ▪ With the implementation of water quality controls outlined in **Chapter 5** and other mitigation measures outlined in **Chapter 11**, and the embankment around the storage facility which would also provide protection, the risk of adverse water quality if spoil was mobilised due to runoff or wind is low

Waterway	Consequence	Likelihood	Risk	Rationale
				▪ Groundwater collected during construction from tunnel and shaft excavation is proposed to be treated and may be discharged directly to Bendeela Pondage. Groundwater would be treated at a treatment plant to meet SSTVs, ANZG (2018) and the Kangaroo Valley Raw Water Supply Agreement and therefore discharges present a low risk to water quality.
Unnamed tributary of Kangaroo River	Moderate	Unlikely	Low	▪ Unnamed tributary to Kangaroo River traverses much of the study area from its upstream reaches near Laydown / Work Area 3 and the Promised Land Trail to where it discharges to Kangaroo River upstream of Lake Yarrunga. ▪ Runoff is proposed to be captured via temporary sediment basins which would capture and treat water. Controlled discharge of water from the sediment basins would be treated to meet NoRBE at the time of discharge and therefore presents a low risk to downstream water quality ▪ Given the ephemeral nature of the tributary and distance from Kangaroo River, should any runoff result in poor water quality, for example uncontrolled discharge, it is unlikely to cause a measurable change in the Kangaroo River.
Lake Yarrunga	High	Unlikely	Medium	▪ Construction of a new intake structure at Lake Yarrunga presents a medium risk to water quality from earthworks and vegetation removal, instream works, establishment of a cofferdam (if required), dewatering, rock blasting and runoff and or spills/leakages from site facilities at Laydown / Work Area 6 ▪ Temporary instream works have the potential to result in minor downstream impacts to geomorphology from deposition of sediment ▪ Groundwater collected during construction from tunnel and shaft excavation is proposed to be treated and may be discharged directly to Lake Yarrunga. Groundwater would be treated at a treatment plant to meet SSTVs, ANZG (2018) and therefore discharges present a low risk to water quality ▪ In addition, when Bendeela Power Station is in pumping mode, it will draw water from the surrounding area which would transfer to Bendeela Pondage. If water is highly turbid from instream activities, this may result in higher turbidity of water delivered to the Kangaroo Valley WTP from Bendeela Pondage

Waterway	Consequence	Likelihood	Risk	Rationale
				▪ To manage the risks, water quality and management controls will be implemented. This may include the construction of a cofferdam. This will require dewatering during construction of the cofferdam and of any water that seeps in during construction of the intake. Water to be dewatered could be highly turbid from instream works. To minimise risk, it is proposed to treat water from dewatering activities to meet SSTVs of Lake Yarrunga and therefore meet NorBE.

7. Potential operational impacts

During the operational phase of the Project, all construction access roads for the various Project elements would be maintained, cleared areas would be stabilised and rehabilitated as required and scour protection would be installed at any outlets along the pipeline alignment. All Project elements would be constructed and commissioned, and construction work sites would be progressively decommissioned following the completion of the works.

The potential impacts to surface water of waterways and waterbodies associated with operation relates to stabilisation of instream structures and maintenance, ongoing discharge of groundwater seepage collected in underground structures, infrequent maintenance flows at the Penstock Anchor Block discharge point and transfer of water between Fitzroy Falls and Lake Yarrunga reservoirs. Potential impacts and their associated risk to water quality, hydrology and geomorphology during operation are identified in **Section 7.1**, **Section 7.2** and **Section 7.3**, respectively. With the implementation of recommended mitigation measures, a risk assessment of residual impacts to waterways and waterbodies in the study area is provided in **Section 7.4**.

7.1 Impacts to water quality from operation

7.1.1 Minor impacts due to instream structures and maintenance

Erosion and sedimentation

There is a period of time following the completion of construction where recently disturbed soils are susceptible to scour and erosion from stormwater runoff. This results in sedimentation, which can have both direct and indirect impacts on water quality.

Direct impacts of large volumes of sediments mobilising to downstream receivers include reducing light penetration (limiting the growth of macrophytes), clogging fish gills, smothering of benthic organisms and reduced visibility for fish.

Indirect impacts of sedimentation occur over the longer term and include accumulation of sediments instream, altering stream geomorphology and release of pollutants such as heavy metals and nutrients which may contribute to algal blooms.

Suitable stabilisation and management techniques would be implemented during the periods of vegetation establishment to minimise the potential for erosion within areas of rehabilitation. Provided appropriate controls are implemented, short-term impacts during the establishment period would be expected to be manageable with negligible impacts on receiving water quality.

Accidental spills

There is potential for contamination of downstream waterways from accidental spill of vehicle oils, lubricants and hydraulic fluids and other accidental spill from maintenance vehicles. Spills and leakages can impact water quality by:

- Increasing toxicant concentrations into downstream watercourses which may be toxic to aquatic biota and fish
- Creating oily surface films which can reduce the visual amenity of the watercourse.

While there is potential for minor impacts, maintenance activities will be carried out in accordance with standard Origin operational management procedures which aim to ensure protection of the environment. As such, impacts would be negligible and managed through standard spill response procedures which are applied under current management.

7.1.2 Discharge of tunnel seepage

Once operational, the tailrace and headrace tunnels, and the pressure shaft will be undrained, however the main access tunnels and caverns will be drained and therefore ongoing water infiltration is expected over the life of the asset. Water would be collected via a drainage and sump system at the lowest level in the underground power station. Seepage rates are estimated as approximately 2.78 ML/month (91.26 kL/day or 1.06 L/s) (refer Appendix J of the EIS (Groundwater impact assessment)).

While the quality of groundwater of the area is generally unknown, captured groundwater may have elevated conductivity and may contain traces or small concentrations of hydrocarbons. During operation natural groundwater that is collected will be mixed with water collected from the operation of the underground power station. This groundwater and runoff from operation is likely to be of poorer quality than the water quality of the receiving environment which is proposed to be Lake Yarrunga. It is proposed that water would be separated via an oily water separator, monitored and treated to an acceptable standard (where required) and then injected into the tailrace tunnel where it would mix with water from the reservoirs inside the tunnels, before flowing out to Lake Yarrunga during generation or Fitzroy Canal during pumping. Based on generation and pumping rates of over 30,000 l/s, the level of dilution is high. Confirmation of seepage water quality would dictate the need for additional water treatment such that it would achieve neutral or beneficial outcomes at the point of discharge to the existing scheme.

Following treatment and dilution via the tailrace tunnel, water quality of the groundwater seepage that reaches Lake Yarrunga or Fitroy Canal is expected to be indistringuishable from the water quality of the intake water and as the Project would operate in accordance with the WAL that authorises water transfers between the two reservoirs is considered a neutral water quality outcome.

7.1.3 Maintenance works – Penstock pipeline

System maintenance during operation would require drainage of the pipeline section between the Canal and the surge tank at times. When required, drainage would necessarily be via the discharge control structure at the Penstock low point to Trimbles Creek. This is expected to take place infrequently (once every 5 years) when the pipeline needs to be entirely emptied for maintenance, inspection, repair, or in the event of an emergency. The risk to water quality of the downstream environment is dependent on the quality within the pipeline at the time of discharge. As water in the pipe will frequently move between the two reservoirs, it is expected that the water quality within the system would be reflective of Lake Yarrunga SSTVs and in accordance with scheme operating rules and as such acceptable for release downstream.

The potential for scouring at the outlet and sedimentation of downstream Trimbles Creek is an identified risk requiring management. Scour of the channel would be all but prevented by the design of the outlet and by limiting the discharge rate. As a result, it is expected that this activity would result in negligible impact on water quality.

7.1.4 Transfer of water between reservoirs

While the pumping of water between reservoirs is already occurring under the existing scheme, the Project would involve almost doubling the electricity generation capacity of the existing scheme and as such increase the rate at which water is transferred. Therefore while the total volume transferred in any cycle would not increase, the rate of transfer would approximately double if both the existing scheme and the new scheme are operated at the same time.

A consideration for the existing scheme which would be extended to the new scheme is the risk of transfer of algae between reservoirs, and subsequently on the effectiveness of the Kangaroo Valley WTP to adequately treat water.

Table 7-1 provides median algal counts and biovolume between the three storages. Algal counts in Fitzroy Falls Reservoir are eight times higher and almost three times higher than counts in Lake Yarrunga and Bendeela Pondage respectively. Similarly, toxic cyanobacteria counts in Fitzroy Falls are 13 times higher than counts in Lake Yarrunga and eight times higher than counts in Bendeela Pondage. Similarly, Fitzroy Falls Reservoir had higher cyanobacteria and toxic algal biovolume compared with the other reservoirs most notable was median toxic algal cyanobacteria which was 20 to 25 times higher than Lake Yarrunga and Bendeela Pondage respectively. It is important to note that these transfers occur under the existing scheme and the increased rate of transfer within the new scheme under operation is not expected to increase the risk of this occurring as the volume transferred would not change.

Further, the Project does not involve additional transfers of water to Bendeela Pondage from which the Kangaroo Valley WTP draws water.

To manage this risk, the existing scheme and the new scheme will continue operating in accordance with the Water Supply Work and Water Use Approval whereby transferring water between storages is not permitted when Cyanobacteria counts are above 50,000 cells/mL toxic *Microcystis aeruginosa* or toxic cyanobacteria biovolume is >4mm^3/L. Over the reported monitoring period neither toxic *Microcystis aeruginosa counts* or toxic cyanobacteria biovolume threshold have been exceeded at the three sites

Table 7-1 Median algal counts and biovolume in Lake Fitzroy Falls, Lake Yarrunga and Bendeela Pondage

Indicator	Lake Fitzroy Falls at Midlake	Lake Yarrunga at Kangaroo River at Bendeela Pondage Station	Bendeela Pondage
Algal Total Count (cells/mL)	172800	21260	58970
Toxic Total Algal Count	1810	69	207
Cyanobacteria Total Count (cells/mL)	167600	12350	46080
Toxic Cyanobacterial Count (cells/mL)	1670	0	138
Cyanobacterial biovolume (mm^3/L)	1.24	0.08	0.286
Total toxic algal biovolume (mm^3/L)	0.05	0.002	0.005

7.2 Impacts on hydrology from operation

7.2.1 Transfer of water between reservoirs

Extraction from catchment streams is not proposed for the operational stage of the Project, however, water transfers between Fitzroy Falls Reservoir and Lake Yarrunga will continue to be undertaken under the water allocation for the existing pumped hydro scheme and in accordance with the WAL. So while no more water will be used during operation of the Project, it will involve almost doubling the electricity generation capacity of the existing scheme therefore if under the worst case scenario the Project is operated at the same time as the existing scheme, then the rate at which water will be exchanged between the reservoirs will approximately double. This is not expected to result in any significant hydrological changes within the catchment, although water level in the reservoirs will fluctuate more rapidly. This may lead to changes in channel bank geomorphology (further discussed in **Section 7.3.1**), which could lead to in-lake water quality impact from increased turbidity.

The increase in flow rate will result in an increase in water velocities in the Fitzroy Canal both during pumping and generation. This change is not expected to have any effect on sediment movement or other water quality parameters.

Noting that combined scheme operation is limited by design flow rates in the Fitzroy Canal, the minimum time in which the full 4021ML water allowance could be transferred in generation mode is 13 hours. This would result in a water level change in Fitzroy Falls reservoir of between 0.8 and 1 m, and 0.5 m in Lake Yarrunga. As previously stated, the Project would not alter the minimum or maximum water levels in either the Fitzroy Falls Reservoir or Lake Yarrunga which are approximately two and five m below full supply level respectively.

With appropriate design, discharge velocities at Lake Yarrunga would be managed such that scour at the discharge point is avoided.

7.2.2 Underground tunnels and cavern

While there is possibility of groundwater drawdown from seepage in the access tunnels and caverns, based on groundwater hydrological modelling (refer to *Technical Report 6 – Hydrogeology*), significant changes to baseflows in creeks within the catchment are not expected from groundwater seepage during operation. As such, impacts to surface environmental water availability and flows are not expected.

7.3 Impacts on geomorphology from operation

7.3.1 Transfer of water between reservoirs

Under the existing scheme, it would take approximately 68 hours to transfer the full 4021 ML water transfer allocation and complete a full power generation cycle (40 hours pumping and 28 hours of power generation). Note that in reality the existing scheme and proposed Project operating regime respond to the electricity price fluctuations as dictated by the NEM, with pumping and generation cycles typically being of much shorter duration.

With the proposed expansion a complete full power generation cycle will be reduced to approximately 28.5 hours (15.5 hours pumping and 13 hours of power generation). The range of operational water levels will stay the same for Fitzroy Falls (1.01 m) and Lake Yarrunga (0.528 m), but the rate of rise/fall in water levels will be increased if the scheme is operated together with the existing scheme. **Table 7-2** shows a comparison of changes in level and rate of rise/fall with current and future proposed operations.

Table 7-2 Comparison of changes in range of levels and rate of rise/fall (+/-) with current and future proposed operation (source: Origin Energy 2018).

Phase	Fitzroy Falls				Lake Yarrunga			
	Current		Future		Current		Future	
	Range (m)	Rise/Fall (+/-)	Range (m)	Rise/Fall (+/-)	Range (m)	Rise/Fall (+/-)	Range (m)	Rise/Fall (+/-)
Pumping	1.01	+0.025 m/hr	1.01	+0.065 m/hr	0.528	-0.013 m/hr	0.528	-0.034 m/hr
Power Generation	1.01	-0.036 m/hr	1.01	-0.078 m/hr	0.528	+0.019 m/hr	0.528	+0.041 m/hr

Notes:
1. Current Operations - Assumes 40 hrs of pumping and 28 hours power generation
2. Future Operations – Assumes 15.5 hrs of pumping and 13 hours power generation

During a pumping phase, under current operations water levels will rise at Fitzroy Falls at a rate of +0.025 m/hr. This would increase to +0.065 m/hr under future operations. At Lake Yarrunga, water levels fall at -0.013 m/hr under current operations. This would rise to -0.034 m/hr with future operations.

During power generation, under current operations water levels will fall at Fitzroy Falls at a rate of -0.036 m/hr. This would increase to -0.078 m/hr under future operations. At Lake Yarrunga, water levels would rise at +0.019 m/hr under current operations. This would rise to +0.041 m/hr with future operations.

The range in operational water levels will vary with many cycles having a range of less than 0.5 m at Fitzroy Falls and less and 0.25m at Lake Yarrunga. In addition, after a generation cycle, it may be days before the water is pumped back up to Fitzroy Falls.

In addition to variation in lake levels due to the existing scheme and proposed Project, both reservoirs are subject to inflows from their catchments, and experience losses mainly due to releases for downstream water users. The rates of rise in water level during large rainfall events can be higher than the combined existing scheme and proposed Project, the rate of fall due to downstream releases is lower than that caused by generation and pumping.

However, the effect of all this variability in water levels is that the reservoirs generally experience varying water levels and therefore the banks are not exposed to wind generated wave erosion at the same height which can cause notching and increased localised erosion. Frequent wetting and drying of the same area of shoreline/riverbank can weaken substrates, increasing the risk of erosion. Rapid lowering of water levels, in particular, has the potential to initiate bank erosion and slope failures. If water levels drop at a rate faster than the rate in which the banks would naturally drain, the risk of failure is increased. The rate of water level drop is greatest in Fitzroy Falls, but this reservoir has relatively gentle bank slopes which reduces the risk of slope failure.

Figure 7-1 shows photographs of Kangaroo River within the vicinity of Bendeela Pumping Station. The riverbanks appear to be generally stable. There are no obvious signs of bank instability, although some notching of the riverbank appears to be evident, this is represented by linear features which indicate that water has remained at a constant level for period of time forming an erosion notch.

Some sedimentation in the formation of bar development is noted in the channel which is what is expected in the upper parts of the weir pool (**Figure 7-1**) and is a response to the backwater effects of Lake Yarrunga Weir (deacceleration of flow velocity and pondage of water which leads to sedimentation and bar development). Transfers of water between the reservoirs would not impact on sedimentation and bar development in Lake Yarrunga. Transfer of water between the reservoirs will also increase fluxes of water through Fitzroy Canal and connecting inlet/outlet to Fitzroy Falls Reservoir. This has the potential to cause increased scour along the canal and also localised scour in the area where water flows into and out of the reservoir. With the Fitzroy Canal design flow limits not being exceeded by the Project in combined operation with the existing scheme, the risk is considered limited.

Overall, it is considered that there is low risk of erosion of riverbanks in both Fitzroy Falls and Lake Yarrunga with proposed operations.

Figure 7-1 Photos of Kangaroo River within the vicinity of Bendeela Pumping Station (September 2004)

The risk of erosion to shorelines at Fitzroy Falls Reservoir is considered very low, due to the shallow gradient of shoreline and vegetated cover.

7.3.2 Maintenance works – Penstock pipeline

At any such time that the system requires maintenance during operation, drainage of the pipeline via the outlet at the Penstock Anchor Block discharge point to Trimbles Creek would occur. Currently the maximum discharge through the existing scour valve is 25ML/d and it is proposed that scour valve installed on the new pipeline will have the same discharge capacity. It is intended to adopt the current release schedule in place at the existing pipeline for the new pipeline when maintenance works are required. Under most circumstances this would involve progressive dewatering over a 45 hour period to avoid unnecessarily high flows down Trimbles Creek, I.e. flows would be limited to 10ML/d. If, however the pipeline needs to be dewatered in an emergency, it will have the ability to be safely drained in 13 hours which is consistent with the existing release schedule of up to 25ML/d. The proposed discharge rates to be adopted during maintenance are provided in **Table 7-3** and based on the existing release schedule.

Table 7-3 Kangaroo Pipeline dewatering rates

Timing Fast Drain in 13 hours	Timing Slow Drain in 45 hours	Discharge
Initial	Initial	5 ML/d
+60 mins	+24 hours	10 ML/d
+120 mins	N/A	15ML/d
+180 mins	N/A	25ML/d

7.4 Risk assessment

Identified operational impacts largely relate to maintenance works, transfer of water between reservoirs, and the discharge of groundwater seepage. A risk assessment for residual impacts to downstream waterways is provided in **Table 7-4**, with the rationale for the risk assessment outcome provided based on works required, existing conditions and mitigation measures that will be implemented.

Table 7-4 Determination of overall potential impact risk per waterway

Waterway	Consequence	Likelihood	Risk	Rationale
Fitzroy Falls Reservoir	Minor	Likely	Medium	▪ While no additional water would be transferred between Fitzroy Falls Reservoir and Lake Yarrunga, the rate of transfer will double which would result in increased flow velocity in and out of Fitzroy Canal ▪ Increase in rate of changes to water levels within Fitzroy Falls Reservoir may result in minor geomorphological changes around the perimeter of the reservoir through erosion of soft sediment banks but the risk is low based on low slopes and vegetation present.
Trimbles Creek	Moderate	Rare	Low	▪ Flows from the penstock anchor block to Trimbles Creek may occur infrequently. This would include the pipeline being entirely emptied for maintenance, inspection, repair, or in the event of an emergency ▪ Water in the pipe will frequently move between the two reservoirs and therefore the water quality should be acceptable for release downstream. However, the large volume of water to be released during the flow event presents a risk to downstream water quality from erosion and scour at the outlet and downstream if flows are not managed appropriately ▪ The risk of scour would be reduced with controls such as designing scours with downgradient rip-rap section as well as minimising flow rates ▪ Further, due to the very low frequency and short duration of the events, it is expected that this activity would not result in a lasting impact on water quality.
Kings Creek	Minor	Unlikely	Low	▪ While there is possibility of groundwater drawdown from seepage in the access tunnels and caverns, it is considered unlikely that it would result in significant reduction in baseflows to Kings Creek as upstream portion of Kings Creek and the tributaries which are located above the access tunnel and cavern locations are ephemeral. The tailrace tunnel which would be located below the perennial section of Kings Creek will be constantly full with transfer water therefore would not result in seepage.
Lake Yarrunga	Minor	Likely	Medium	▪ Groundwater seepage which is collected from the access tunnel and caverns will require discharge ▪ It is proposed that water would be separated via an oily water separator, monitored and treated to an acceptable standard (where required) and then injected into the tailrace tunnel where it will be further diluted and representative of the quality of inside the tailrace tunnel when it flows out to Lake Yarrunga during generation

Waterway	Consequence	Likelihood	Risk	Rationale
				▪ Following treatment and dilution via the tailrace tunnel, water quality of the groundwater seepage that reaches Lake Yarrunga is expected to reflect the intake water quality, therefore the risk of impacts to water quality from groundwater discharges is minor and unlikely ▪ Additional pumping between reservoirs also increases the risk of poor water quality, particularly with respect to algae, being transferred between reservoirs. ▪ Algal counts and toxic cyanobacteria counts in Fitzroy Falls Reservoir (and Bendeela Pondage) are higher than Lake Yarrunga. Therefore, the pumping of water more frequently increases the risk of poor water quality being transferred from one storage to another. This increases the risk of algal blooms occurring in Lake Yarrunga due to the transfer of water high in algal species ▪ Water transfers will adhere to algal and cyanobacteria concentration limits which are set out in the Water Supply Works and Water Use Approval ▪ With implementation of existing mitigation measures, it is expected that water quality risks from algal transfers between reservoirs would be adequately mitigated. As such, water quality impacts are not expected ▪ The increased rate of changes to water levels within Lake Yarrunga may result in minor geomorphological changes along the banks of the Lake through erosion of soft sediment banks.

8. Water Balance

Water supply will be required during the construction period for the Project and during operations. The Project will also result in groundwater inflows during construction, with some ongoing seepage to drained underground structures during Project operation. The following section provides an indicative water balance for the Project construction phase, summarising the water uses or demands and the main sources of Project water supply.

8.1 Construction Duration

The construction duration applied to the water balance is based on the reference concept design and comprises a period of approximately five years. Durations for individual water demands are provided in **Table 8-1**. A full Project description and schedule is provided in Chapter 3 of the EIS.

8.2 Construction Water Demand

Water supply would be required during the construction phase of the Project. Key Project water demands include:

- Water for underground tunnelling operations and boring
- Dust suppression
- Concrete production
- Equipment wash down
- Amenities.

For the Upper Scheme area, it is assumed that all concrete will be imported from a local supplier, and, as such, water will not be required for concrete batching. For the lower scheme a concrete batching plant would be used.

Water demands at this stage have been assessed based on the reference concept design and a number of necessary assumptions. Key assumptions are provided on **Table 8-1**.

Table 8-1 Project water demand assumption

Water Use	Key Assumption
Dust Suppression	▪ 10,000 L per hour for 12 hour day ▪ Wet/dry season weighting. Half usage applied during wetter months (October to March) ▪ Applied over full construction period (51 months)
Underground Usage	▪ Roadheaders - 20,000 L per day per work front for cooling and dust suppression ▪ Drilling / rock bolting - 5,000 L per day per work front for bit lubrication and cooling and dust suppression ▪ Applied for active work fronts only over a 32 month period (month 4 to month 35 inclusive)
Washdown	▪ Allowance - 5,000 L per day ▪ Wet/dry season weighting. Double usage during wetter months (October to March) ▪ Applied over full construction period (51 months)
Concrete Batching	▪ 200 L per cubic metre of concrete, shotcrete and grout ▪ Shotcreting applied over 26 month period (month 4 to month 29 inclusive) ▪ Concrete lining and grouting applied over a 15 month period (month 27 to month 41 inclusive)

Water Use	Key Assumption
Amenities	▪ 50 L per day per person ▪ Weighted 80% Lower Scheme, 20% Upper Scheme ▪ Applied over full construction period (51 months)
Water Recycling	▪ Allowance of 50% water recycling for underground water usage ▪ Allowance of 50% water recycling for washdown water usage ▪ Applied over period of water usage

Total estimated Project water demands are presented on **Table 8-2**, showing demands for the Upper and Lower Scheme areas and Project totals. The most substantial water demand is for dust suppression, followed by use in underground tunnelling. Total estimated water demand is estimated at approximately 362 ML over the four-year construction period.

Water demand will vary over the Project construction phase. The estimated total Project monthly water demand is presented on **Figure 8-1**. Total Project water demand is estimated to peak at approximately 10.7 ML/month in months 16 and 17 of construction.

Table 8-2 Project water demand

Water Use	Water Demand (ML)		
	Upper Scheme	Lower Scheme	Total
Dust Suppression	125.8	125.8	251.7
Underground Usage	8.4	71.3	79.7
Washdown	0	10.9	10.9
Concrete Batching	0	8.4	8.4
Amenities	2.3	9.1	11.4
Total	**136.5**	**225.5**	**362.0**

Estimated annual water demands are as follows, with water demand peaking during the second year of construction. It is noted that "Year 1", encompasses a 15-month period:

- Year 1 – 104.2 ML
- Year 2 – 110.9 ML
- Year 3 – 80.7 ML
- Year 4 – 66.3 ML.

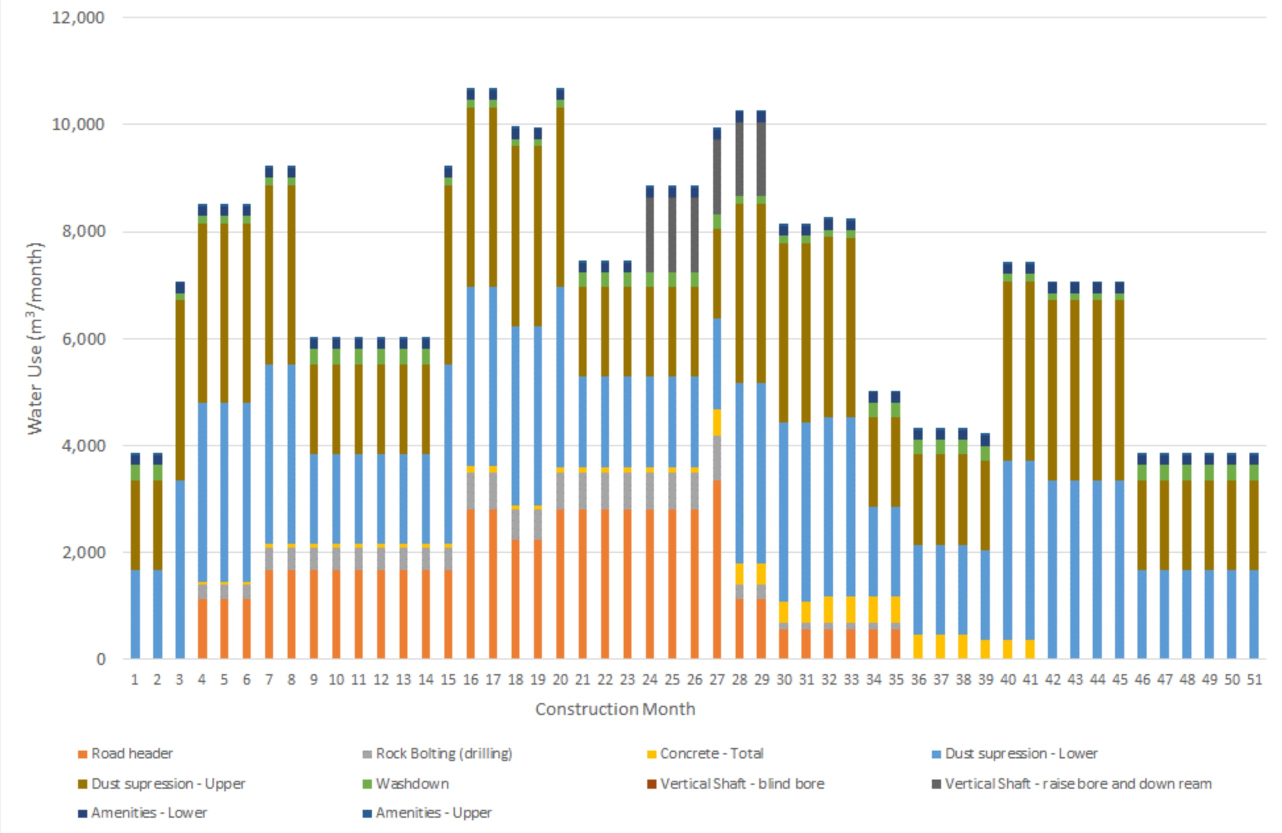


Figure 8-1 Project construction water demand

8.3 Construction Water Sources

The water supply for the Project during construction is anticipated to be a combination of groundwater inflows and seepage to underground workings and make-up water supply.

A detailed assessment of the anticipated groundwater inflows is provided in Appendix J of the EIS (Groundwater impact assessment).

Water recycling will also form an important component of water supply. Water recycling will include both active and passive recycling:

- Passive recycling includes water used underground, such as for the cooling of cutting heads that, by default, is incorporated in the underground dewatering system with groundwater seepage and pumped back to the water treatment plant for treatment and re-use
- Active recycling is anticipated from water uses such as wash-down bays, where water will be captured and passed through sediment retention tanks and oil-water separators prior to be pumped to the water treatment plant for treatment and re-use.

An allowance of 50% water returns has been assumed for both underground water usage and washdown water usage.

Where groundwater inflows and recycled water do not meet the water demand or water quality requirements, then a source of make-up water will be required. Make-up water for the Lower Scheme is assumed to be sourced from Bendeela Pondage, and for the Upper Scheme is assumed to be sourced from Fitzroy Canal subject to agreement with WaterNSW. As all water collected from underground will be pumped to the water treatment plant in the Lower Scheme area, all water supply for the Upper Scheme area is assumed to be make-up water.

Rainfall run-off captured in sediment retention ponds has not been considered as a water source. This is due to the fact that the ponds require emptying within five days of a rainfall event and don’t not provide a reliable supply of water. Nonetheless, there is potential for opportunistic use of captured rainfall runoff for incidental water uses that are not captured in this water balance.

An assessment of total Project water sources is provided on **Figure 8-2**.

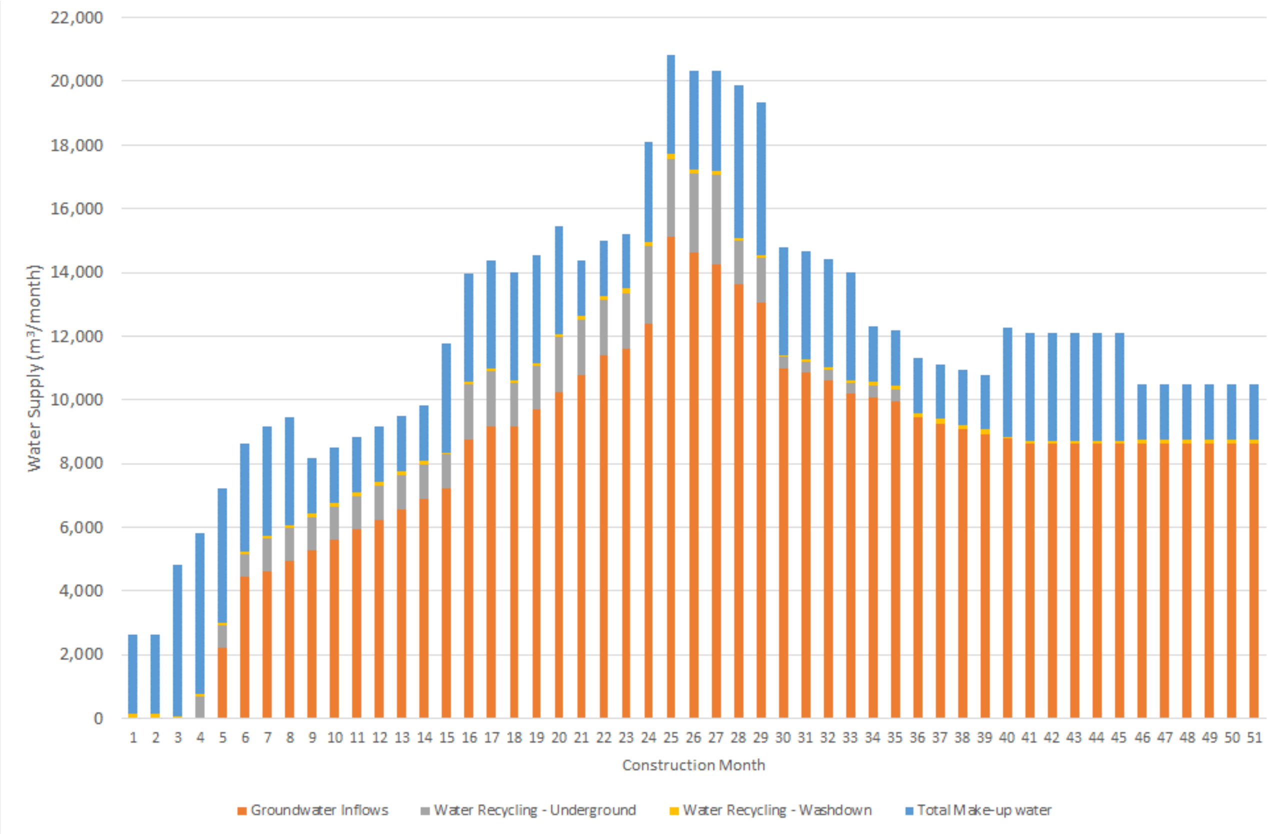


Figure 8-2 Project construction water sources

8.4 Water Balance

A water balance has been compiled of total Project water demands and water sources. An assessment of water surplus (excess supply) and water deficit (make-up water required) is provided for the Lower Scheme on **Figure 8-3**.

For the purposes of this water balance it is assumed that groundwater inflows will either be of suitable quality for Project use or can be treated to suitable quality.

A previously mentioned for the Upper Scheme, as all groundwater inflows and water recycling reports to the Lower Scheme, the Upper Scheme operates in deficit and all water is required to be sourced from the make-up water supply (Fitzroy Canal).

For the Lower Scheme, overall there is a water surplus, with make-up water only required during the first five to seven months of construction.

The construction water balance is represented graphically on **Figure 8-4**, and is summarised on **Table 8-3** and **Table 8-4**.

Overall, the Project is estimated to require a total of approximately 141.9ML of make-up water, with approximately 5.4ML to be sourced from Bendeela Pondage and 136.5ML to be sourced from Fitzroy Canal.

Approximately 251.9ML of controlled discharge is anticipated, averaging approximately 4.9ML/month over the period of construction. This is surplus water that will be treated to suitable quality prior to discharged to either Bendeela Pondage or Lake Yarrunga. From **Figure 8-3**, a peak surplus requiring discharge of up to approximately 12ML/month is anticipated midway during construction.

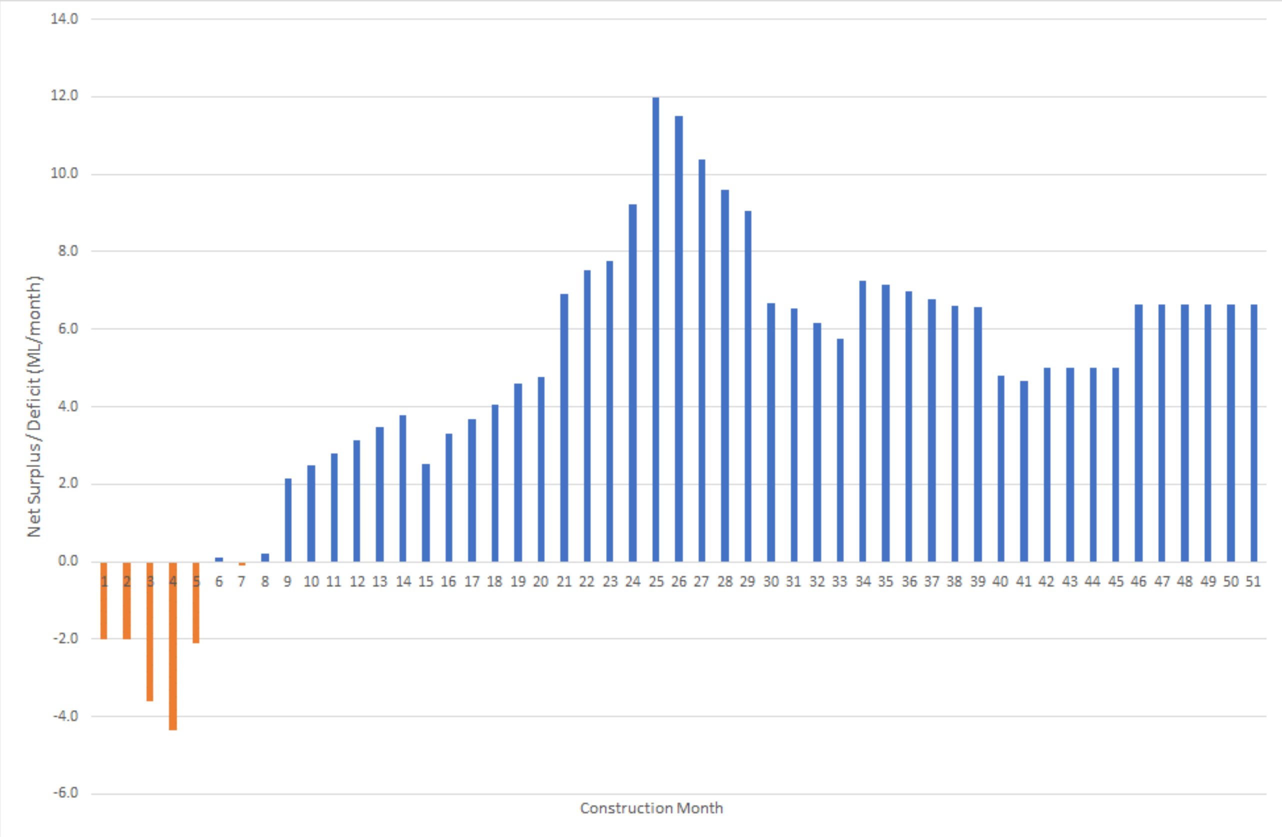


Figure 8-3 Lower Scheme water surplus / deficit

Table 8-3 Lower Scheme water balance

Water Demand / Source	Volume (ML)
Inputs	
Groundwater Inflow	426.7
Recycled water	45.3
Make-up Water	5.4
Total Inputs	**477.4**
Outputs	
Concrete Batching	8.4
Dust Suppression	125.8
Tunnelling	71.3
Washdown	10.9
Amenities	9.1
Controlled Discharge	251.9
Total Outputs	**477.4**

Table 8-4 Upper Scheme water balance

Water Demand / Source	Volume (ML)
Inputs	
Groundwater Inflow	0
Recycled water	0
Make-up Water	136.5
Total Inputs	**136.5**
Outputs	
Concrete Batching	0
Dust Suppression	125.8
Tunnelling	8.4
Washdown	0
Amenities	2.3
Controlled Discharge	0
Total Outputs	**136.5**

8.5 Operation

Water requirements for storage and generation of electricity for the power station are not included in this assessment on the basis that water transfers would be undertaken within the existing scheme WAL allowance.

During operation, ongoing seepage of groundwater to permanently drained structures is estimated to be approximately 2.78 ML/month (91.26 kL/day or 1.06 L/s) (refer Appendix J of the EIS (Groundwater impact assessment)). This water will be treated to suitable quality and discharged to the Tailrace.

Water required from ongoing operation of site amenities will be sourced from Project scheme water at the Lower Schemes as required consistent with existing scheme arrangements.

8.6 Wastewater

All wastewater produced during Project construction and operation will be removed from site and disposed of at a suitable waste facility.

Wastewater streams produced during construction are likely to include:

- Blind boring cuttings and slurry
- Sludge from washdown settling ponds and oil water separators
- Water treatment brines
- Grey and black-water from site amenities.

Wastewater streams produced during operation are likely to include:

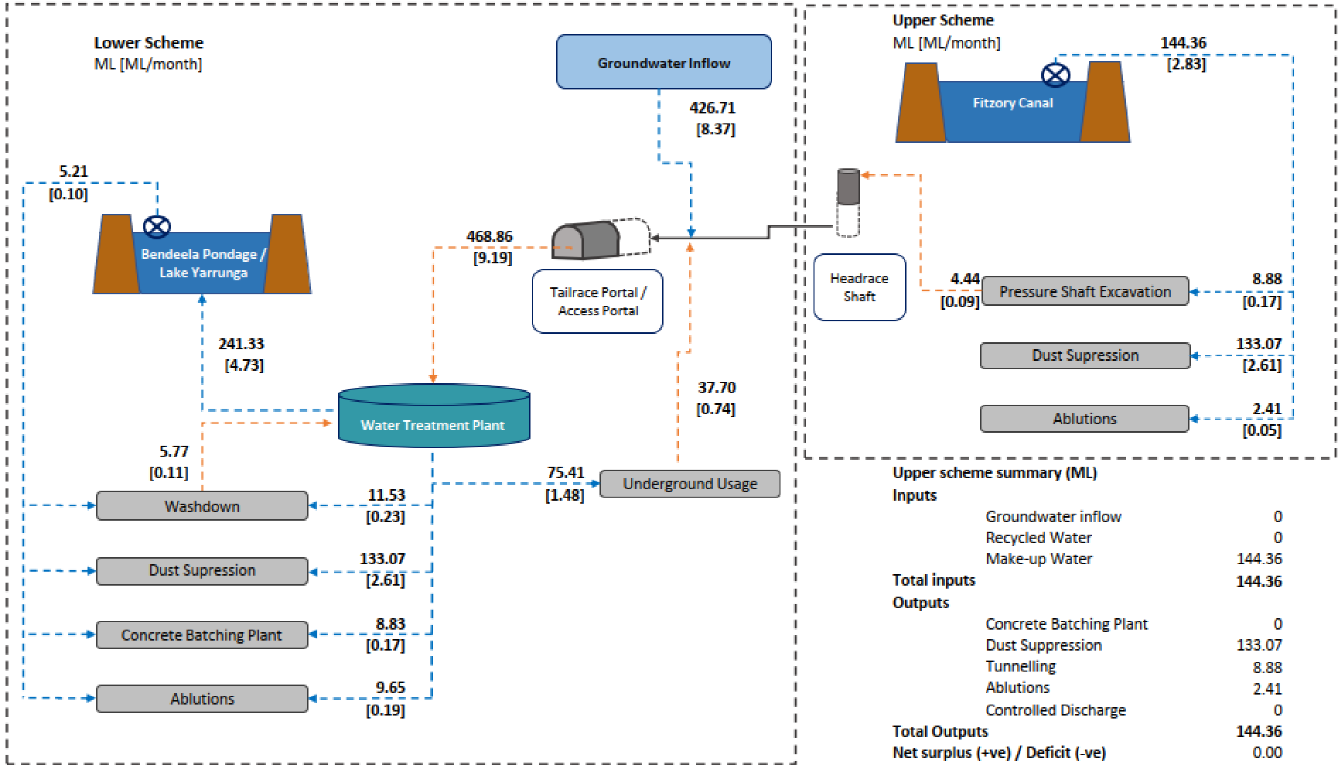
- Grey and black-water from site amenities.

Shoalhaven Construction Water Balance

Total and Average (ML and [ML/Month])

Lower scheme summary (ML)

Inputs	
Groundwater inflow	426.71
Recycled Water	47.91
Make-up Water	5.21
Total inputs	**479.83**
Outputs	
Concrete Batching Plant	8.83
Dust Suppression	133.07
Tunnelling	75.41
Washdown	11.53
Ablutions	9.65
Controlled Discharge	241.33
Total Outputs	**479.83**
Net surplus (+ve) / Deficit (-ve)	0.00



Upper scheme summary (ML)

Inputs	
Groundwater inflow	0
Recycled Water	0
Make-up Water	144.36
Total inputs	**144.36**
Outputs	
Concrete Batching Plant	0
Dust Suppression	133.07
Tunnelling	8.88
Ablutions	2.41
Controlled Discharge	0
Total Outputs	**144.36**
Net surplus (+ve) / Deficit (-ve)	0.00

Figure 8-4 Construction water balance

9. Neutral or Beneficial Effect (NorBE) Assessment

As stated in the SEARs (refer **Table 1-2**), the EIS must assess whether the Project would have a neutral or beneficial effect on water quality. **Table 9-1** below details the NorBE Assessment for proposed Project activities.

Table 9-1 NorBE assessment

NorBE assessment – will there be a neutral or beneficial effect on water quality? ***(Assessment must consider surface and ground waters and must consider construction and operational stages)***	
1. Are there any identifiable impacts on water quality? What pollutants are likely? *Major potential pollutants are sediments (fine & coarse), nitrogen, phosphorus, pathogens and hazardous chemicals and contaminants such as oil/fuel.* At what stage do the impacts occur? i.e. during construction and/or post construction?	Both the construction and operation of the Project have the potential to impact on surface water quality. Potential pollutants to water quality during construction are identified in **Chapter 6** and include: ▪ Sedimentation and associated increased turbidity in downstream receivers due to disturbance and mobilisation of exposed soils from vegetation clearance, movement and use of machinery on exposed earth, bulk earthworks, spoil stockpiling, movement and emplacement, as well as instream works ▪ Elevated concentrations of nutrients in downstream receivers transported via sediment ▪ Increased toxicants, including heavy metals, oils and grease, petroleum hydrocarbons and other hazardous chemicals (potentially ammonia and nitrate) from accidental spills and leaks from vehicles, construction machinery, steelworks and rock blasting ▪ Tannin leachate from clearing ▪ Concrete dust and slurries, leading to increased pH and chromium concentrations in downstream receivers, from concrete works for surge tank footings, the vertical shaft, tunnels and caverns ▪ Bacterial and other gross pollutants (litter or debris) from wastewater at site facilities and laydown / work areas ▪ Increased sedimentation and associated increase turbidity of downstream receivers from uncontrolled sediment basin discharges ▪ Increased salinity and heavy metal contaminants in downstream receivers from ground water seepage discharges ▪ Increased acidity of downstream receivers from mobilisation of acid leachate runoff from temporary stockpiles of PAF spoil. Potential impacts to water quality during operation are identified in **Chapter 7** and include: ▪ Sedimentation leading to increased turbidity and elevated nutrients in downstream receivers from disturbed soils where sites have not yet stabilised ▪ Contaminants, including heavy metals, oils and grease and petroleum hydrocarbons from accidental spills and leaks from maintenance vehicles ▪ Saline water, heavy metal contaminants and hydrocarbons in downstream receivers from ground water seepage discharges. Key potential pollutants during construction include sediments, nutrients (nitrogen and phosphorus), heavy metals, hydrocarbons, oil and grease, hydraulic fluids, saline water, acidic pH and other hazardous chemicals (potentially ammonia and nitrate).

NorBE assessment – will there be a neutral or beneficial effect on water quality? ***(Assessment must consider surface and ground waters and must consider construction and operational stages)***	
	Key potential pollutants during operation include sediment, nutrients (nitrogen and phosphorus), heavy metals, saline water and hydrocarbons.
2. For each pollutant list the mitigation measures needed to prevent or mitigate potential impacts on water quality? *These may be WaterNSW endorsed current recommended practices (CRPs) and/or equally effective other practices*	Mitigation measures for the construction and operational water quality impacts are provided in **Chapter 11**. Management and mitigation of water quality impacts will be achieved through the following: ▪ Measures to minimise/manage erosion and sediment transport within the construction footprint and offsite including requirements for the preparation of ESCPs for all progressive stages of construction ▪ Measures to manage stockpiles including locations, sediment controls and stabilisation ▪ Measures to manage accidental spills in accordance with WaterNSW incident management protocols, including the requirement to maintain materials such as spill kits ▪ Measures to manage potential tannin leachate ▪ Measures to treat water collected in sediment basins for reuse on-site or discharge to downstream waterways ▪ Measures to manage water (including dewatering), groundwater ingress into vertical shafts and tunnels, drilling fluids, grout and cement contaminated water from construction, including water collection protocols, water quality standards to be achieved for various reuse (eg. dust suppression) purposes, and release to downstream receiving environment ▪ Truck loads to be adequately covered when transporting loose material (ie. spoil) ▪ Dust suppression, spoil rehabilitation/emplacement to ensure no sedimentation or air quality impacts ▪ A groundwater discharge water treatment facility will be designed to treat groundwater seepage generated from tunnel groundwater ingress from tunnels and the cavern during both construction and operation.
3. Will the mitigation measures be adequate for the time required? How will they be maintained?	A Construction Soil and Water Management Plan (CSWMP) will be prepared as a sub plan of the CEMP and will outline measures to manage soil and water impacts associated with the construction works. Erosion and sediment controls will be developed and outlined in an Erosion and Sediment Control Plan during construction. Erosion and sediment controls will be designed in accordance with the principles and requirements in *Managing Urban Stormwater – Soils and Construction Volume 1* (Landcom, 2004) and *Volume 2D* (DECCW, 2008), commonly referred to as the "Blue Book". The proposed mitigation measures outlined in **Chapter 11** will be implemented and maintained for the entire construction period. Work Areas will be progressively rehabilitated as construction is completed. Spoil removed as part of the tunnelling and underground works will involve identification and appropriate management of NAF and PAF materials as per Appendix K of the EIS (Spoil Management Strategy). Spoil identified as PAF will be

NorBE assessment – will there be a neutral or beneficial effect on water quality? *(Assessment must consider surface and ground waters and must consider construction and operational stages)*	
	identified and managed so as to remove the risk of acid rock drainage or placed in a containment cell away from other materials and capped with an impermeable layer so no water can seep into the containment cell. During operation, the sites would be stabilised and would be no risk of additional erosion from disturbed areas. Further, regulating flow rates and operating water in accordance with the Water Supply and Water Use licence will continue to serve to ameliorate water quality impacts from increased rate of transfer between reservoirs. Groundwater seepage discharges and operational runoff collected in the underground power station cavern will be treated to an acceptable standard and injected into the tailrace tunnel where it will assimilate with water in the tunnel before flowing out to Lake Yarrunga. Scour protection and energy dissipators will be placed downstream of the Penstock Anchor Block outlet to prevent erosion and sedimentation. Flows will be regulated at the time of release to minimise erosion. Additionally, preventative measures will be implemented to ensure that only one penstock can be dewatered at a time.
4. Will all impacts on water quality be effectively contained on the site by the identified mitigation measures above, and not reach any watercourse, waterbody or drainage depression? Or will impacts on water quality be transferred outside the site for treatment? How? Why?	Under standard conditions, all potential impacts as a result of both construction and operation of the Project would be contained on site and not reach any waterway, waterbody or drainage depression by the environmental mitigation measures presented in **Chapter 5** and **Chapter 11**. The exception of this would be in during and following large rainfall event when controls may fail, however it is expected that any water quality impact would be minor and temporary, and would be rectified as soon as practicable. Water would either be treated on-site for reuse during construction or would be treated to appropriate water quality standards before discharged at a licenced discharge point. Water treatment is likely to involve settlement of suspended solids with flocculation to ensure TSS concentrations meet existing water quality of receiving waterways and waterbodies.
5. Is it likely that a neutral or beneficial effect on water quality will occur?	From the qualitative assessment undertaken, the Project is likely to have a neutral effect on water quality as the risks have been adequately mitigated through the proposed design, construction methodology, as well as construction staging and timing. Further, the proposed mitigation measures including erosion and sediment control, appropriate design and locations of stockpiles, appropriate management of construction activities on site, as well as the treatment and discharge (or re-use) construction site runoff are expected to result in a neutral impact to water quality.

10. Cumulative impacts

Cumulative impacts have the potential to occur when impacts from a project interact or overlap with impacts from other projects and can potentially result in a larger overall effect (positive or negative) on the environment, businesses or local communities. Cumulative impacts may occur during construction stages when projects are constructed concurrently or consecutively. Projects constructed consecutively (or sequentially) can result in construction activities occurring over an extended period of time with little or no break in construction activities, potentially causing increased impacts and construction fatigue for local communities.

The extent to which another development or activity could interact with the construction of the Project would depend on its scale, location and/or timing of construction. Generally, cumulative impacts would be expected to occur where multiple long-duration construction activities are undertaken close to, and over a similar timescale to, construction activities for the project, or where consecutive construction occurs in the same area.

The overall effect of cumulative benefits or impacts could be positive or negative, depending on the nature of the projects and the nearby communities and environment.

10.1 Identification of projects

Projects that were considered in the cumulative impact assessment are:

- Shoalhaven Hospital Redevelopment
- Nowra Biogas Project
- Shoalhaven Starches Mod 22 – Beverage Grade Ethanol Plant Stage 3
- Shoalhaven Starches Modification 25 Rail Line Extension & Addition to Product Dryers
- Dendrobium Mine Extension
- Moss Vale Plastics Recycling Facility
- New Shellharbour Hospital and Integrated Services
- Berrima Cement Works Solid Waste Derived Fuels & Delivery Variation Project
- Sutton Forest Sand Quarry
- Moss Vale Road Urban Release Area: Maculata Park and Taylors Landing
- Shoalhaven Community and Recreational Precinct – Artie Smith Oval Development
- Shoalhaven Community and Recreational Precinct – Shoalhaven Indoor Sports Centre (SISC) Extension
- Shoalhaven Community and Recreational Precinct – Northern Section – Bomaderry Sporting Complex
- Moss Vale Sewage Treatment Plant Upgrade
- Moss Vale Bypass
- Ritters Creek, Meryla Road, Meryla - Bridge Replacement
- Fitzroy Falls RFS
- Bowral and District Hospital Redevelopment Stage 2
- Bay and Basin Leisure Centre Redevelopment
- East Nowra Sub Arterial Road ENSA
- Shoalhaven Resource Recovery Facility (RRF) and West Nowra Resource Recovery Park Stage 2
- Nowra Bridge Project – Princes Highway Upgrade
- Jervis Bay Road and Princes Highway intersection upgrade at Falls Creek.

10.2 Assessment of cumulative impacts

Cumulative surface water impacts associated with construction and operation of the Project and other major projects in the area have been considered and are discussed in **Table 10-1**. Of the projects listed in **Section 10.1**, only two projects are within proximity to the Project and/or have common downstream receivers. All other projects were generally more than 10 km away from the Project and had no common downstream receivers and therefore no cumulative impacts are expected.

Cumulative impacts of the combined operation of the Project and existing scheme have been considered in prior sections.

Table 10-1 Summary of potential cumulative impacts

Project (approval status)	Common receivers	Potential cumulative impact on common receivers during construction and operation
Fitzroy Falls RFS	Fitzroy Falls Upper Canal	The new Fitzroy Falls Rural Fire Service building will be constructed at the corner of Myra Vale Road and Nowra Road, Fitzroy Falls, which is adjacent to Fitzroy Canal upstream of the Project. The construction period of the new RFS is unknown however is likely to overlap with the construction of the Project which is likely to occur between August 2023 to January 2028. Construction of both projects presents a risk to the water quality of Fitzroy Falls Upper Canal, namely from sedimentation from dust. With the implementation of appropriate management controls during construction of the RFS, together with the proposed controls for construction of the Project, there is unlikely to be any cumulative impact to downstream water quality of the Fitzroy Canal. Operation of the RFS which is located upstream of the Project would not present any risks to downstream water quality and therefore no cumulative impacts are expected.
Ritters Creek, Meryla Road, Meryla - Bridge Replacement	Kangaroo River	Construction works associated with the bridge replacement would occur more than two km from the Project. Works associated with the bridge replacements have the potential to impact on the water quality of Ritters Creek which flows into Bundanoon Creek which eventually reaches the Kangaroo River Arm on the western side of Tallowa Dam just upstream of the dam wall. Construction of the bridge is due to be completed in March 2023, whereas construction of this Project would not commence until August 2023. As there would be no overlap with construction of both projects there will be no cumulative impact to water quality during construction. Operation of the new bridge would be similar to previous and therefore would not present any cumulative impact to water quality with the construction and/or operation of this Project.

10.3 Mitigation measures

Origin will coordinate and consult with key stakeholders where required to manage the interface of projects under construction at the same time. Co-ordination and consultation with these stakeholders would include:

- Provision of regular updates to the detailed construction program, construction sites and haul routes
- Identification of key potential conflict points with other construction projects
- Developing mitigation strategies in order to manage conflicts. Depending on the nature of the conflict, this could involve:
  - Co-ordination of traffic management arrangements between projects
  - Dust suppression activities to be coordinated and managed concurrently for project occurring at the same time.

11. Mitigation measures

Environmental mitigation measures would form an integral part of construction activities and Project operation. This section provides an overview of the identified measures to minimise potential impacts to surface water from the construction and operation of the Project.

11.1 Management and mitigation measures

The following identified mitigation measures detailed in **Table 11-1** have been developed to specifically manage potential surface water quality, hydrological and geomorphological impacts which have been predicted during construction and operation of the Project.

Table 11-1 Surface water quality, hydrology and geomorphology mitigation measures

Reference	Impact	Mitigation measure	Timing
SW01	General	A Construction Soil and Water Management Plan (CSWMP) will be prepared for the Project as part of detailed design. The CSWMP will be reviewed by WaterNSW prior to finalisation. The plan will outline measures to manage soil and water impacts associated with the construction works. The CSWMP will include but not be limited to: ▪ Measures to minimise/manage erosion and sediment transport within the disturbance area and offsite including requirements for the preparation of ESCPs for all progressive stages of construction ▪ Measures to manage stockpiles including locations, sediment controls and stabilisation ▪ Measures to manage accidental spills in accordance with WaterNSW incident management protocols, including the requirement to maintain materials such as spill kits ▪ Measures to manage potential tannin leachate ▪ Details of surface water quality monitoring to be undertaken prior to, throughout and following construction ▪ Outline appropriate water quality criteria for discharge and re-use onsite ▪ Measures to treat water collected in sediment basins for reuse on-site or discharge to downstream waterways ▪ Measures to manage water (including dewatering), groundwater ingress into vertical shafts and tunnels, drilling fluids, grout and cement contaminated water from construction, including water collection protocols, water quality standards to be achieved for various reuse (eg. dust suppression) purposes, and release to downstream receiving environment. The Construction Contractor would be	Pre-construction/ Construction

Reference	Impact	Mitigation measure	Timing
		required to obtain and comply with an EPL and any other approvals to discharge treated water into Trimbles Creek, Kings Creek, and other unnamed tributaries.	
SW02	Erosion and sedimentation	A Construction ESCP would be developed as a sub plan of the CSWMP and would detail the erosion and sediment control measures to be implemented at all work sites in accordance with the principles and requirements in *Managing Urban Stormwater – Soils and Construction Volume 1* (Landcom, 2004) and *Volume 2D* (NSW department of Environment, Climate Change and Water, 2008), commonly referred to as the "Blue Book". The Construction ESCP would include but not be limited to: ▪ Plans for temporary drainage, scour protection and control measures to reduce erosion and water quality impacts from increased sediment loads from construction sites, ancillary sites and access tracks. These water quality controls will likely consist of sediment fencing, sediment sumps and sediment basins. ▪ The locations of construction sediment basins, sediment sumps, sediment fences, diversion drains etc considering detailed design and selected construction methods ▪ Truck loads to be adequately covered when transporting loose material (ie. spoil) ▪ Dust suppression, spoil rehabilitation/emplacement to ensure no sedimentation or air quality impacts.	Pre-construction/ Construction
SW03	Spills and leakages	Site specific controls and procedures would be developed and implemented as part of the CSWMP to reduce the risk of the release of potentially harmful chemicals from spills entering downstream watercourses. The CSWMP would include the following measures: ▪ All fuels, chemicals and liquids would be stored on level ground at least 20 m away from waterways and would be stored in a sealed bunded areas within works areas ▪ Spill response kits will be kept at all sites in the event of a spill, and site personnel will be appropriately trained in the use of spill response equipment ▪ An emergency spill response procedure would be prepared to minimise the impact of accidental spillages of fuels, chemicals and fluids during construction. The procedure will have regard to notification and reporting of incident to relevant authorities, eg WaterNSW and EPA ▪ Regular visual water quality checks (for hydrocarbon spills/slicks, turbid plumes and other water quality issues) will be carried out when working near waterways.	Pre-construction/ Construction

Reference	Impact	Mitigation measure	Timing
SW04	Impacts of Stockpiles	Stockpiles, spoil loading, processing, transport and emplacement activities will be managed to minimise the potential for mobilisation and transport of dust, sediment, contamination and leachate in runoff. This will include: ▪ Minimising the number of stockpiles, the area used for stockpiles and time that they are left exposed ▪ Designing and locating temporary stockpiles away from drainage lines and waterways and managing stockpile areas (including during inclement weather events) ▪ Stabilising stockpiles, establishing appropriate sediment controls and suppressing dust as required ▪ Installation of a retention pond to collect leachate from the spoil emplacement area ▪ Separation of non-acid forming and low risk potential acid forming materials from moderate to high potentially acid forming materials. Subsequent treatment of potentially acid forming material with lime prior to emplacement or emplacement within a containment cell which would be capped with an impermeable layer to avoid water ingress ▪ Rehabilitation of disturbed areas used for temporary stockpiling would be undertaken as soon as practical. This would include any areas used for stockpiling, particularly Laydown / Work Area 3 and 5 due to their proximity to waterways.	Pre-construction/ Construction
SW05	Concrete works	To avoid ingress of concrete waste material into downstream waterways, the CSWMP would outline procedures to capture, contain and appropriately dispose of any concrete wastes from concrete works associated with foundations, lining of vertical shaft and tunnels and for installation of the anchor block at the Penstock. Concrete structures would be pre-fabricated prior to installation instream, where practicable.	Pre-construction/ Construction
SW06	Construction discharges	▪ Prior to disposal of construction water collected in sediment basins, water should be treated to the appropriate standard specified in the CSWMP and repurposed on site wherever possible. For instance, for dust suppression activities ▪ A construction discharge water treatment plant will be designed to treat groundwater seepage generated from tunnel groundwater ingress and runoff in tunnel portals ▪ Site specific trigger values will be developed during construction planning to set the discharge water treatment plant and sediment basin discharge criteria to prevent pollution of water.	Pre-construction/ Construction

Reference	Impact	Mitigation measure	Timing
		▪ Water that cannot be repurposed on site may be discharged locally provided the Construction Contractor obtains an EPL for this activity. The Construction Contractor would therefore be required to adhere to regulations specified in the EPL which would include specifying discharge locations subject to detailed design, and resulting water quality concentration limits to be met prior to discharge ▪ Monitoring at all discharge points should be undertaken prior to and during construction to determine background water quality and detect any environmental degradation as a result of the construction works and allow for understanding the amount of flocculation that might need to be applied to treat sediment laden water.	
SW07	Water quality monitoring - construction	A Construction Surface Water Monitoring Program would be developed and included in the CSWMP to establish baseline conditions, to observe any changes in surface water quality and condition in watercourses withing 500 m of the Project that maybe be attributable to construction of the Project and inform management responses. Monitoring during pre-construction and construction would occur at all waterways with the potential to be impacted. Monitoring sites would be located upstream and downstream of the Project and would include sampling for key indicators of concern. Should the results of monitoring identify that the water quality management measures are not effective in adequately mitigating water quality impacts associated with works in particular areas, works where exceedances occur would be curtailed until suitable additional mitigation measures are identified and implemented as required.	Pre-construction/ Construction
SW08	Instream works	All works in the bed of bank of Lake Yarrunga would occur within a sediment curtain, coffer dam or alternate measure to manage water quality.	Construction
SW09	Water quality monitoring - operation	The operational surface water quality monitoring program will be based on the construction monitoring program but refined to target issues relating to the operation of the Project, eg monitoring of Trimbles Creek at the Penstock should water require discharging from the pipeline. Erosion and sediment controls during operation would be outlined in the Operational Management Plan and would detail procedures and protocols for maintaining scour protection measures at the outlets, groundwater seepage, and ongoing rehabilitation of disturbed areas and spoil emplacement facility.	Operation

Reference	Impact	Mitigation measure	Timing
SW10	Water discharges	A permanent water treatment facility will be designed to treat ground water seepage generated from groundwater ingress in the main access tunnel and caverns and runoff from operation in the caverns. The collected water will be separated via an oily water separator and treated to an acceptable standard (where required) prior to being injected into the tailrace tunnel where it would further dilute to the water quality of inside the tailrace tunnel, which would flow out to Lake Yarrunga during generation. The level of treatment provided will consider the characteristics of the receiving environment. Following treatment and dilution via the tailrace tunnel, water quality of the groundwater seepage that reaches Lake Yarrunga or Fitroy Canal is expected to be indistringuishable from the water quality of the intake water and as the Project would operate in accordance with the WAL that authorises water transfers between the two reservoirs.	Operation

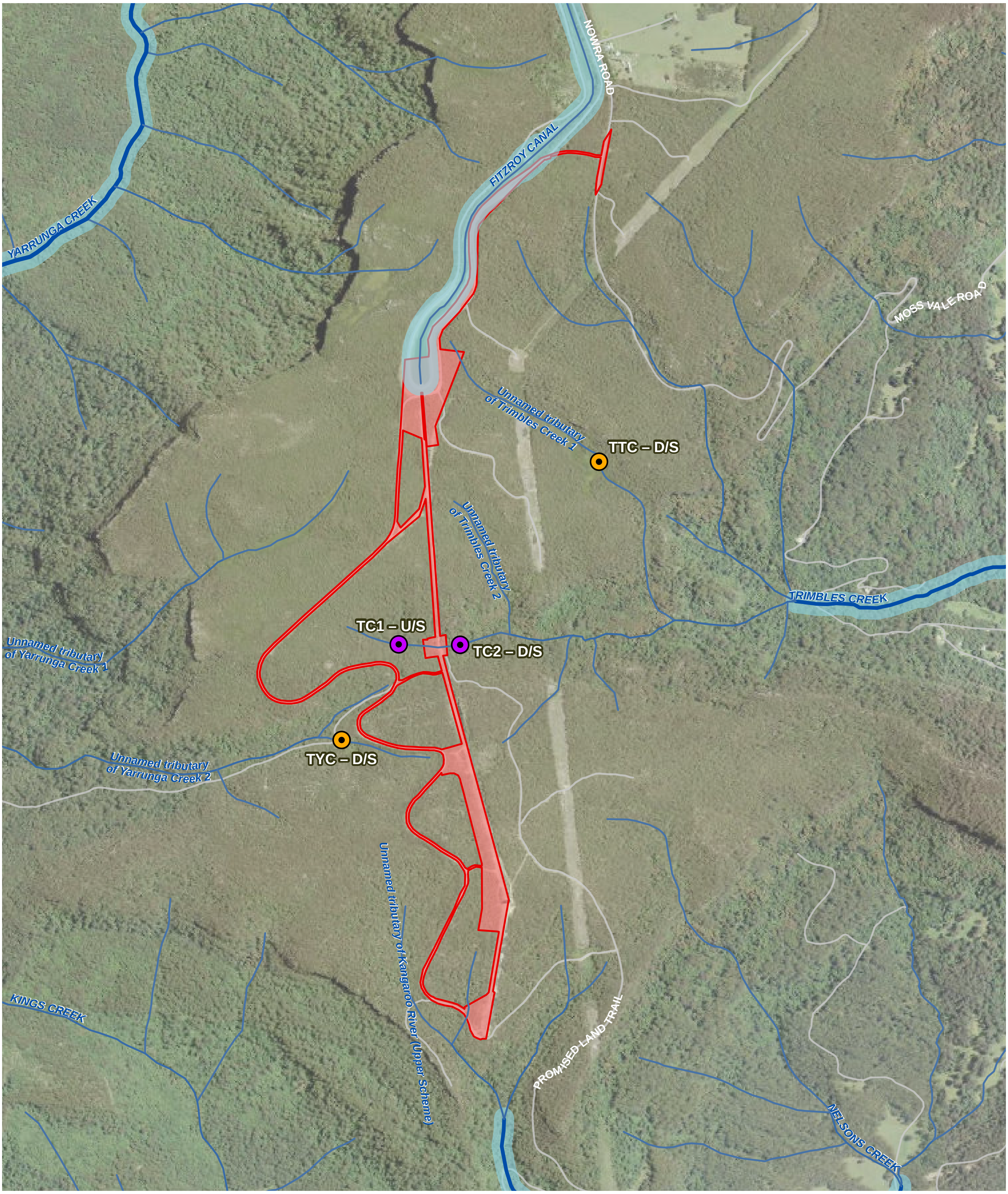
11.2 Water quality monitoring program

The surface water quality monitoring program will be developed and implemented to gain an appreciation of background water quality, to observe any changes in surface water quality that may be attributable to the Project and inform appropriate management responses.

The surface water quality monitoring program will be carried out during the pre-construction, construction and operational stages of the Project. The surface water quality indicators to be monitored are common to all stages of the monitoring program and would include those outlined in **Table 11-4** with the addition of temperature and visible oil and grease. If oil or grease is visible, samples would be assessed for total petroleum hydrocarbons (TPH).

11.2.1 Monitoring locations

Monitoring sites would be located on waterways with potential to be impacted by Project activities and will be confirmed during detailed design. Monitoring locations for surface water quality during pre-construction (baseline), construction and operation are shown on **Figure 11-1** and described in **Table 11-2**.



Legend

Proposed surface water monitoring sites

- Baseline and construction
- Construcion only

Strahler stream order

- 1
- 2
- 3
- 4

- Construction disturbance area
- Key fish habitat
- Road

0 0.6 1.2 km

1:20,000 at A4

GDA2020 MGA Zone 56

Data sources1

Jacobs 2022
Department of Planning and Environment 2022
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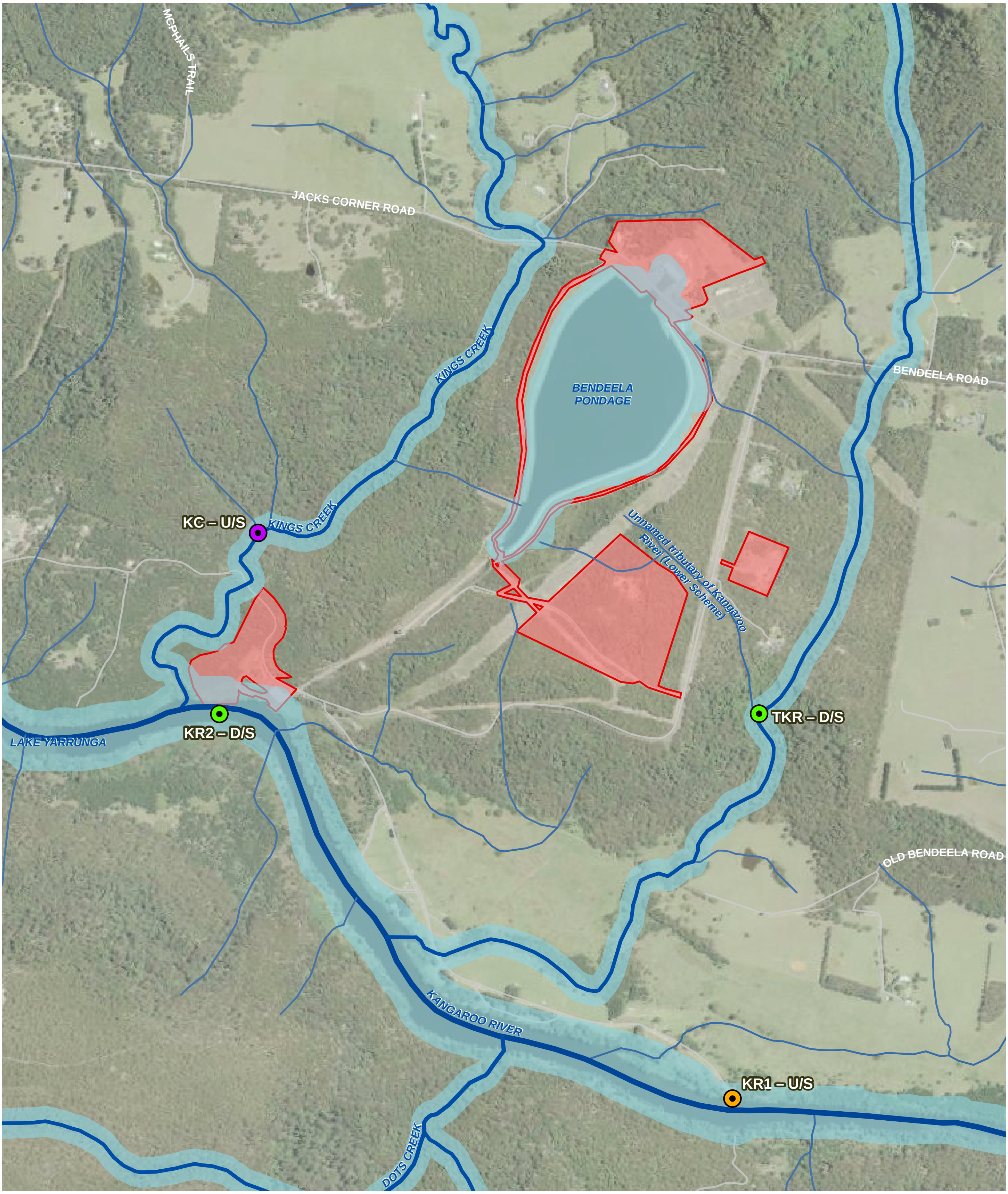
Figure 11-1a Proposed water monitoring locations - Upper Scheme (plateau)



Legend

Proposed surface water monitoring sites

- Baseline and construction
- Construcion only
- Construction and operation

Strahler stream order

- 1
- 2
- 3
- 4
- 6
- Construction disturbance area
- Key fish habitat
- Road

0 0.5 0.9 km

1:15,000 at A4

GDA2020 MGA Zone 56

Data sources2

Jacobs 2022
Department of Planning and Environment 2022
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Figure 11-1b Proposed water monitoring locations - Lower Scheme (Kangaroo Valley)

Sampling locations will be named according to **Table 11-2**. Where possible it is proposed to monitor upstream and downstream of the Project works so as to gain an understanding of changes to water quality as a result of construction and operation. Monitoring locations may be refined during initial investigations subject to site access and availability of water. In addition to the proposed sites in **Table 11-2**, monitoring sites (and data) currently being sampled by WaterNSW as detailed in **Table 3-1** will be utilised where relevant, particularly where they can act as a Trigger, Action, Response, Plan (TARP) site for the proposed monitoring sites and/or to derive SSTVs for water quality indicators.

Table 11-2 Surface water quality monitoring location details

Monitoring site	Site number	Coordinates		Basis for monitoring	Project stage monitoring required[1]
		Eastings	Northings		
Unnamed tributary of Trimbles Creek	TTC – D/S	269943.8142	6158607.268	Downstream of Laydown / Work Area 1 and runoff from sumps	Construction
Trimbles Creek TARP	TC1 – U/S	269181.4497	6157912.113	TARP site for Trimbles Creek	Baseline Construction
Trimbles Creek d/s of basin discharges	TC2 – D/S	269415.3734	6157910.328	Capture instream water quality of Trimbles Creek immediately downstream of basins discharges but upstream of existing disturbance	Baseline Construction
Unnamed tributary to Yarrunga Creek	TYC – D/S	268964.0402	6157548.03	Downstream of sediment basin discharge from Laydown / Work Area 2	Construction
Kings Creek	KC – U/S	268030.2454	6154017.876	TARP site upstream of works	Baseline Construction
Kings Creek at confluence with Kangaroo River	KR2 – D/S	267919.6579	6153500.937	Located downstream of both basin discharge points.	Construction Operation
Unnamed tributary to Kangaroo River	TKR – D/S	269460.4883	6153501.82	Downstream of sediment basin discharges from stockpiles/ Laydown / Work Area 5	Construction Operation
Kangaroo River at Bendeela Campground	KR1 – U/S	269384.48	6152402.896	TARP site located just upstream of Project boundary	Construction

1. Baseline monitoring proposed at waterways where no data currently exists and/or there is no downstream waterway with adequate water quality monitoring data. Operational monitoring is proposed to only be at those sites downstream of major work areas until such time as site is adequately rehabilitated

11.2.2 Baseline monitoring

The surface water quality monitoring program would include collection of baseline water quality data during the pre-construction phase at Trimbles creek only, where adequate baseline data is not already available. Baseline water quality would be collected and compared to recommended ANZG (2018) guidelines in order to accurately define existing water quality conditions and determine if WQO are currently being met. The baseline data can also be used for comparison to construction and operational monitoring data to characterise and inform an appropriate response (in accordance with the Triger Action Response Plan) to any changes to water quality that may be associated with Project activities.

Sampling over the pre-construction monitoring period will comprise of a minimum of one dry weather sampling event per month and one opportunistic wet weather sampling event per month at nominated sites.

Baseline monitoring data would be used to supplement existing data and used for the development of discharge criteria in discussion with WaterNSW and the EPA as part of EPL application process.

11.2.3 Construction monitoring

Monthly surface water monitoring would occur throughout the duration of the construction phase and will be carried out at all nominated monitoring sites that is reflective of the works being undertaken at that time. Visual monitoring of other points of release will also be carried out during construction particularly following rainfall. Opportunistic wet weather sampling will also occur when more than 40mm of rain falls within a 24 hour period and/or prior to discharge of sediment basins within 5 days of a rainfall event.

Data collected during construction at monitoring sites with the potential to be impacted by the Project will be compared to the respective SSTV and/or ANZG (2018) default guideline value to determine if sampling results are within acceptable range.

If downstream sampling results are outside the acceptable range, then the results will be compared to upstream sampling results from reference and TARP sites relevant to the location of exceedance. If downstream results are less than or withing acceptable threshold of the upstream result, then no further action would be required. However, if downstream results are greater than upstream results then further investigation of the existing water quality control measure would be carried out to determine the potential cause of the impact and relevant authorities and stakeholders would be notified of the exceedance.

11.2.4 Operational monitoring

Monthly monitoring would occur for a minimum of 12 months during operation of the Project. The operational surface water monitoring period shall continue following the completion of construction at select sites (refer **Table 11-2**) until the affected waterways demonstrated as successfully rehabilitated to an acceptable condition and/or the permanent water quality structures are deemed to be operating satisfactorily. During operation, a similar approach to exceedance of water quality criteria outlined for construction will be adopted.

No changes to the current cyanobacteria monitoring is proposed. The current monitoring required in accordance with the Water Supply Work and Water Use Approval entails monitoring at a minimum of weekly between 1 October and 31 May and monthly between 1 June to 30 September at nominated sites and procedures as provided in **Table 11-3**.

Table 11-3 Cyanobacteria sampling and analysis (DPI, 2013b)

Storage	Site number	Sample Type	Analytes
Fitzroy Falls Reservoir	DFF6	Horizontal composite of the four samples collected in the reservoir	Total cyanobacteria with known toxin producers reported Total biovolume of all cyanobacteria species (mm^3/L) Species count (cells/mL) Microcystin toxin (µg/L)
	DFF7		
	DFF8		
	DFF9		
Lake Yarrunga	DTA8 (inside Bendeela Power Station boom)	Sample collected below the surface	
	DPAE (Bendeela Camping Area)		
Bendeela Pondage	DBP1	Sample collected below the surface	

11.2.5 Wet weather monitoring

Wet weather monitoring events will be determined as 40mm or more of rain within 24 hours recorded at the nearest BOM site. The following rainfall gauges will be used to obtain daily rainfall figures:

- Fitzroy Falls (Red Hills). – Station number 68248
- Hampden Bridge (Kangaroo River) – Station number 68181.

11.2.6 Trigger, Action, Response Plan (TARP)

A TARP for water quality impacts related to the Project will be developed and detailed within the Project CSWMP. Water quality triggers will take into consideration:

- The ANZG (2018) water quality guideline trigger values for 95% species protection and 99% species protection for toxicants that bioaccumulate
- The SSTVs developed where sufficient data is available
- The baselines/pre-construction monitoring data (for waterways which are currently not meeting the relevant WQOs based on pre-construction/baseline water quality data)
- Other relevant guidelines criteria specific to some sites, eg, ADWG (2011) and the raw water supply agreement with Kangaroo Valley WFP.

If an indicator is determined to exceed the nominated trigger value or outside background water quality for some indicators), an investigation will be carried out to identify the case and subsequently an appropriate management response will be implemented to rectify the issue.

11.2.7 Sampling parameters

Surface water quality monitoring will include both field parameters and laboratory analysis. The analytical suite is presented in **Table 11-4** and is based on those parameters that have the potential to be modified by the Project. Not all sites will require all indicators to be analysed.

Table 11-4 Surface water sampling – analytical suite

Field parameters	Laboratory analysis
pH	Total suspended solids (TSS) (mg/L)
Turbidity (NTU)	Total dissolved solids (TDS)
Temperature (°C)	Total nitrogen (TN) (mg/L)
Dissolved oxygen (% Sat and mg/L)	Total phosphorus (TP) (mg/L)
Electrical conductivity (µS/cm)	Oxidised Nitrogen (NOx) (mg/L)
Redox potential (eH)	Ammoniacal Nitrogen (NH_3) (mg/L)
Oil and grease (visual inspection)	Total metals (Al, Fe and Mn)
	Dissolved metals (Al, Fe and Mn)

Details regarding Quality Assurance and Quality Control will be provided in the CSWMP.

12. Conclusion

The purpose of this report has been to identify and assess the risk of impacts of construction and operation of the Shoalhaven Hydro Expansion Project on surface water quality, hydrology and geomorphology, and recommend mitigation measures to manage the risks. The assessment has been conducted to address Secretary's Environmental Assessment Requirements relevant to water.

Methodology

The surface water quality, hydrology and geomorphology assessment for the construction and operation of the Project has been prepared based on a review and analysis of available water level and water quality data, aerial photography, relevant literature and background reports, applicable legislation, policies and guidelines, and a site visit comprising of waterway condition assessment.

Existing environment

The desktop review identified that key waterways and waterbodies within the study area form part of the Sydney Water Drinking Catchment, as well as provide raw drinking water supply to Kangaroo Valley Water Filtration Plant for use by Kangaroo Valley township. The Project is surrounded by Morton National Park in the Upper portion of the study area. Key waterways within the study area include Fitzroy Falls Reservoir and Fitzroy Falls Upper Canal, Trimbles Creek and several tributaries of Trimbles Creek, Yarrunga Creek and several tributaries of Yarrunga Creek, Bendeela Pondage, Kings Creek, Kangaroo River (upstream of the full supply level (FSL) of Lake Yarrunga) and several tributaries of Kangaroo River, as well as Lake Yarrunga.

Analysis of existing water quality data included comparison of key water quality indicators against relevant water quality guidelines (ANZG, 2018; NHMRC, 2011) as well as legislated standards for raw water supply (WaterNSW, 2021; DPI, 2013b). Indicators which were analysed included turbidity, total suspended solids, pH, electrical conductivity, dissolved oxygen, nutrients, some heavy metals, algal count and toxic cyanobacteria counts. The analysis found that water quality of the drinking water supply storages and waterways which flow to catchment storages (Kangaroo River, Yarrunga Creek, Lake Yarrunga and Fitzroy Falls Reservoir) was variable with only around half of the indicators complying with relevant guidelines and standards. Indicators which generally did comply included pH, turbidity, dissolved oxygen and dissolved metals (dissolved iron, aluminium and manganese). Those that generally did not comply with guideline trigger values were nutrients (nitrogen and phosphorus in various forms), electrical conductivity, and total metals (total iron and aluminium). Compliance with algal and toxic cyanobacteria standards was also variable.

Waterway condition assessment identified that waterways and waterbodies within the study area were in fair to good condition, and all waterways and waterbodies were identified as sensitive receiving environments (SREs). It was noted however that the level of sensitivity varied for different waterways based on their human and aquatic ecosystem values. Waterways which were identified as highly sensitive SREs were Kangaroo River / Lake Yarrunga, Kings Creek, Unnamed tributary of Kangaroo River (Lower Scheme), Bendeela Pondage, and Fitzroy Falls Reservoir. All other waterways were considered to have low or very low sensitivity, with the exception of Fitzroy Canal which was classified as medium sensitivity due to its connection with Fitzroy Falls Reservoir.

With respect to geomorphology, the banks of Lake Yarrunga appeared to be generally stable. Historic photographic evidence suggested there were no obvious signs of bank instability, although some notching of the bank was evident. Some sedimentation in the formation of bar development was noted in the channel which is to be expected in the upper section of the weir pool. Fitzroy Falls Reservoir and Bendeela Pondage were considered to have low erosion potential due to the constructed nature of these storages, as well as the shallow gradient of shoreline and vegetated cover along the perimeter of Fitzroy Falls Reservoir.

Construction impacts

Upon review of the reference concept Project design, construction methodology and proposed construction activities, it was determined that without management, risks to water quality, hydrology and geomorphology during construction could be:

- Erosion and sedimentation of downstream waterways from vegetation clearing, earthworks, overflow discharges of sediment basins, movement of spoil, spoil stockpiling and emplacement, and instream works

- Mobilisation of poor-quality construction or stormwater runoff to downstream waterways during road works and from activities carried out at site laydown / work areas (i.e. Use of site facilities, concrete works, rock blasting and steel works)
- Mobilisation of tannin leachate from vegetation clearing
- Mobilisation of acid leachate from low risk potentially acid-forming rock transported to and placed in the spoil emplacement area
- Release of poor-quality tunnel process water (including groundwater) and construction sediment basin discharges to downstream waterways
- Temporary water table drawdown and minor reduction in groundwater baseflows in Kings Creek as a result of tunnelling and underground works.

With the implementation of mitigation measures outlined below, it was determined that risk of these impacts occurring were very low or low for waterways and waterbodies within the study area. The only waterway that was identified as having a medium risk was Lake Yarrunga. This was because construction activities are expected to occur within and in close proximity of this sensitive waterway therefore the likelihood of impact was slightly higher. It is expected, however, that recommended nominated water quality mitigation measures will adequately mitigate the risks. As such, the Project is expected to have a neutral effect on water quality during construction.

Operational impacts

During operation, risks to water quality, hydrology and geomorphology were identified as:

- Release of poor-quality groundwater seepage during operational discharges
- Erosion and sedimentation of downstream Trimbles Creek during discharge of the Penstock Pipeline for maintenance
- Bank erosion in Lake Yarrunga from repeated wetting and drying of the same section of the riverbank from the increased rate of water fluctuation in the reservoirs (when the existing scheme and new scheme are being operated at the same time).

With the implementation of mitigation measures outlined below, it was determined that risk of these impacts occurring were low for waterways and waterbodies within the study area. The only waterway that was identified as having a medium risk was Lake Yarrunga due to possibility of increased bank erosion. Despite this slightly higher risk, it is expected that the Project would be designed and operated to reduce this risk. As such, the Project is expected to have a neutral effect on water quality during operation.

Recommended mitigation measures

To reduce the risk of identified impacts on water quality, hydrology and geomorphology, it is recommended that the Project implement a suite of mitigation measures.

During construction, these measures would be outlined in a Construction Soil and Water Management Plan (CSWMP) and should include but not be limited to:

- Measures to minimise/manage erosion and sediment transport within the disturbance area and offsite, including development of site-specific Erosion Sediment Control Plans
- Measures to manage spoil and stockpiles including transport between area, stockpile locations, sediment controls and stabilisation
- Measures to manage accidental spills in accordance with WaterNSW incident management protocols
- Measures to manage potential tannin leachate
- Details of surface water quality monitoring to be undertaken prior to, throughout and following construction
- Measures to treat water collected in sediment basins for reuse on-site or discharge to downstream waterways
- Measures to manage groundwater ingress into vertical shafts and tunnels and tunnel process water including dewatering
- Procedures to capture, contain and appropriately dispose of any concrete wastes from concrete works
- Concrete structures to be pre-fabricated prior to installation instream or within the riparian zone (40m of any waterway), where practicable
- Prior to disposal of construction water collected in sediment basins, water should be treated to the appropriate standard specified in the CSWMP and repurposed on site wherever possible. For instance, for dust suppression activities

- A construction discharge water treatment plant will be designed to treat groundwater seepage and tunnel process water
- Site specific trigger values will be developed during construction planning to set the discharge water treatment plant and sediment basin discharge criteria ensuring water will be treated to a level that is representative of background concentration of a suitable reference site and/or the ANZG (2018) guidelines
- Water that cannot be repurposed on site may be discharged locally provided the Construction Contractor obtains an EPL for this activity. The Construction Contractor would therefore be required to adhere to regulations specified in the EPL which would include specified discharge locations, and water quality concentration limits to be met prior to discharge
- Monitoring at all discharge points undertaken prior to and during construction to determine background water quality and detect any environmental degradation as a result of the construction works. This will also allow for understanding treatment to be applied to sediment laden water.

During operation, the following mitigation measures are recommended and would be outlined in the Operational Management Plan:

- The operational surface water quality monitoring program will be based on the construction monitoring program but refined to target issues relating to the operation of the Project, e.g. monitoring of Trimbles Creek at the Penstock should water require discharging from the pipeline
- Erosion and sediment controls during operation would be outlined in the Operational Management Plan and would detail procedures and protocols for maintaining scour protection measures at the outlets, groundwater seepage, and ongoing rehabilitation of disturbed areas
- A permanent water treatment facility will be designed to treat groundwater seepage generated from groundwater ingress in the main access tunnel and caverns, and runoff from operation in the caverns. The collected water will be separated via an oily water separator and treated to an acceptable standard (where required) prior to being injected into the tailrace tunnel where it would be further diluted and representative of the water quality of inside the tailrace tunnel, which would flow out to Lake Yarrunga or Fitzroy Falls during generation / pumping. The level of treatment provided will consider the characteristics of the receiving environment.

Overall, on the basis of the assessment of the existing environment, the design of the Project, and on the assumption that recommended mitigation measures are implemented, the assessment concludes that there would be minimal impacts to the surface water quality, hydrology or geomorphology of waterways and waterbodies within the study area. As such, aquatic and human environmental values of waterways and waterbodies within the study area are expected to be protected and a neutral effect on water quality met.

<u>Summary</u>

This report has been necessarily prepared on the basis of the reference concept as described in the EIS. The Project water impacts, and recommended mitigation measures are identified on the basis of reasonable worst case assumptions and are subject to detailed design. Based on these identified impacts and recommended mitigation, monitoring and adaptive management responses it is considered that the Project would have a neutral outcome on existing water quality.

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Appendix A Applicable water quality guidelines and interim site-specific trigger values

Table A-1 Key water quality indicators and related numerical criteria for environmental values using the ANZG (2018) and ANZECC/ARMCANZ (2000) Water Quality Guidelines; Raw water supply agreement to the Kangaroo Valley WFP (WaterNSW, 2019) and the ADWG (2011)

Environmental value	Indicator	Guideline value	
		Upland River	Lowland River
Aquatic ecosystems (upland river and lowland rivers) – maintaining or improving the ecological condition of waterbodies and riparian zones over the long term	Total nitrogen	<0.25mg/L	<0.35mg/L
	Ammoniacal Nitrogen	<0.013mg/L	<0.02mg/L
	Oxidised Nitrogen	<0.015mg/L	<0.04mg/L
	Total phosphorus	<0.02mg/L	<0.025mg/L
	Filterable Reactive Phosphorus	<0.015mg/L	<0.005mg/L
	Chlorophyll-a	-	<0.003mg/L
	Turbidity	<25NTU	<50NTU
	Salinity (electrical conductivity)	<0.35mS/cm	0.125 – 2.2mS/cm
	Dissolved oxygen	90-110% Sat	85-110% Sat
	pH	6.5 – 8	6.5 – 8
	Toxicants	As per ANZG (2018) toxicant default guideline values (95% level of protection for slightly to moderately disturbed ecosystems and 99% level of protection for toxicants that bioaccumulate)	
	Visual clarity and colour	Natural visual clarity should not be reduced by more than 20%. Natural hue of water should not be changed by more than 10 points on the Munsell Scale. The natural reflectance of the water should not be changed by more than 50%	
Visual amenity – aesthetic qualities of waters	Surface films and debris	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour Waters should be free from floating debris and litter. n/a (no quantitative value specified)	

Environmental value	Indicator	Guideline value	
		Upland River	Lowland River
	Nuisance organisms	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae, sewage fungus and leeches should not be present in unsightly amounts. n/a (no quantitative value specified)	
	Turbidity	<20NTU	
Raw water supply agreement to the Kangaroo Valley and Wingecarribee WFP	True Colour at 400nm	70CU	
	Iron	1.1mg/L	
	Manganese	0.4mg/L	
	Hardness	36.5mg/L as CaCO3	
	Alkalinity	29mg/L as CaCO3	
	pH	6.5 – 8.5	
	Algae	5000ASU	
	Synthetic Organic Compounds	As per the ADWG guidelines (NHMRC, 2011)	
	Pesticides	As per the ADWG guidelines (NHMRC, 2011)	
	Toxicants	As per the ADWG guidelines (NHMRC, 2011) for metals not specified in the Raw water supply agreement to the Illawarra WFP	

Table A-2 Interim SSTVS for Lake Yarrunga and Bendeela Pondage

Indicator	BP - 20th percentile	BP - 80th percentile	LY - 20th percentile	LY - 80th percentile
Aluminium Filtered (mg/L)	N/A	0.025	N/A	0.05
Aluminium Total (mg/L)	N/A	0.5	N/A	0.5
Chlorophyll-a (μg/L)	N/A	15.6	N/A	15.2
Conductivity (μS/cm)	99.6	106.8	86.9	107.7
Dissolved Oxygen (%Sat)	87.4	99.2	86.2	90.4
Iron Filtered (mg/L)	N/A	0.32	N/A	0.36
Iron Total (mg/L)	N/A	0.63	N/A	0.66

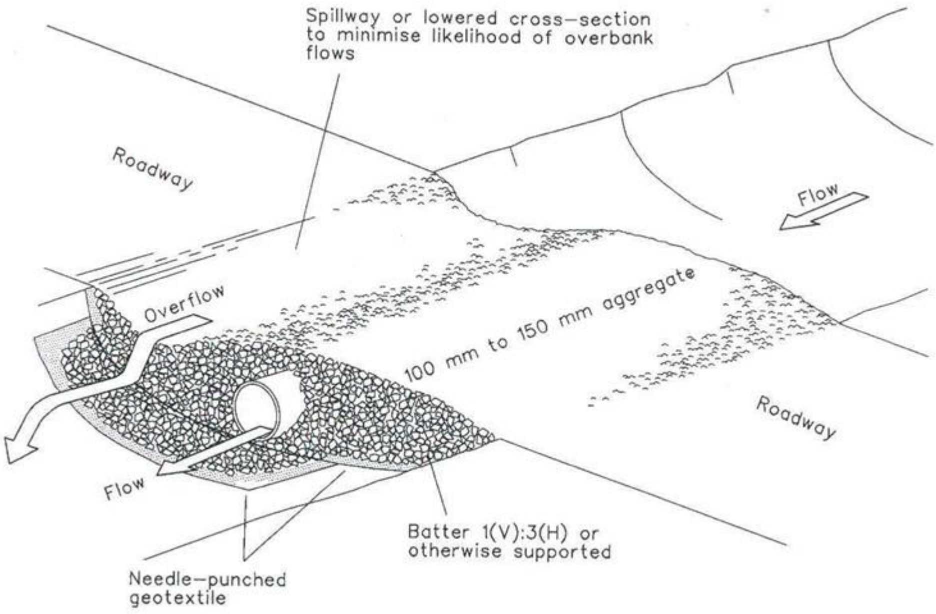
Indicator	BP - 20th percentile	BP - 80th percentile	LY - 20th percentile	LY - 80th percentile
Manganese Filtered (mg/L)	N/A	0.012	N/A	0.028
Manganese Total (mg/L)	N/A	0.054	N/A	0.061
Ammoniacal Nitrogen (mg/L)	N/A	0.036	N/A	0.043
Oxidised Nitrogen (mg/L)	N/A	0.24	N/A	0.19
Total Nitrogen (mg/L)	N/A	0.48	N/A	0.48
Soluble Reactive Phosphorus (mg/L)	N/A	0.007	N/A	0.007
Total Phosphorus (mg/L)	N/A	0.024	N/A	0.034
pH	7.29	7.44	6.7	7.9
Suspended solids (mg/L)	N/A	9	N/A	7.4
Turbidity (NTU)	N/A	5.95	N/A	6.778
True Colour @ 400nm (CU)	N/A	20.8	N/A	30

Existing water quality data from Lake Yarrunga and Bendeela Pondage was used to calculate the 80th percentile of baseline data (and the 20th percentile where water quality would fall within specified range, eg. pH, dissolved oxygen and electrical conductivity)

Appendix B Blue Book Standard Drawings

A number of Standard Drawings from Landcom (2004) are referred to in this document, either directly or indirectly. These are appended here:

- Standard Drawing SD 5-1 (Temporary Waterway Crossing)
- Standard Drawing SD 5-2 (Sheet Flow)
- Standard Drawing SD 5-3 (Cellular Confinement Systems)
- Standard Drawing SD 5-4 (Rock Check Dam)
- Standard Drawing SD 5-5 (Earth Bank (Low Flow))
- Standard Drawing SD 5-6 (Earth Bank (High Flow))
- Standard Drawing SD 5-7 (RECP: Concentrated Flow)
- Standard Drawing SD 5-8 (Energy Dissipater)
- Standard Drawing SD 6-3 (Earth Basin - Dry)
- Standard Drawing SD 6-4 (Earth Basin - Wet)
- Standard Drawing SD 6-7 (Straw Bale Filter)
- Standard Drawing SD 6-8 (Sediment Fence)
- Standard Drawing SD 6-9 (Alternative Sediment Fence)
- Standard Drawing SD 6-10 (Turbidity Barrier)
- Standard Drawing SD 6-11 (Mesh and Gravel Inlet Filter)
- Standard Drawing SD 6-12 (Geotextile Inlet Filter)
- Standard Drawing SD 6-13 (Kerbside Turf Strip)
- Standard Drawing SD 6-14 (Stabilised Site Access)
- Standard Drawing SD 6-15 (Control of Wind Erosion)
- Standard Drawing SD 7-1 (Seedbed Preparation)

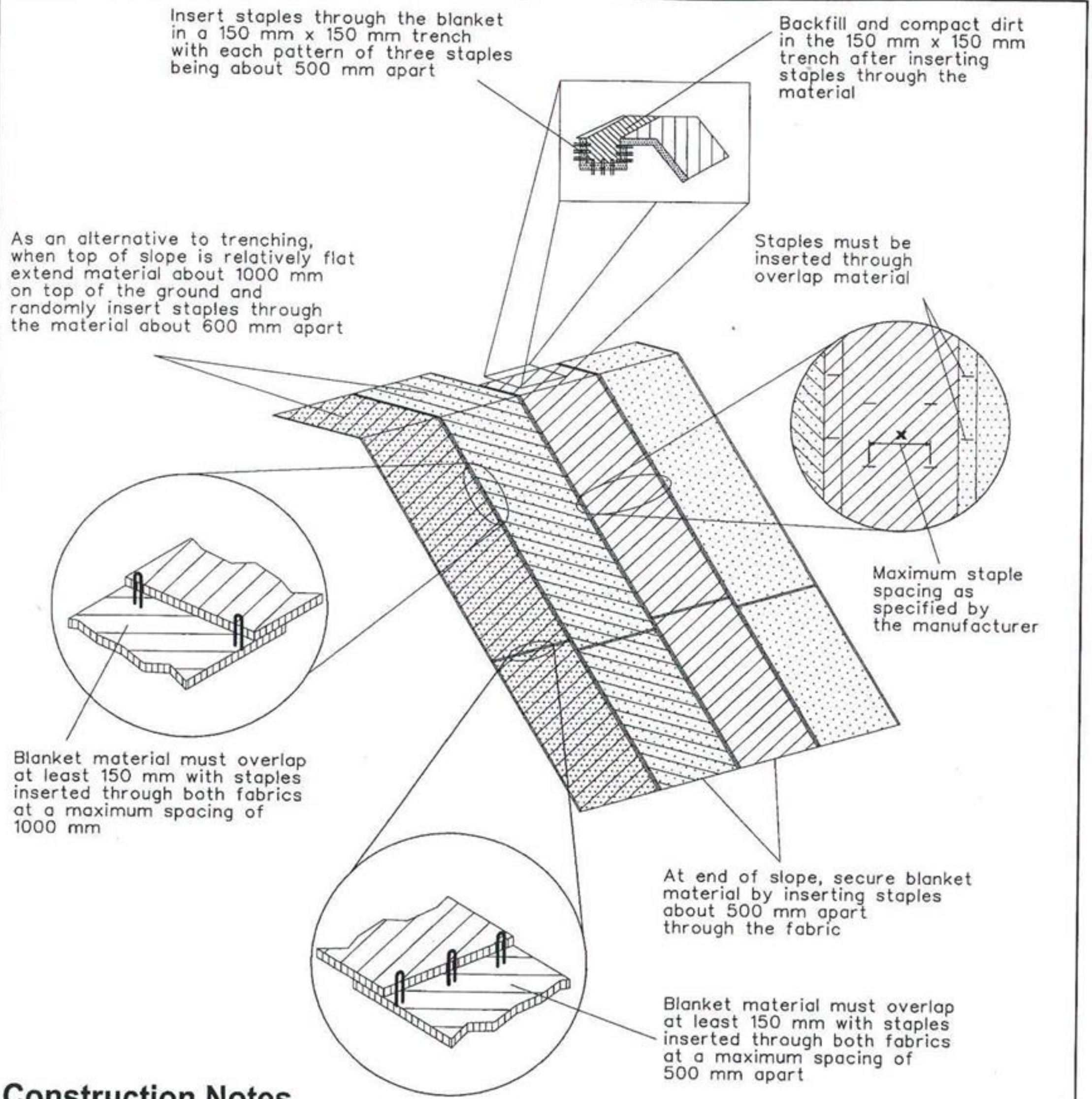


Construction Notes

1. Prohibit all traffic until the access way is constructed.
2. Strip any topsoil and place a needle-punched textile over the base of the crossing.
3. Place clean, rigid, non polluting aggregate or gravel in the 100 mm to 150 mm size class over the fabric to a minimum depth of 200 mm.
4. Provide a 3-metre wide carriageway with sufficient length of culvert pipe to allow less than a 3(H): 1 (V) slope on side batters.
5. Install a lower section to act as an emergency spillway in greater than design storm events.
6. Ensure that culvert outlets extend beyond the toe of fill embankments.

TEMPORARY WATERWAY CROSSING **SD 5-1**

5-14

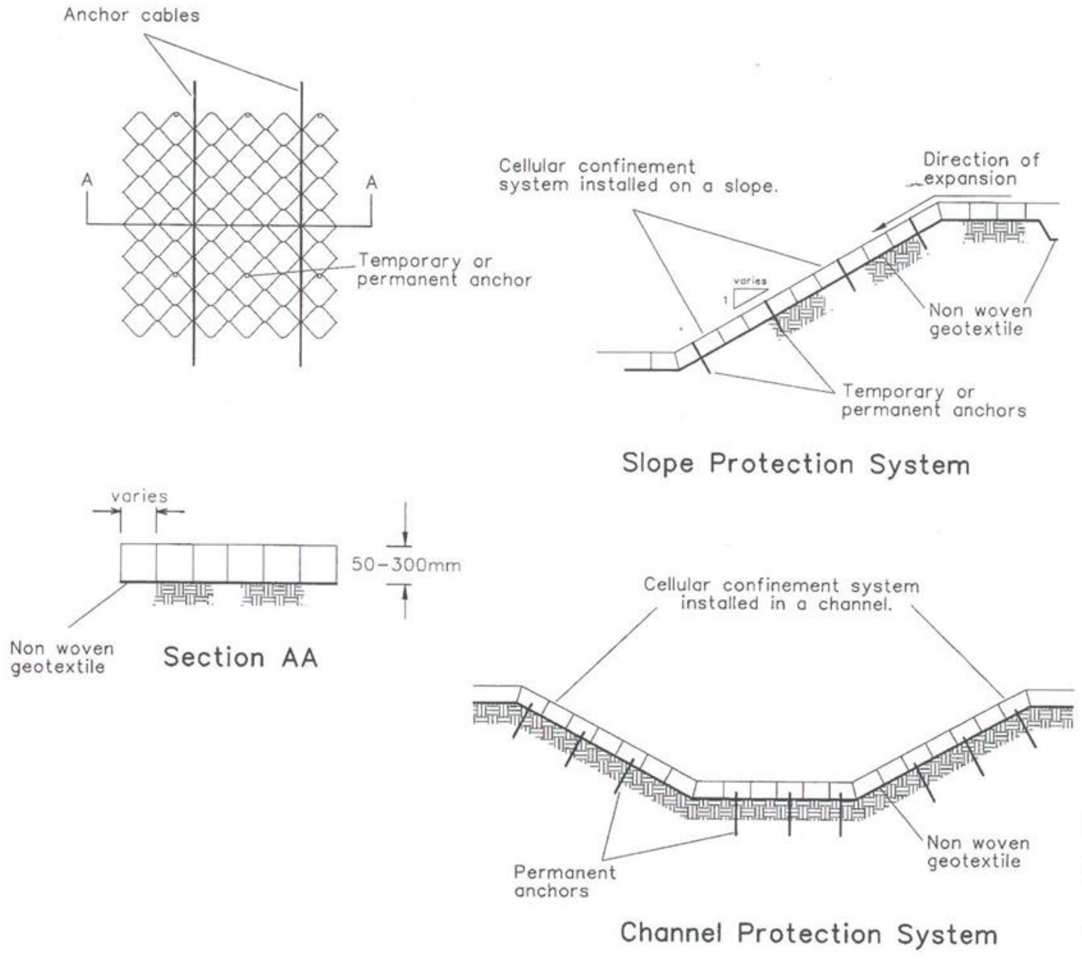


Construction Notes

1. Remove any rocks, clods, sticks or grass from the ground surface before laying the matting.
2. Spread topsoil to at least 75 mm depth.
3. Where appropriate, complete fertilising and seeding on a properly prepared seedbed (Standard Drawing 7-1) before laying the matting.
4. Ensure the fabric can be continuously in contact with the soil by grading the surface carefully first.
5. Lay the matting in "shingle-fashion" with the ends of each upstream roll overlapping the next roll downslope.
6. Ensure sufficient staples are used to maintain a good contact between the soil and the matting.

RECP : SHEET FLOW **SD 5-2**

5-18

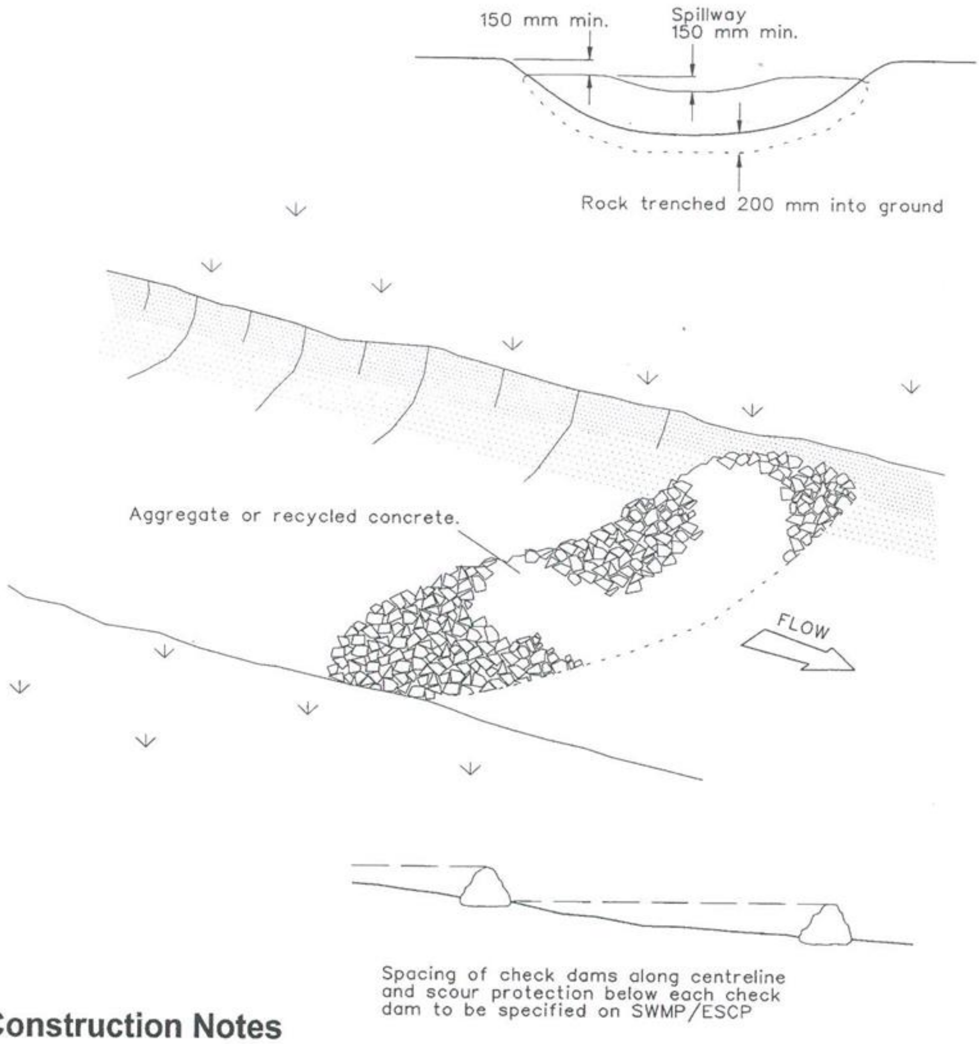


Construction Notes

1. Undertake design only with the help of a suitably qualified geotechnical engineer.
2. Anchor systems on steep slopes to prevent sliding or movement under gravitational forces. This might include the use of high tensile, low creep cables made of polyester (not polypropylene), rope or steel wire.
3. Place thick, non woven geotextiles under the cellular confinement system to allow for lateral drainage.
4. Fill the cells with soil, rock or concrete depending on the application.

CELLULAR CONFINEMENT SYSTEMS **SD 5-3**

5-19



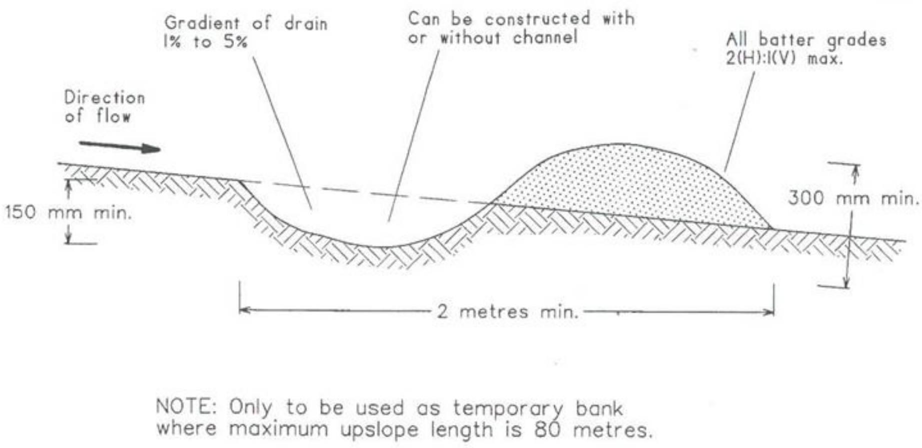
Construction Notes

1. Check dams can be built with various materials, including rocks, logs, sandbags and straw bales. The maintenance program should ensure their integrity is retained, especially where constructed with straw bales. In the case of bales, this might require their replacement each two to four months.
2. Trench the check dam 200 mm into the ground across its whole width. Where rock is used, fill the trenches to at least 100 mm above the ground surface to reduce the risk of undercutting.
3. Normally, their maximum height should not exceed 600 mm above the gully floor. The centre should act as a spillway, being at least 150 mm lower than the outer edges.
4. Space the dams so the toe of the upstream dam is level with the spillway of the next downstream dam.

ROCK CHECK DAM

SD 5-4

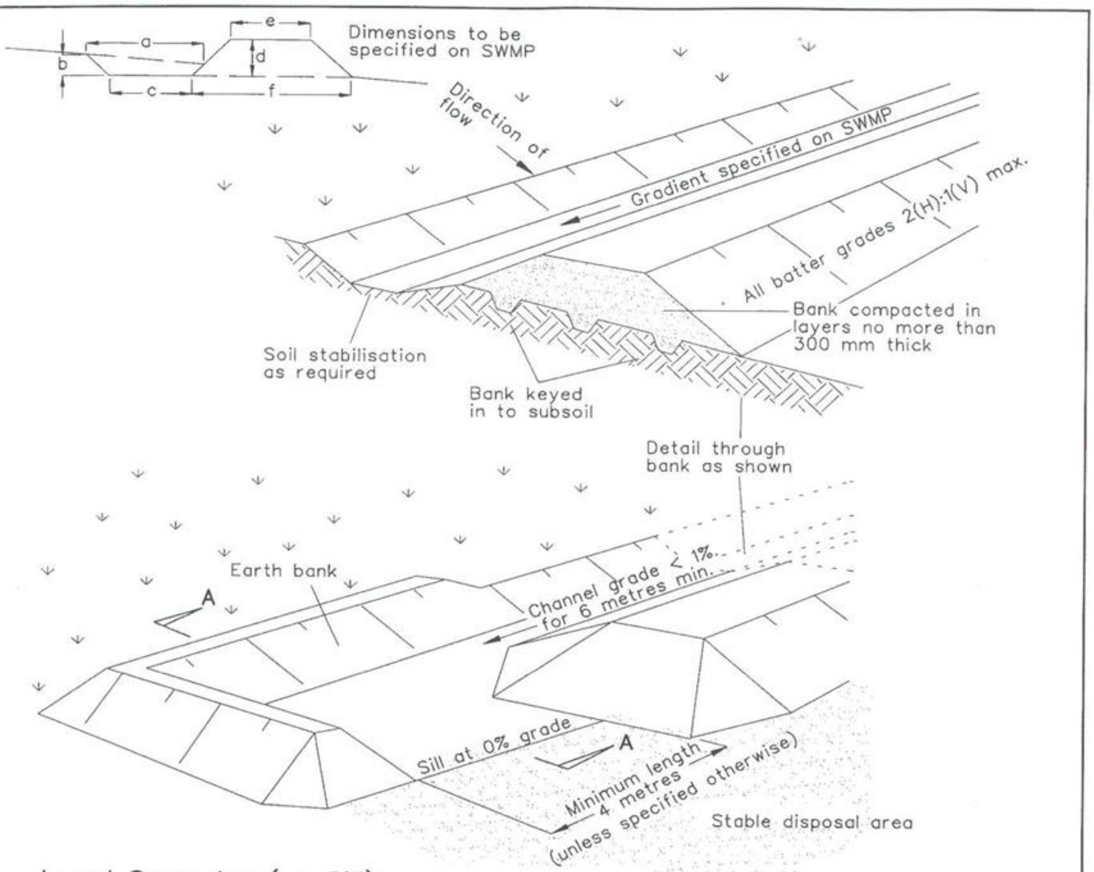
5-22



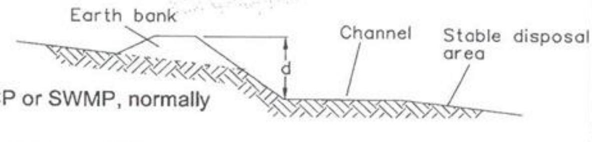
Construction Notes

1. Build with gradients between 1 percent and 5 percent.
2. Avoid removing trees and shrubs if possible - work around them.
3. Ensure the structures are free of projections or other irregularities that could impede water flow.
4. Build the drains with circular, parabolic or trapezoidal cross sections, not V shaped.
5. Ensure the banks are properly compacted to prevent failure.
6. Complete permanent or temporary stabilisation within 10 days of construction.

EARTH BANK (LOW FLOW) **SD 5-5**



Level Spreader (or Sill)



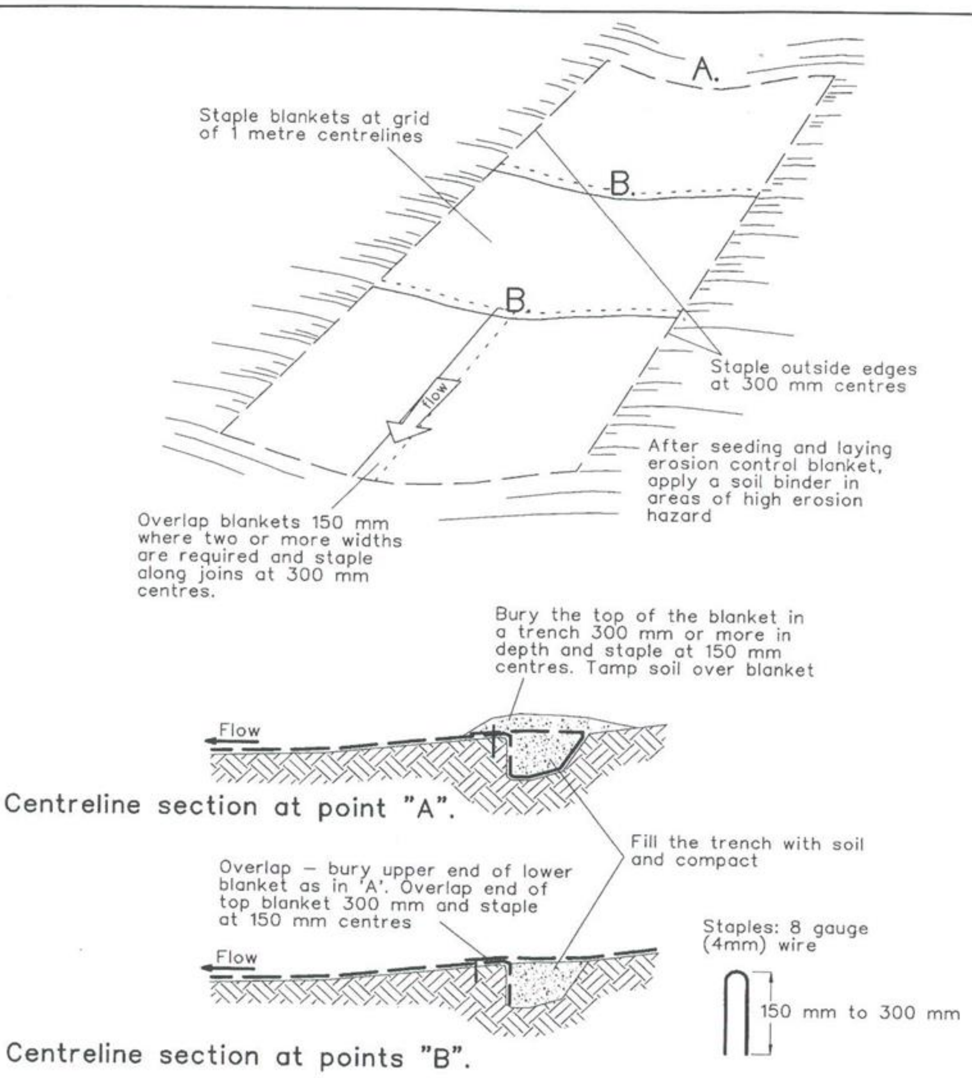
Section AA

Construction Notes

1. Construct at the gradient specified on the ESCP or SWMP, normally between 1 and 5 percent
2. Avoid removing trees and shrubs if possible - work around them.
3. Ensure the structures are free of projections or other irregularities that could impede water flow.
4. Build the drains with circular, parabolic or trapezoidal cross sections, not V-shaped, at the dimensions shown on the SWMP.
5. Ensure the banks are properly compacted to prevent failure.
6. Complete permanent or temporary stabilisation within 10 days of construction following Table 5.2 in Landcom (2004).
7. Where discharging to erodible lands, ensure they outlet through a properly constructed level spreader.
8. Construct the level spreader at the gradient specified on the ESCP or SWMP, normally less than 1 percent or level.
9. Where possible, ensure they discharge waters onto either stabilised or undisturbed disposal sites within the same subcatchment area from which the water originated. Approval might be required to discharge into other subcatchments.

EARTH BANK (HIGH FLOWS) **SD 5-6**

5-26

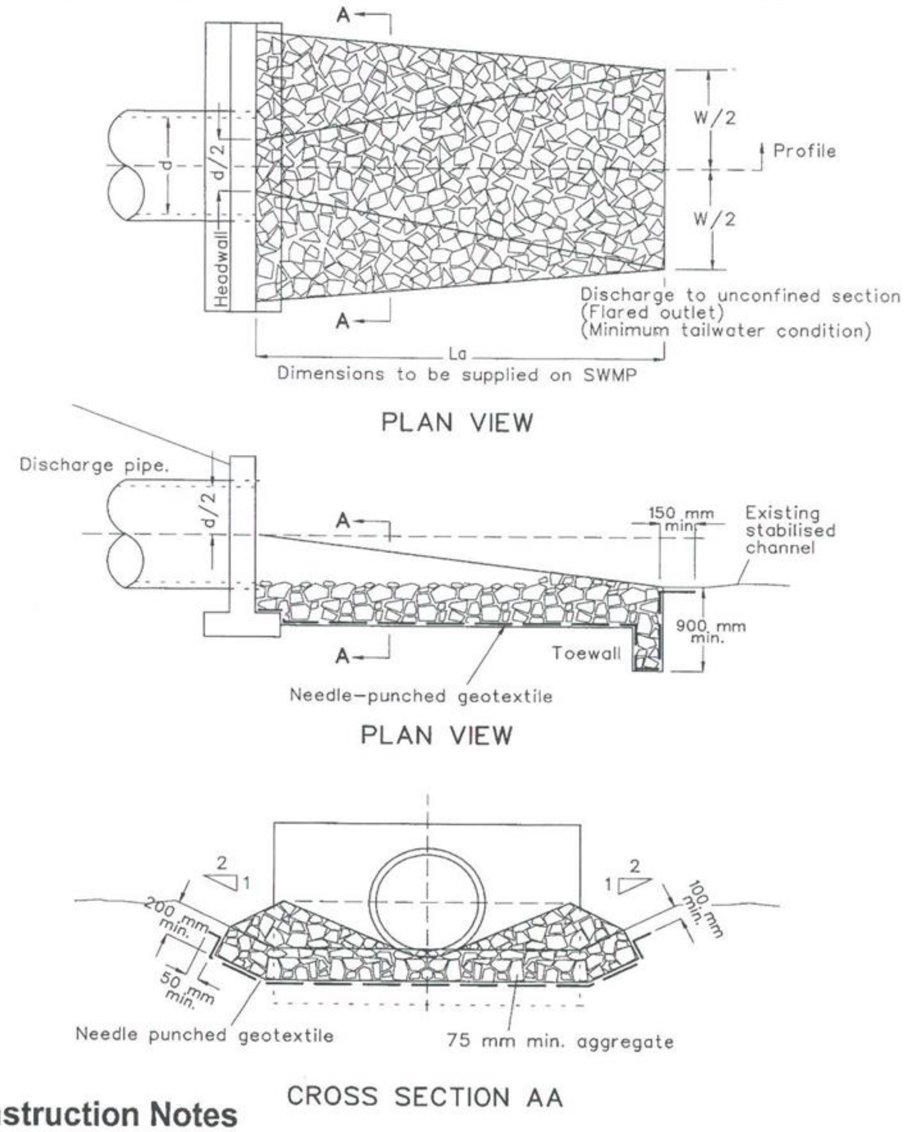


Construction Notes

1. Remove any rocks, clods, sticks or grass from the surface before laying matting
2. Ensure that topsoil is at least 75 mm deep.
3. Complete fertilising and seeding before laying the matting.
4. Ensure fabric will be continuously in contact with the soil by grading the surface carefully first.
5. Lay the fabric in "shingle-fashion", with the end of each upstream roll overlapping those downstream. Ensure each roll is anchored properly at its upslope end (Standard Drawing 5-7b).
6. Ensure that the full width of flow in the channel is covered by the matting up to the design storm event, usually in the 10-year ARI time of concentration storm event.
7. Divert water from the structure until vegetation is stabilised properly.

RECP : CONCENTRATED FLOW **SD 5-7**

5-28

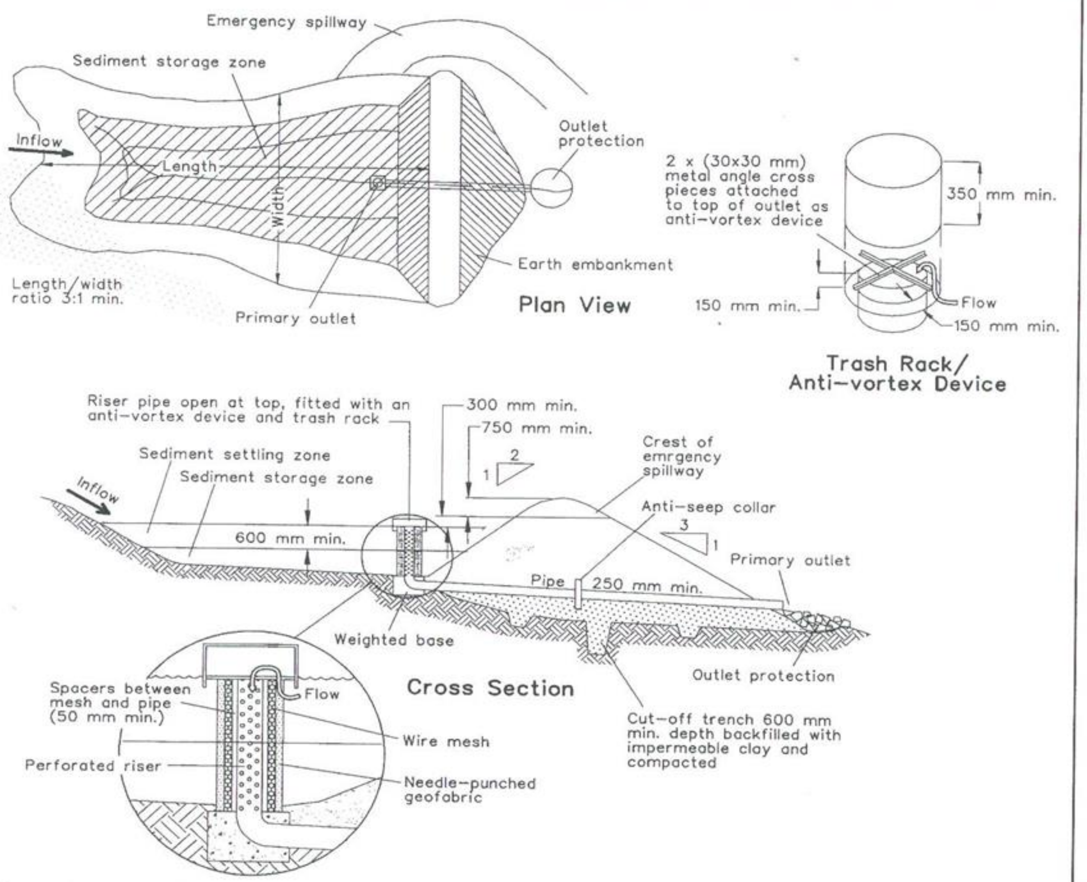


Construction Notes

1. Compact the subgrade fill to the density of the surrounding undisturbed material.
2. Prepare a smooth, even foundation for the structure that will ensure that the needle-punched geotextile does not sustain serious damage when covered with rock.
3. Should any minor damage to the geotextile occur, repair it before spreading any aggregate. For repairs, patch one piece of fabric over the damage, making sure that all joints and patches overlap more than 300 mm.
4. Lay rock following the drawing, according to Table 5.2 of Landcom (2004) and with a minimum diameter of 75 mm.
5. Ensure that any concrete or riprap used for the energy dissipater or the outlet protection conforms to the grading limits specified on the SWMP.

ENERGY DISSIPATER **SD 5-8**

5-34



Construction Notes

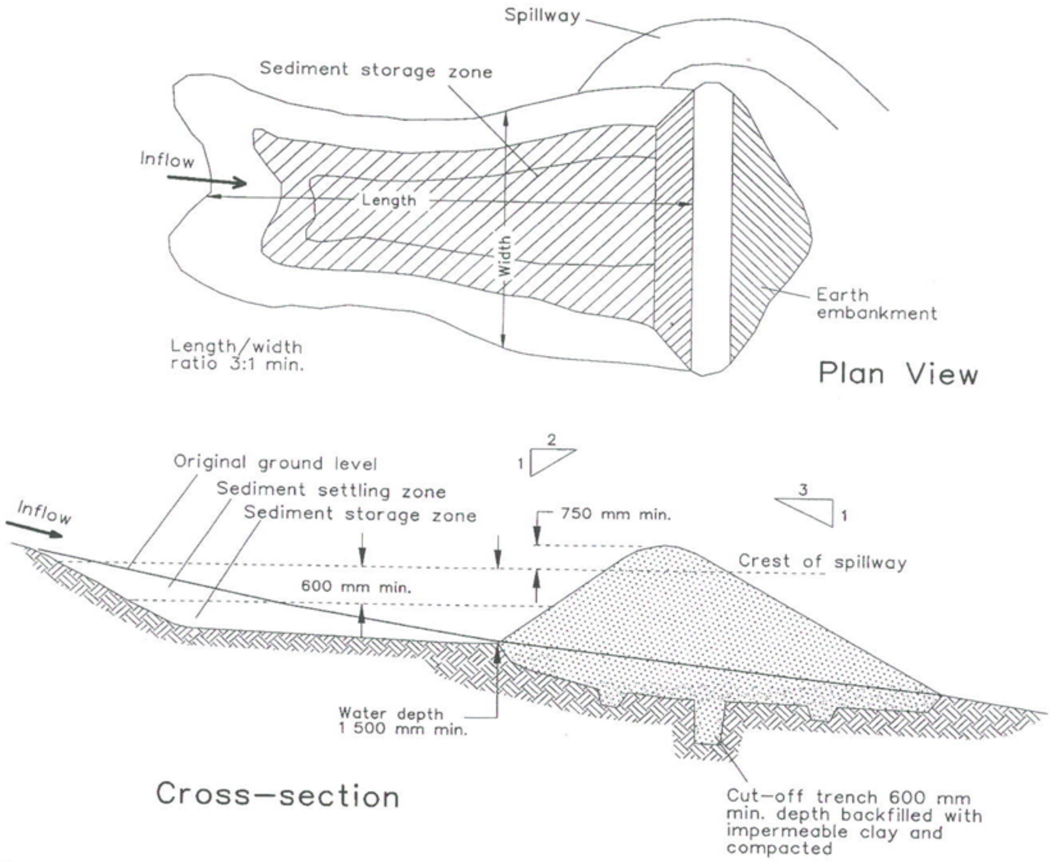
1. Remove all vegetation and topsoil from under the dam wall and from within the storage area.
2. Form a cut off trench under the centreline of the embankment 600 mm deep and 1,200 mm wide, extending to a point on the watercourse wall above the riser sill level.
3. Maintain the trench free of water and recompact the materials with equipment as specified In the SWMP to 95 per cent Standard Proctor Density.
4. Select fill according to the SWMP that is free from roots, wood, rock, large stone or foreign material.
5. Prepare the site under the embankment by ripping to at least 100 mm to help bond the compacted fill to the existing substrate.
6. Spread the fill in 100 mm to 150 mm layers and compact it at optimum moisture content following the SWMP.
7. Install the pipe outlet with seepage collars as specified in the SWMP and Standard Drawing 6-3b.
8. Form batter grades at 2(H):1(V) upstream and 3(H):1(V) downstream or as specified in the SWMP

EARTH BASIN - DRY

(APPLIES TO 'TYPE C' SOILS ONLY)

SD 6-3

6-18



Construction Notes

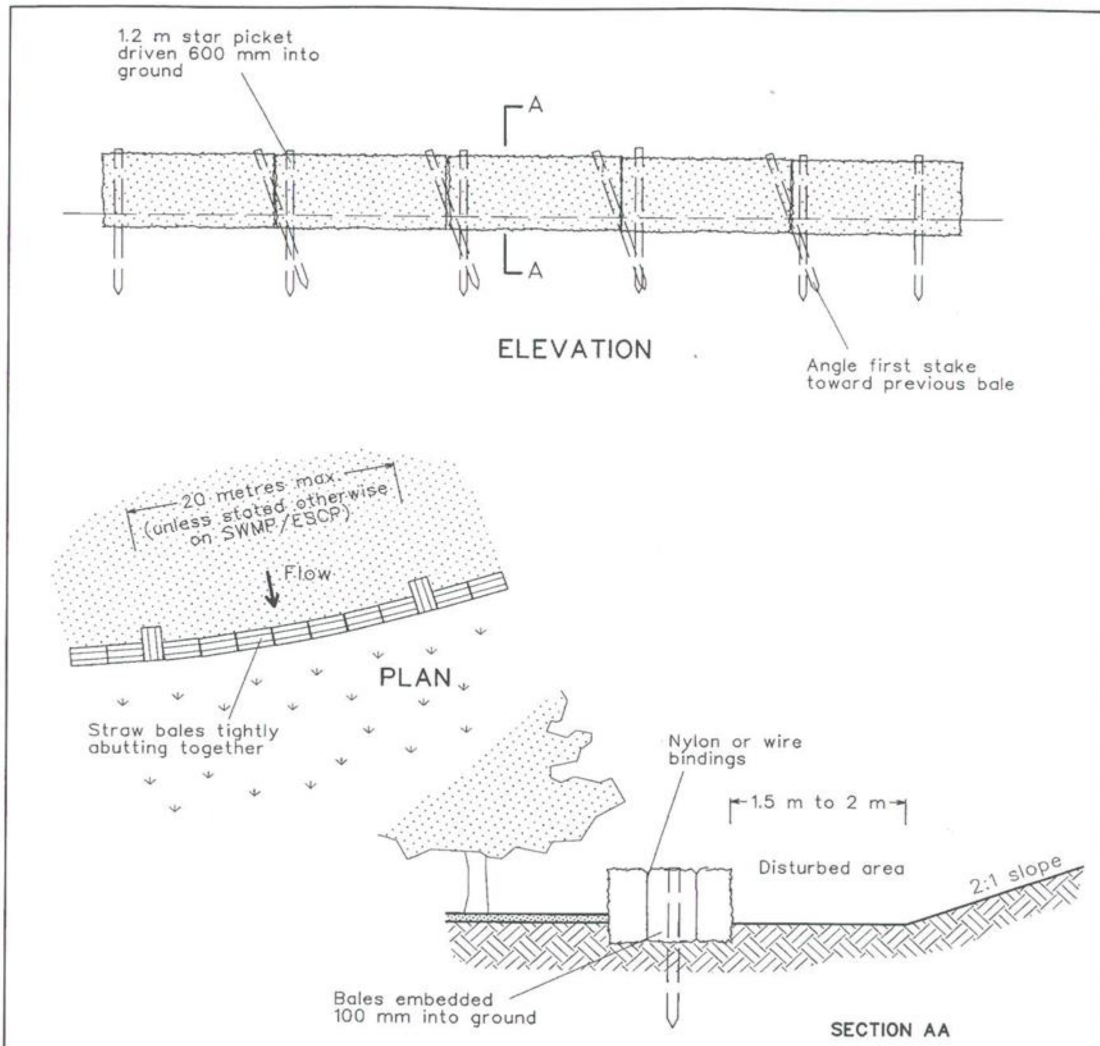
1. Remove all vegetation and topsoil from under the dam wall and from within the storage area.
2. Construct a cut-off trench 500 mm deep and 1,200 mm wide along the centreline of the embankment extending to a point on the gully wall level with the riser crest.
3. Maintain the trench free of water and recompact the materials with equipment as specified in the SWMP to 95 per cent Standard Proctor Density.
4. Select fill following the SWMP that is free of roots, wood, rock, large stone or foreign material.
5. Prepare the site under the embankment by ripping to at least 100 mm to help bond compacted fill to the existing substrate.
6. Spread the fill in 100 mm to 150 mm layers and compact it at optimum moisture content following the SWMP.
7. Construct the emergency spillway.
8. Rehabilitate the structure following the SWMP.

EARTH BASIN - WET

(APPLIES TO 'TYPE D' AND 'TYPE F' SOILS ONLY)

SD 6-4

6-19

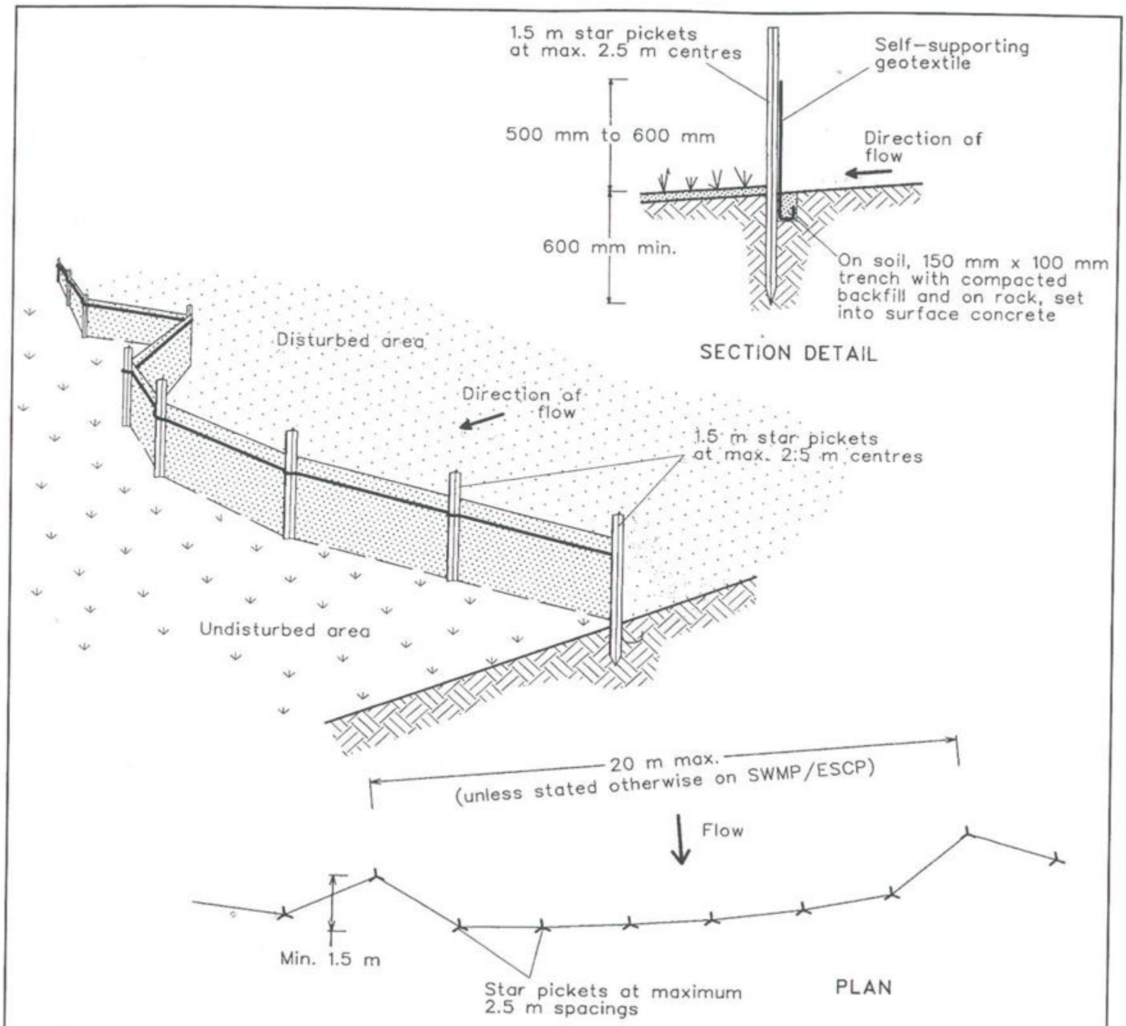


Construction Notes

1. Construct the straw bale filter as close as possible to being parallel to the contours of the site.
2. Place bales lengthwise in a row with ends tightly abutting. Use straw to fill any gaps between bales. Straws are to be placed parallel to ground.
3. Ensure that the maximum height of the filter is one bale.
4. Embed each bale in the ground 75 mm to 100 mm and anchor with two 1.2 metre star pickets or stakes. Angle the first star picket or stake in each bale towards the previously laid bale. Drive them 600 mm into the ground and, if possible, flush with the top of the bales. Where star pickets are used and they protrude above the bales, ensure they are fitted with safety caps.
5. Where a straw bale filter is constructed downslope from a disturbed batter, ensure the bales are placed 1 to 2 metres downslope from the toe.
6. Establish a maintenance program that ensures the integrity of the bales is retained - they could require replacement each two to four months.

STRAW BALE FILTER **SD 6-7**

6-35

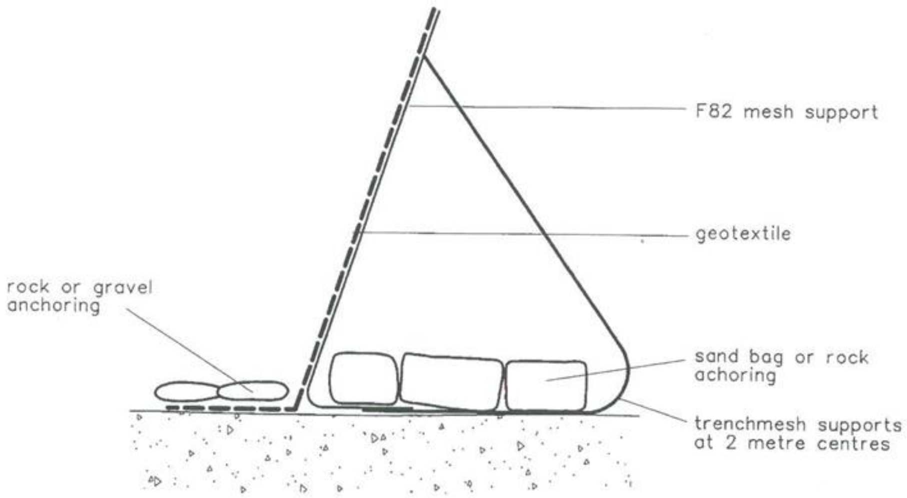


Construction Notes

1. Construct sediment fences as close as possible to being parallel to the contours of the site, but with small returns as shown in the drawing to limit the catchment area of any one section. The catchment area should be small enough to limit water flow if concentrated at one point to 50 litres per second in the design storm event, usually the 10-year event.
2. Cut a 150-mm deep trench along the upslope line of the fence for the bottom of the fabric to be entrenched.
3. Drive 1.5 metre long star pickets into ground at 2.5 metre intervals (max) at the downslope edge of the trench. Ensure any star pickets are fitted with safety caps.
4. Fix self-supporting geotextile to the upslope side of the posts ensuring it goes to the base of the trench. Fix the geotextile with wire ties or as recommended by the manufacturer. Only use geotextile specifically produced for sediment fencing. The use of shade cloth for this purpose is not satisfactory.
5. Join sections of fabric at a support post with a 150-mm overlap.
6. Backfill the trench over the base of the fabric and compact it thoroughly over the geotextile.

SEDIMENT FENCE **SD 6-8**

6-36

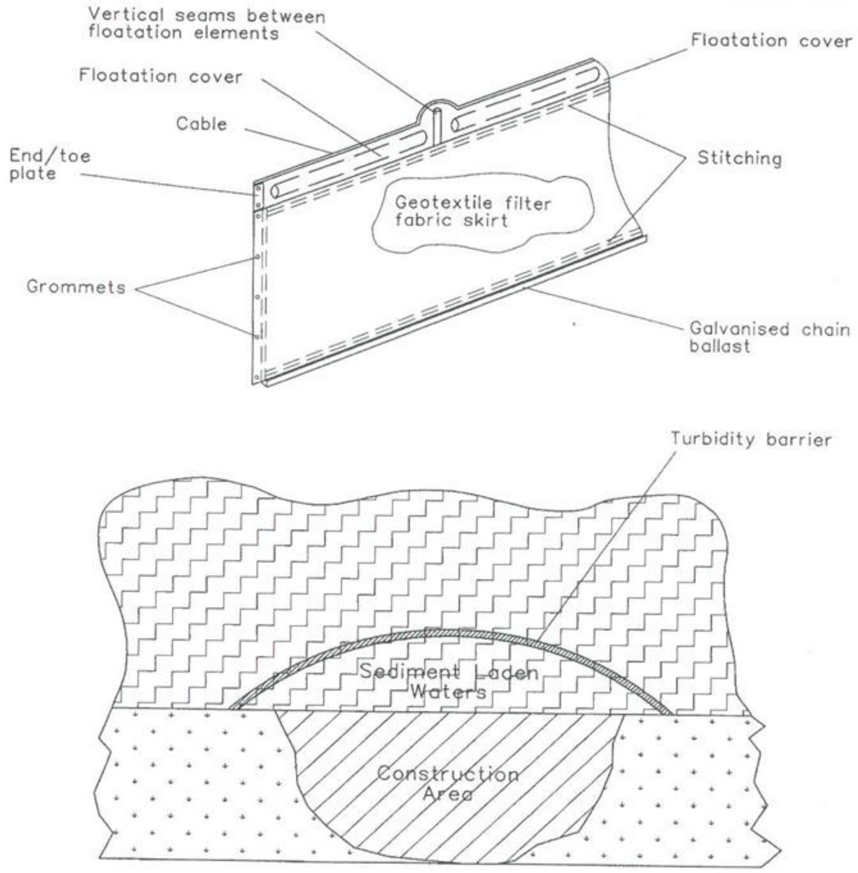


Construction Notes

1. Install this type of sediment fence when use of support posts is not desirable or not possible. Such conditions might apply, for example, where approval is granted from the appropriate authorities to place these fences in highly sensitive estuarine areas.
2. Use bent trench mesh to support the F82 welded mesh facing as shown on the drawing above. Attach the geotextile to the welded mesh facing using UV resistant cable ties.
3. Stabilise the whole structure with sandbag or rock anchoring over the trench mesh and the leading edge of the geotextile. The anchoring should be sufficiently large to ensure stability of the structure in the design storm event, usually the 10 year event.

ALTERNATIVE SEDIMENT FENCE **SD 6-9**

6-38

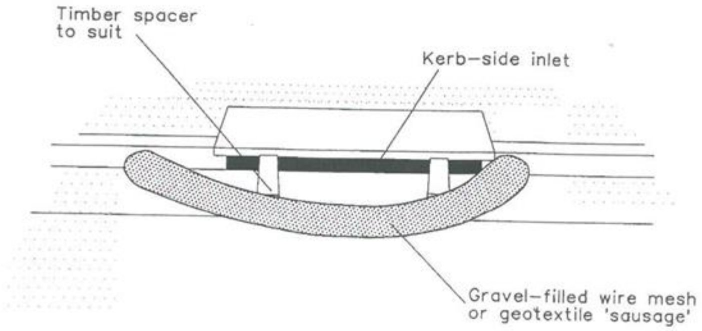


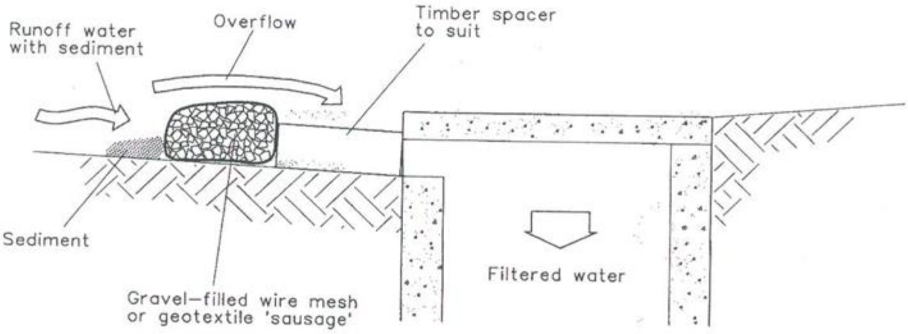
Construction Notes

1. Use turbidity barriers only where high flows are unlikely to remove accumulated sediment and/or move the curtain significantly.
2. Where the barrier is to remain in place for more than one month, ensure the floatation cover is a UV-resistant, durable material.
3. Use only closed cell foam or foam-filled PVC piping as floatation elements. Do not use unfilled pipes.
4. Use only woven or heat-set non woven geotextiles. Needle-punched, non woven geotextiles can become fouled with debris that fray and delaminate them as they move with the waves or currents.
5. Remove captured sediment before the barrier is decommissioned.
6. In tidal areas, ensure the barrier can rise and fall without being moved from its position.

TURBIDITY BARRIER **SD 6-10**

6-39





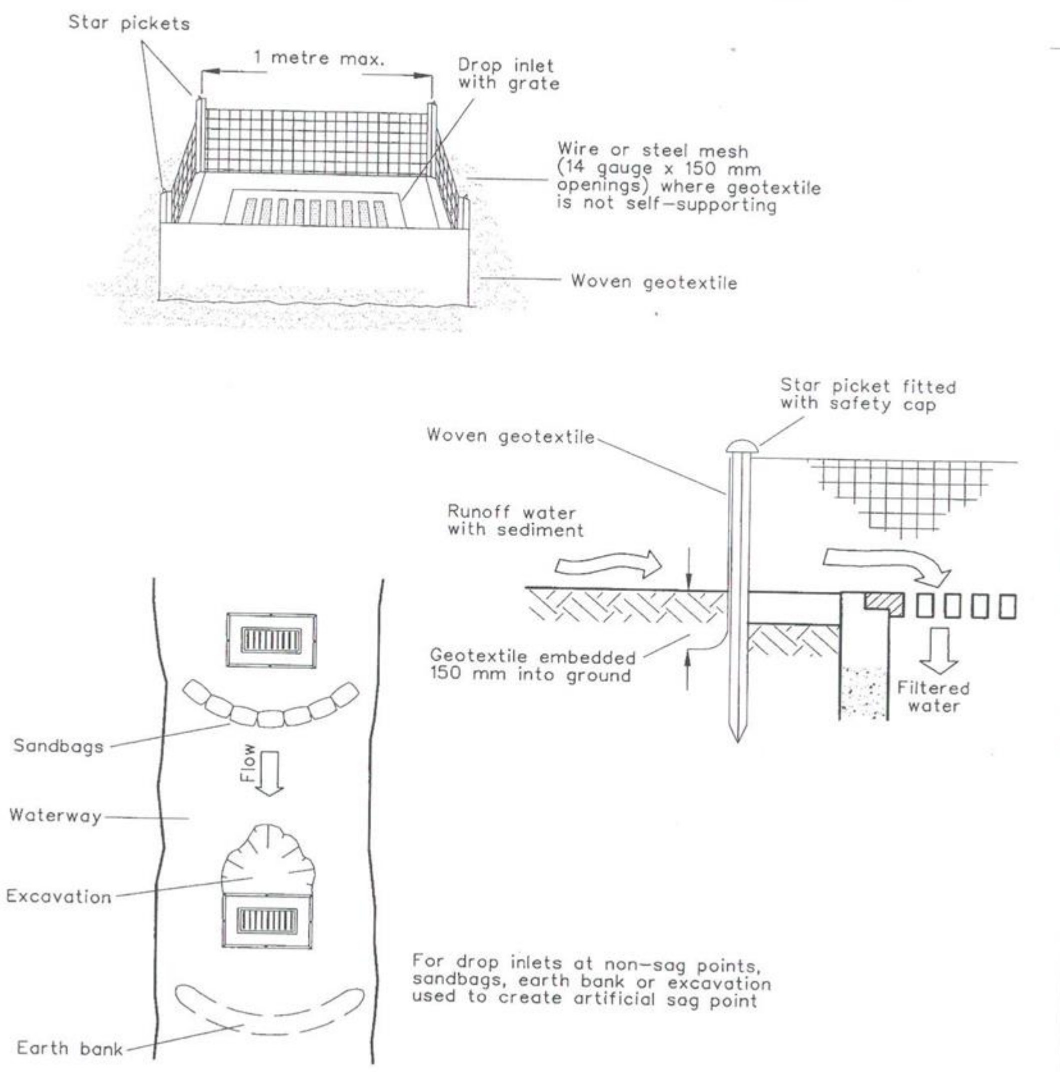
NOTE: This practice only to be used where specified in an approved SWMP/ESCP.

Construction Notes

1. Install filters to kerb inlets only at sag points.
2. Fabricate a sleeve made from geotextile or wire mesh longer than the length of the inlet pit and fill it with 25 mm to 50 mm gravel.
3. Form an elliptical cross-section about 150 mm high x 400 mm wide.
4. Place the filter at the opening leaving at least a 100-mm space between it and the kerb inlet. Maintain the opening with spacer blocks.
5. Form a seal with the kerb to prevent sediment bypassing the filter.
6. Sandbags filled with gravel can substitute for the mesh or geotextile providing they are placed so that they firmly abut each other and sediment-laden waters cannot pass between.

MESH AND GRAVEL INLET FILTER — SD 6-11

6-40

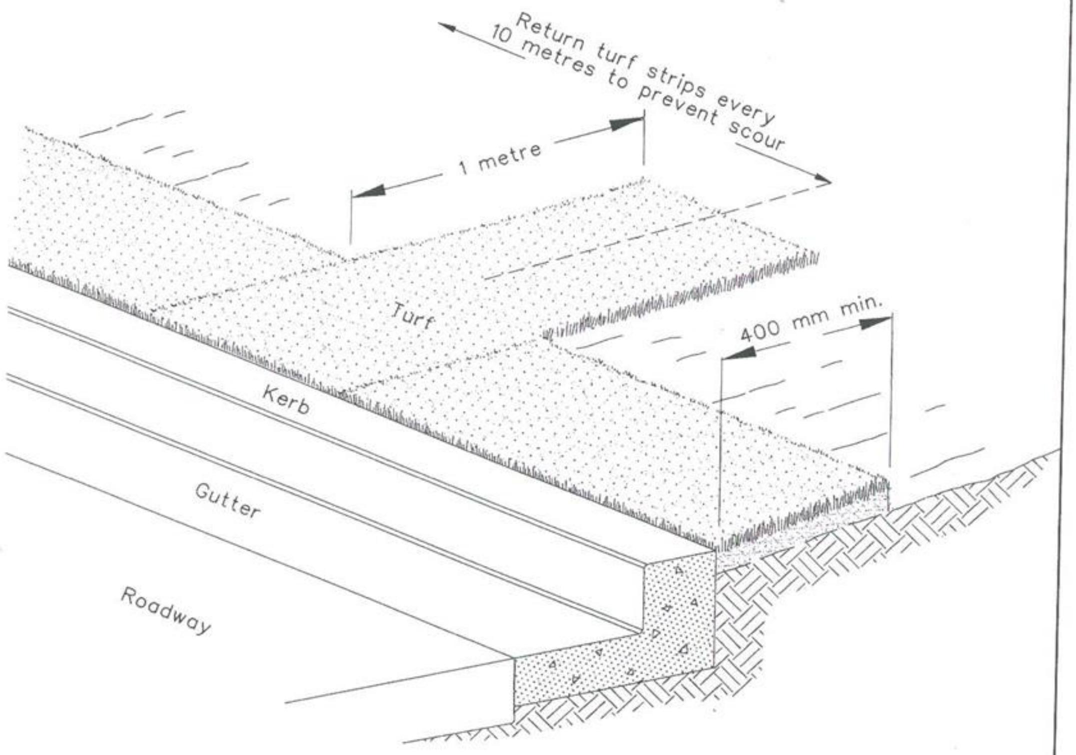


Construction Notes

1. Fabricate a sediment barrier made from geotextile or straw bales.
2. Follow Standard Drawing 6-7 and Standard Drawing 6-8 for installation procedures for the straw bales or geofabric. Reduce the picket spacing to 1 metre centres.
3. In waterways, artificial sag points can be created with sandbags or earth banks as shown in the drawing.
4. Do not cover the inlet with geotextile unless the design is adequate to allow for all waters to bypass it.

GEOTEXTILE INLET FILTER **SD 6-12**

6-41

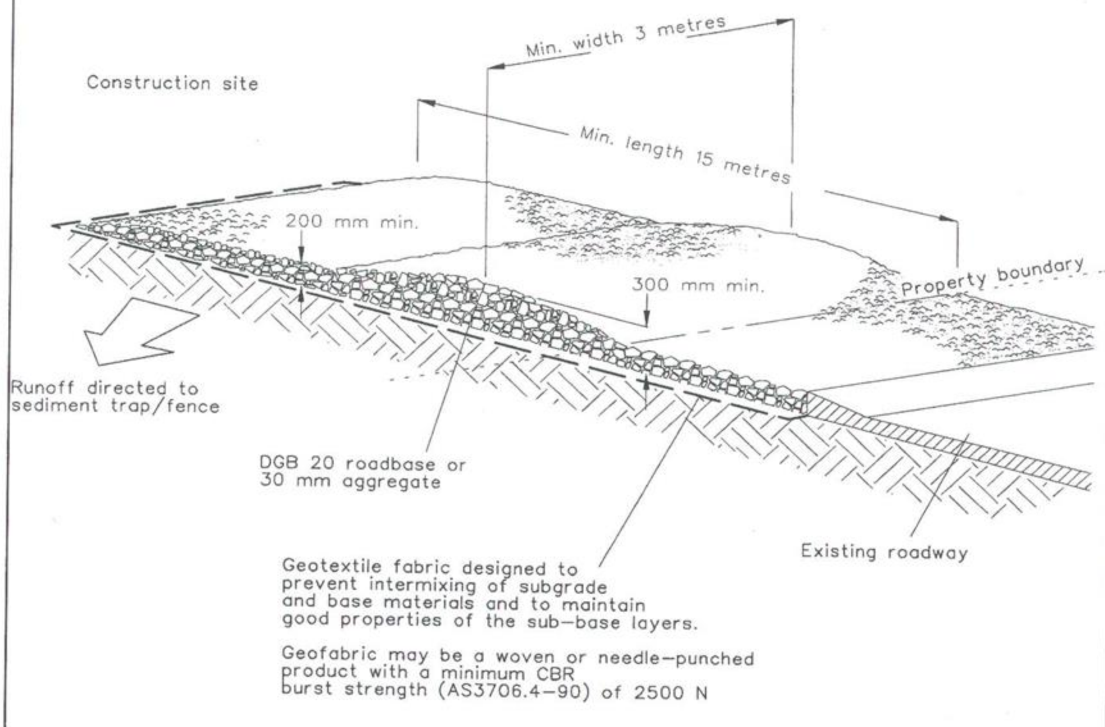


Construction Notes

1. Install a 400-mm minimum wide roll of turf on the footpath next to the kerb and at the same level as the top of the kerb.
2. Lay 1.4 metre long turf strips normal to the kerb every 10 metres.
3. Rehabilitate disturbed soil behind the

KERBSIDE TURF STRIP **SD 6-13**

6-44

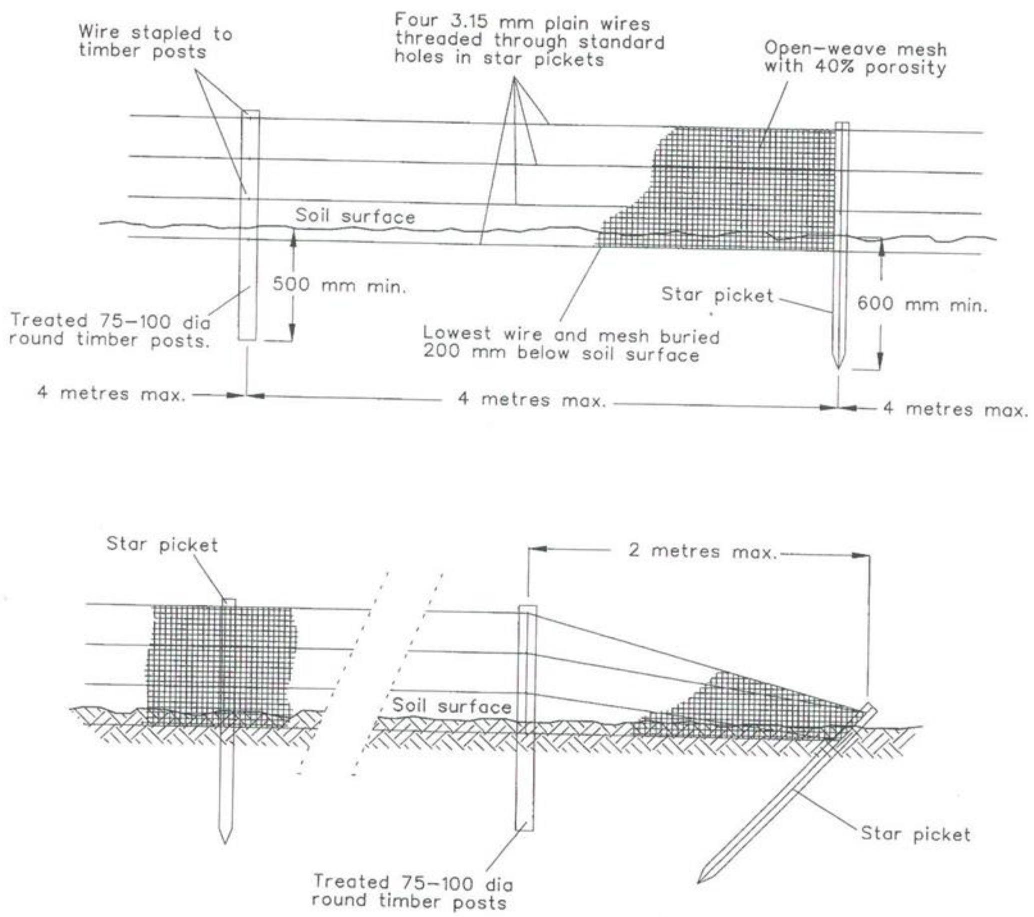


Construction Notes

1. Strip the topsoil, level the site and compact the subgrade.
2. Cover the area with needle-punched geotextile.
3. Construct a 200-mm thick pad over the geotextile using road base or 30-mm aggregate.
4. Ensure the structure is at least 15 metres long or to building alignment and at least 3 metres wide.
5. Where a sediment fence joins onto the stabilised access, construct a hump in the stabilised access to divert water to the sediment fence

STABILISED SITE ACCESS **SD 6-14**

6-48



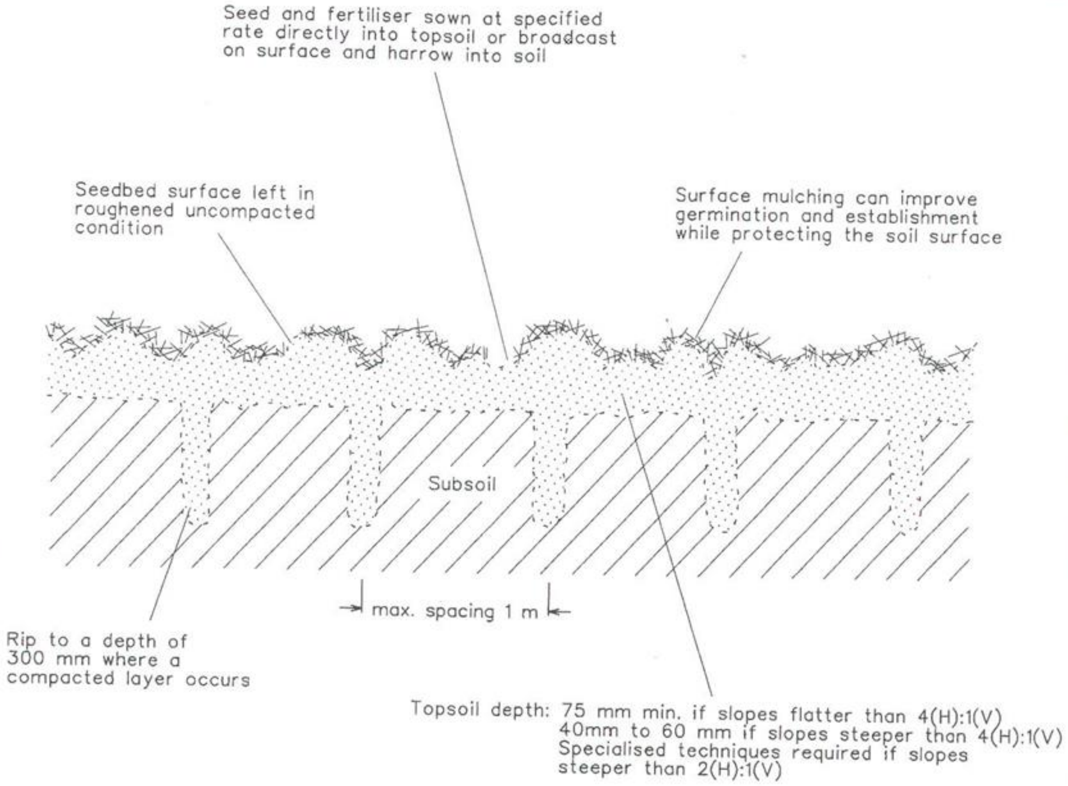
Construction Notes

1. Install the fence to the height specified in the ESCP/SWMP.
2. Cut a channel 200 mm deep along the fence line.
3. Place wire and light resistant, open-weave polymer mesh with 40 percent porosity on the prevailing wind side of fence.
4. Fasten the mesh to all wires using ring fasteners at 100 mm to 150 mm intervals on top wire and 300 mm intervals on other wires.
5. Use one 75-mm to100-mm diameter treated round timber post every 20 metres.
6. Where star pickets are used, ensure they are fitted with safety caps.

CONTROL OF WIND EROSION

SD 6-15

6-49



Construction Notes

1. Loosen compacted soil before sowing any seed. If necessary, rip the soil to a depth of 300 mm. Avoid rotary hoe cultivation.
2. Work the ground only as much as necessary to achieve the desired tilth and prepare a good seedbed.
3. Avoid cultivation in very wet or very dry conditions.
4. Cultivate on or close to the contour where possible, not up and down the slope.

SEEDBED PREPARATION **SD 7-1**

7-7

Appendix C Preliminary Reference Erosion and Sediment Control Plan

Figures C1 to C5

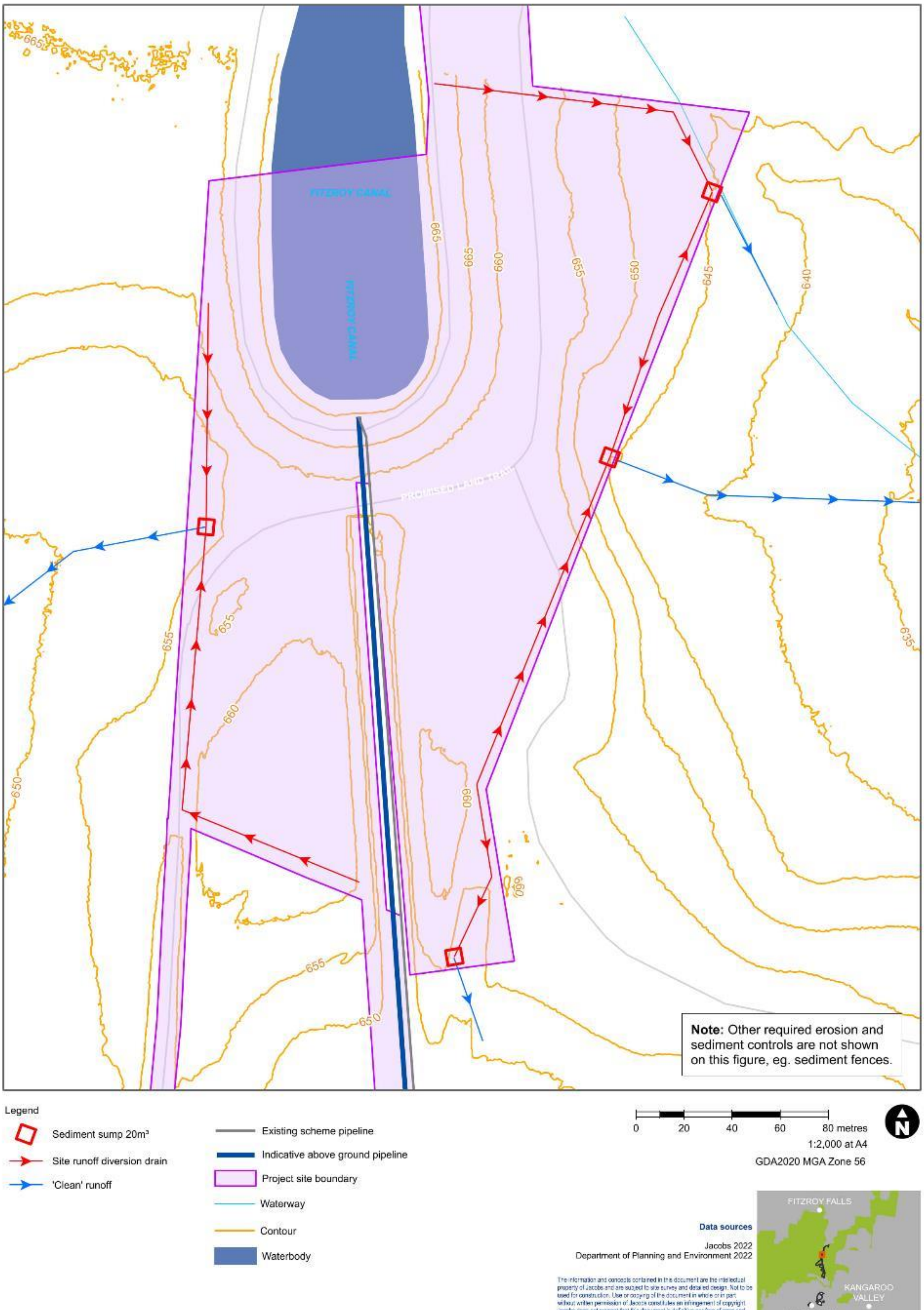


Figure C1 Conceptual Erosion and Sediment Controls Plans - Upper Canal Area

Jacobs NSW Spatial | Buildings & Infrastructure | Eastern Asia Pacific | www.jacobs.com

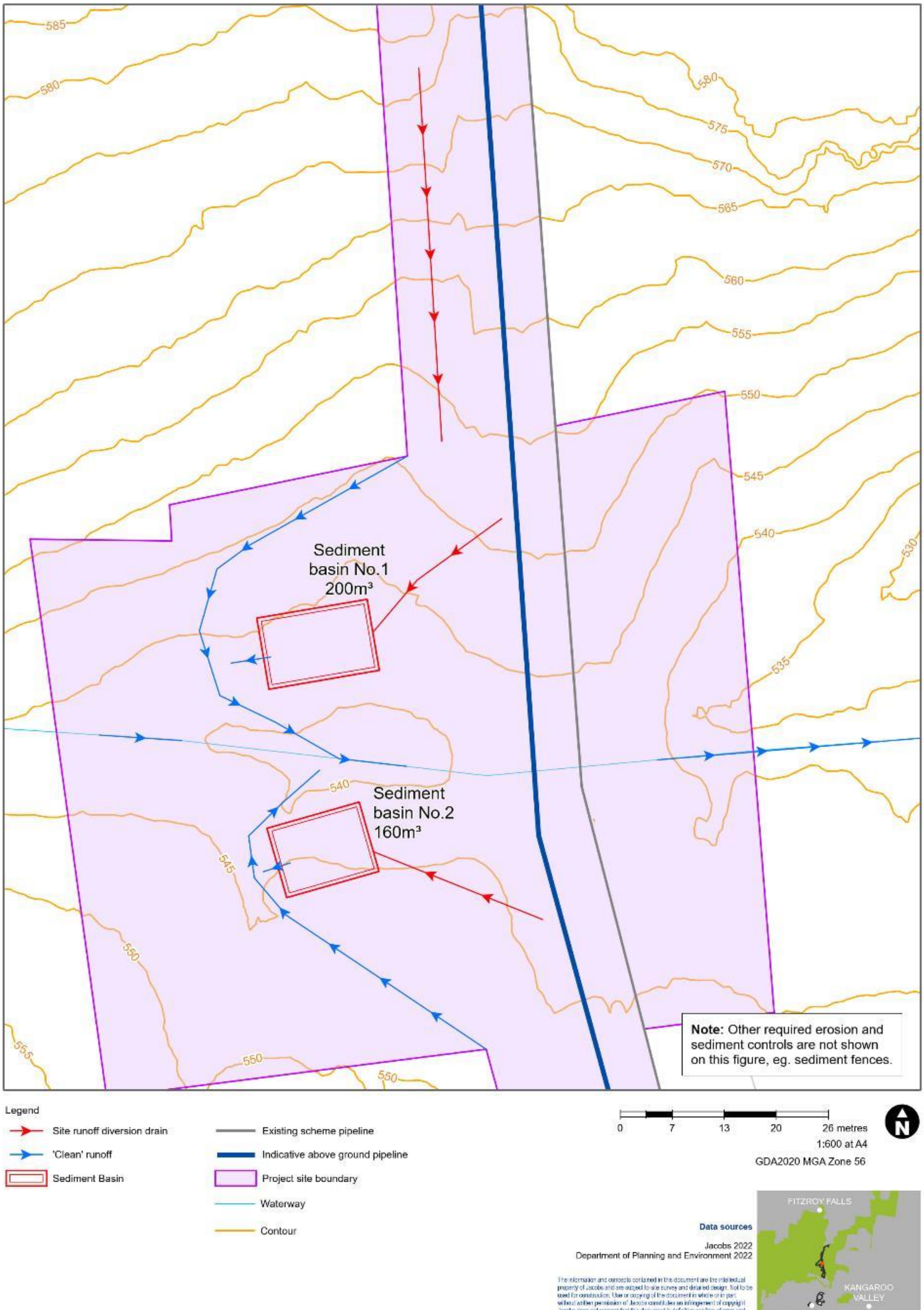


Figure C2 Conceptual Erosion and Sediment Controls Plans - Penstock Anchor Area

Jacobs NSW Spatial | Buildings & Infrastructure | Eastern Asia Pacific | www.jacobs.com

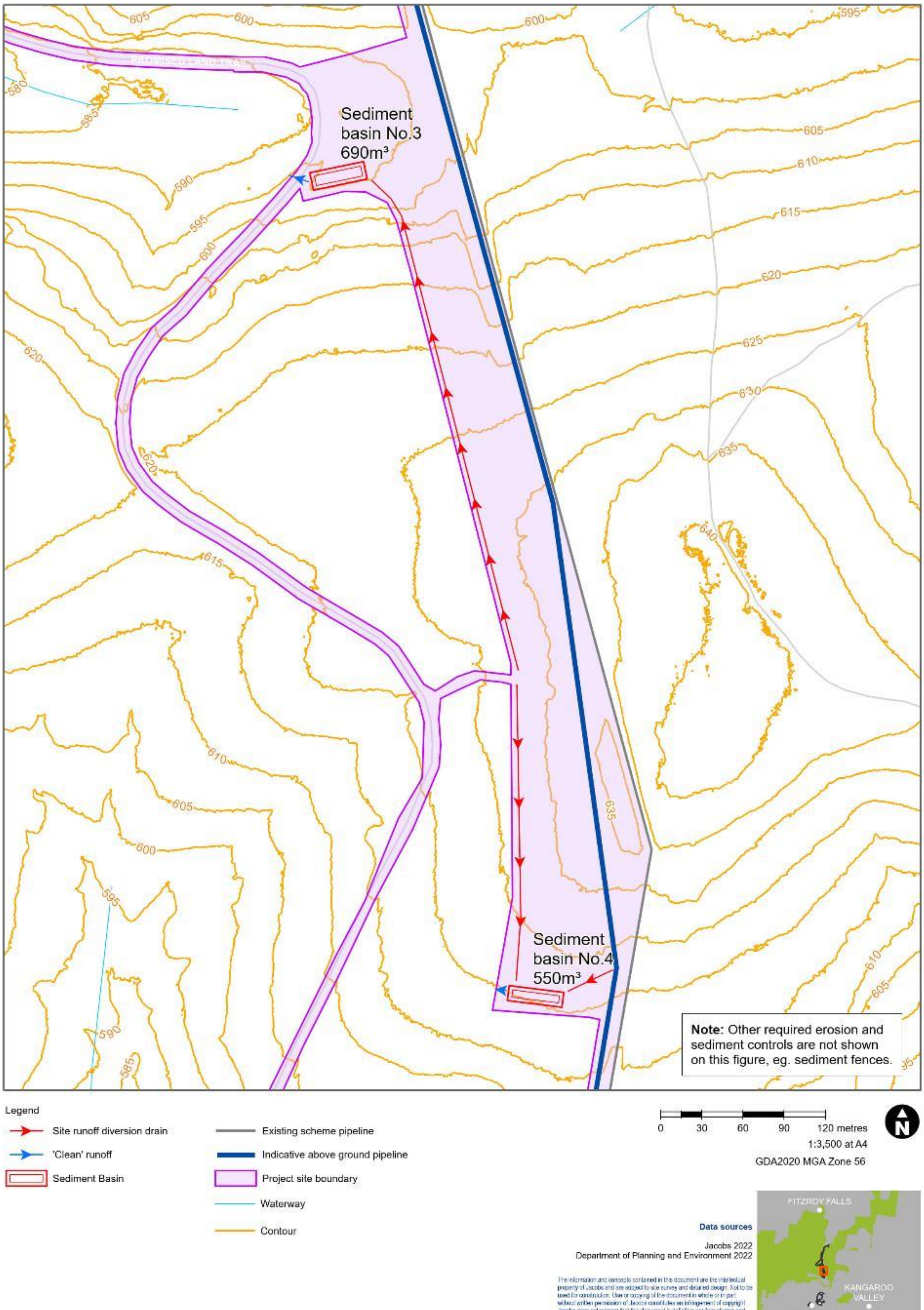


Figure C3 Conceptual Erosion and Sediment Controls Plans - Laydown Area 2

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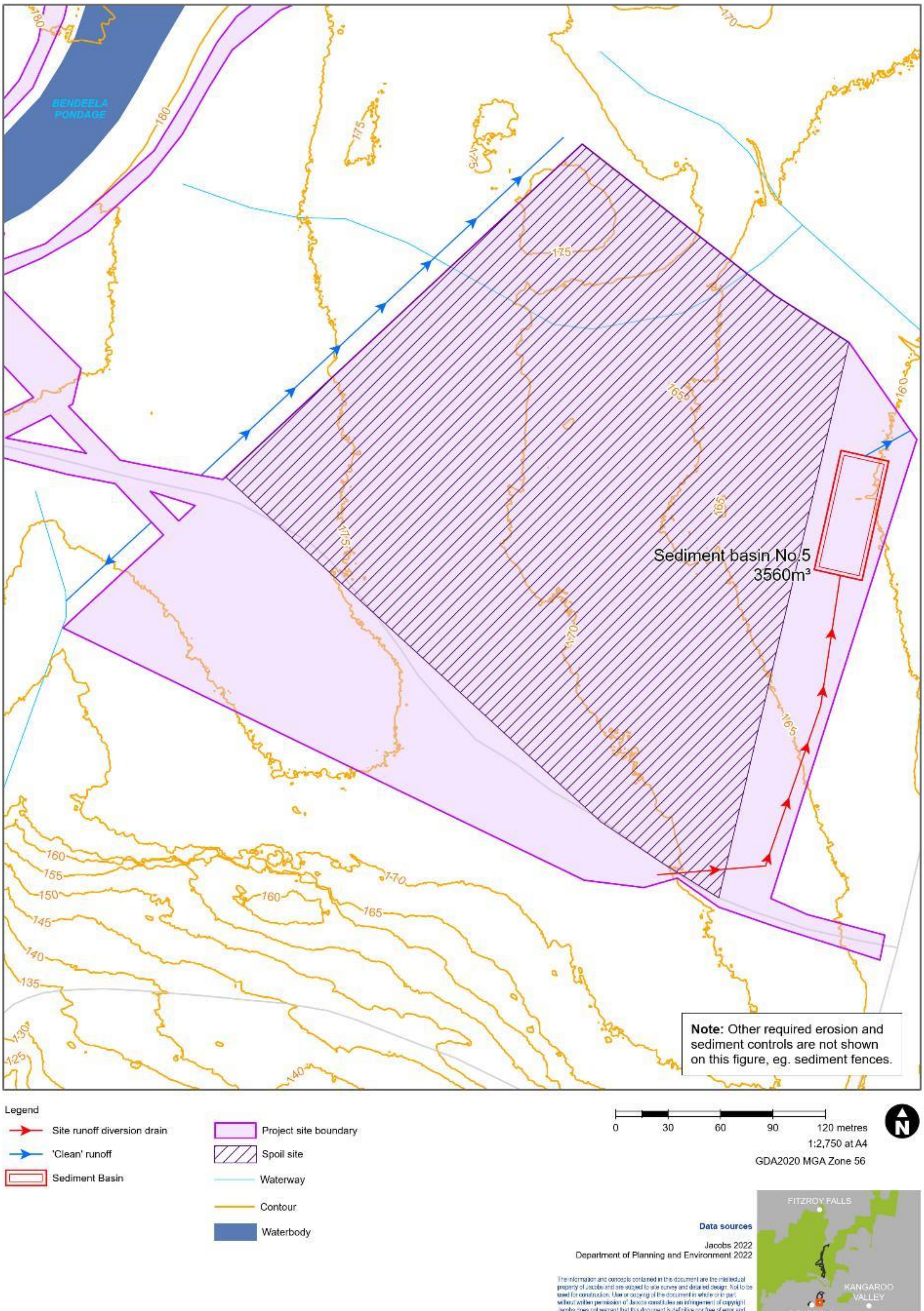

Figure C4 Conceptual Erosion and Sediment Controls Plans - Stockpile Area

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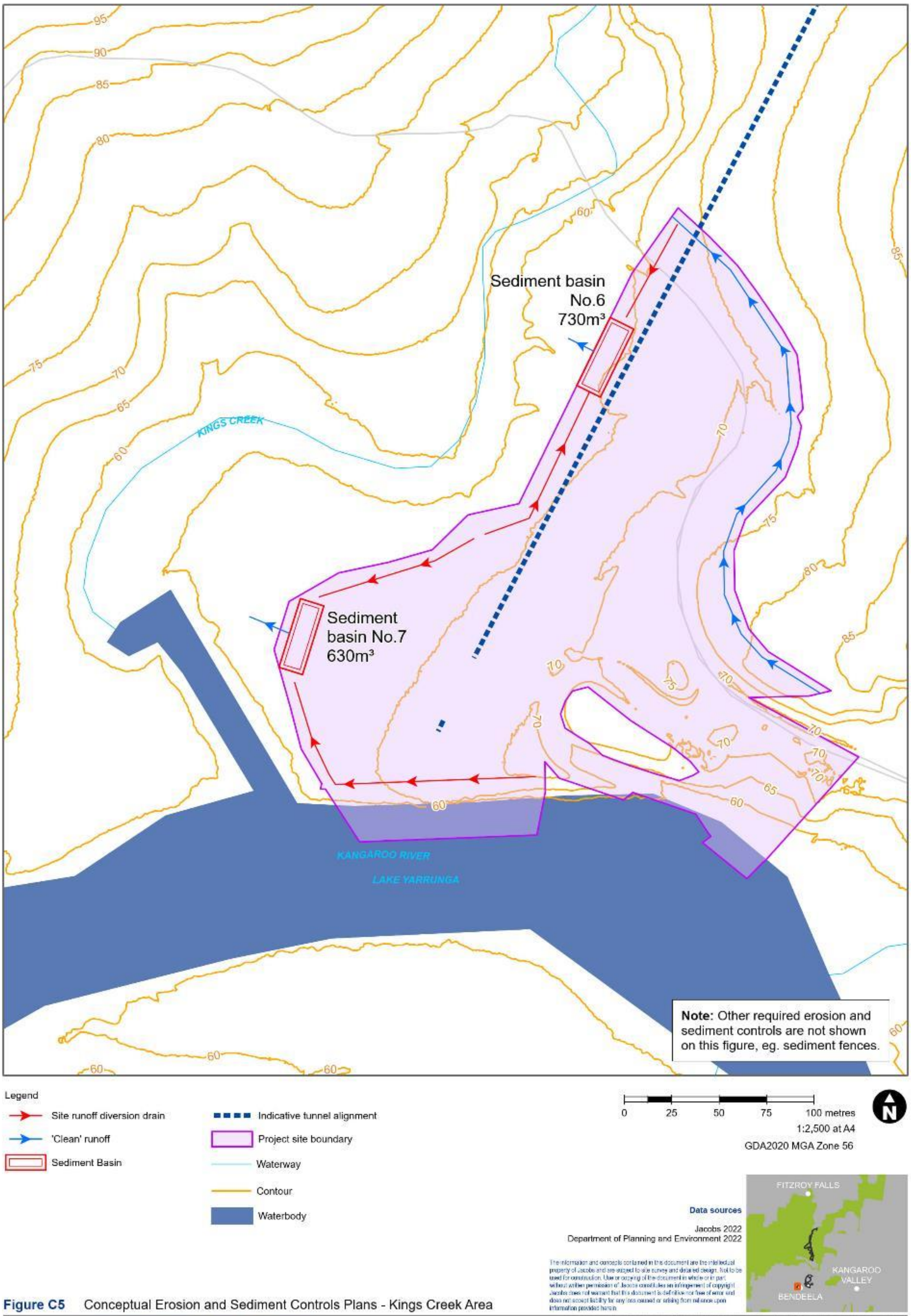

Figure C5 Conceptual Erosion and Sediment Controls Plans - Kings Creek Area

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Appendix D BoM Rainfall intensity data for the site

Design Rainfall Data System (2016)

Conditions of Use | Help | New IFD feedback

New Search >

Analysis - Single Point

Design Rainfalls

- ○ Very Frequent
- ● IFDs (Frequent and Infrequent)
- ○ Rare

Standard Durations

- ☐ 1 - 45 minutes
- ☑ 1 - 18 hours
- ☐ 24 - 168 hours

- Non-Standard Durations

Duration: [ ] minutes +

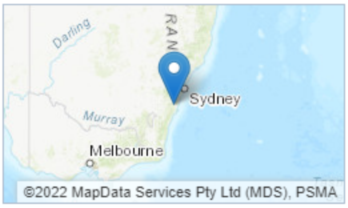
+ Observed Rainfalls

Update Reset

Other Options

- ☐ Coefficients
- ☐ Seasonality

Location



Label: Kangaroo Valley

Latitude: 34° 41 ' 41 "
[Nearest grid cell: 34.6875 (S)]

Longitude: 150° 28 ' 53 "
[Nearest grid cell: 150.4875 (E)]

IFD Design Rainfall Intensity (mm/h)

Issued: 22 April 2022

Rainfall intensity for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).
FAQ for New ARR probability terminology

Table | Chart Unit: mm/h

	Annual Exceedance Probability (AEP)						
Duration	**63.2%**	**50%#**	**20%***	**10%**	**5%**	**2%**	**1%**
1 hour	24.3	27.1	36.8	43.9	51.3	61.8	70.5
1.5 hour	19.2	21.5	29.1	34.6	40.3	48.5	55.2
2 hour	16.5	18.4	24.9	29.6	34.4	41.3	46.8
3 hour	13.4	15.0	20.4	24.2	28.1	33.5	37.9
4.5 hour	11.0	12.5	17.1	20.3	23.5	27.9	31.4
6 hour	9.69	11.0	15.2	18.1	21.0	24.8	27.8
9 hour	8.08	9.24	12.9	15.5	18.0	21.3	23.7
12 hour	7.08	8.15	11.5	13.9	16.2	19.1	21.3
18 hour	5.81	6.73	9.69	11.8	13.8	16.3	18.2

Note:
The 50% AEP IFD **does not** correspond to the 2 year Average Recurrence Interval (ARI) IFD.

New ARR 2016 probability terminology

The probability terminology used for the 2016 design rainfalls is consistent with the probability terminology for the new edition of Australian Rainfall and Runoff (ARR2016). Further details on the new probability terminology can be found in Book 1; Chapter 2; Section 2.2 Terminology of ARR2016 http://arr.ga.gov.au/arr-guideline.

The main terms used to describe design rainfalls are:

- *Exceedances per year (EY):* the number of times an event is likely to occur or be exceeded within any given year.
- *Annual exceedance probability (AEP):* the probability or likelihood of an event occurring or being exceeded within any given year, usually expressed as a percentage.

The table below lists the probability terminology used for the 2016 design rainfalls and shows in **bold** the standard EY and AEP values for which design rainfalls are available. Generally, EY terminology is used for Very Frequent design rainfalls, AEP (%) terminology is used for Frequent and Infrequent design rainfalls, and AEP (1 in x) terminology is used for Rare design rainfalls.

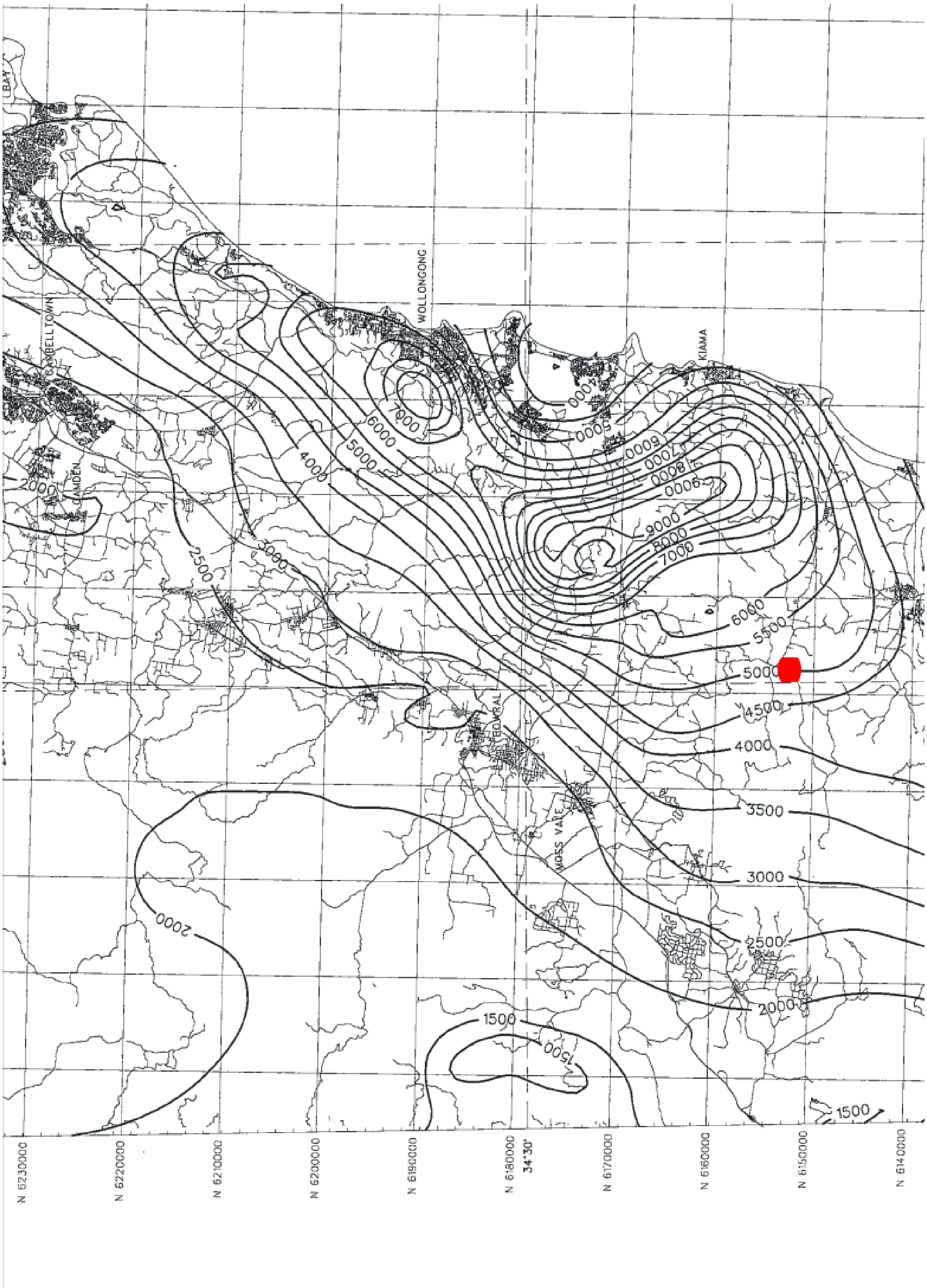
Note:

- The 50% AEP IFD **does not** corresponds to the 2 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 1.44 ARI.
- The 20% AEP IFD **does not** corresponds to the 5 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 4.48 ARI.

Australian Rainfall and Runoff terminology

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI	Uses in Engineering Design
Very frequent	**12**				
	6	99.75	1.002	0.17	Water sensitive urban design
	4	98.17	1.02	0.25	
	3	95.02	1.05	0.33	
	2	86.47	1.16	0.50	
Frequent	**1**	**63.2**	1.58	1.00	Stormwater/pit and pipe design
	0.69	**50.00**	2	1.44	
	0.5	39.35	2.54	2.00	
	0.22	**20.00**	5	4.48	
	0.2	18.13	5.52	5.00	
	0.11	**10.00**	10.00	9.49	

Appendix E Rainfall Erosivity for the site (red dot)

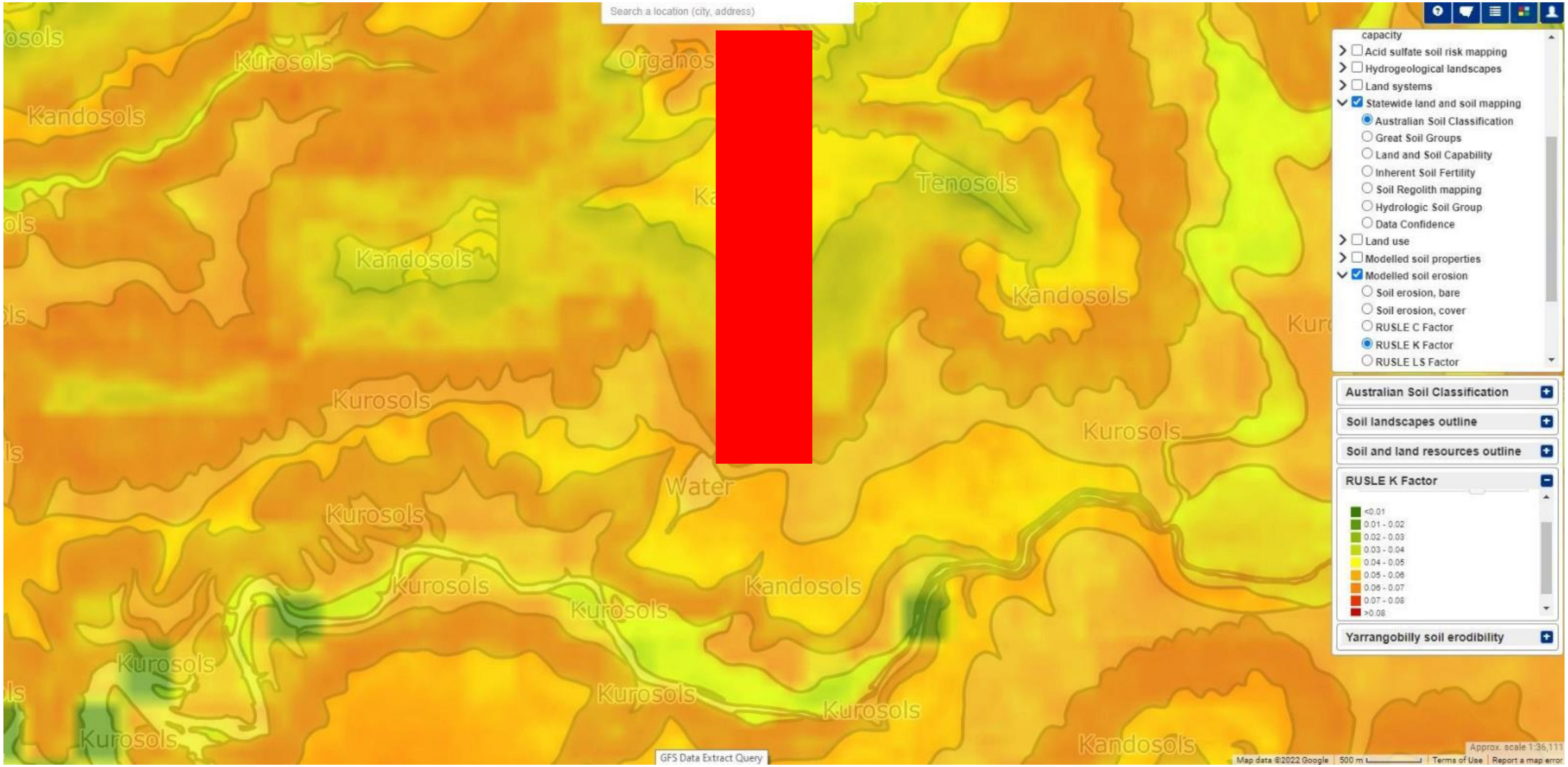


11: Rainfall Erosivity of the Wollongong 1:250,000 topographic Sheet

Appendix F Site photo along the pipeline

Appendix G Soil Erodibility for the site

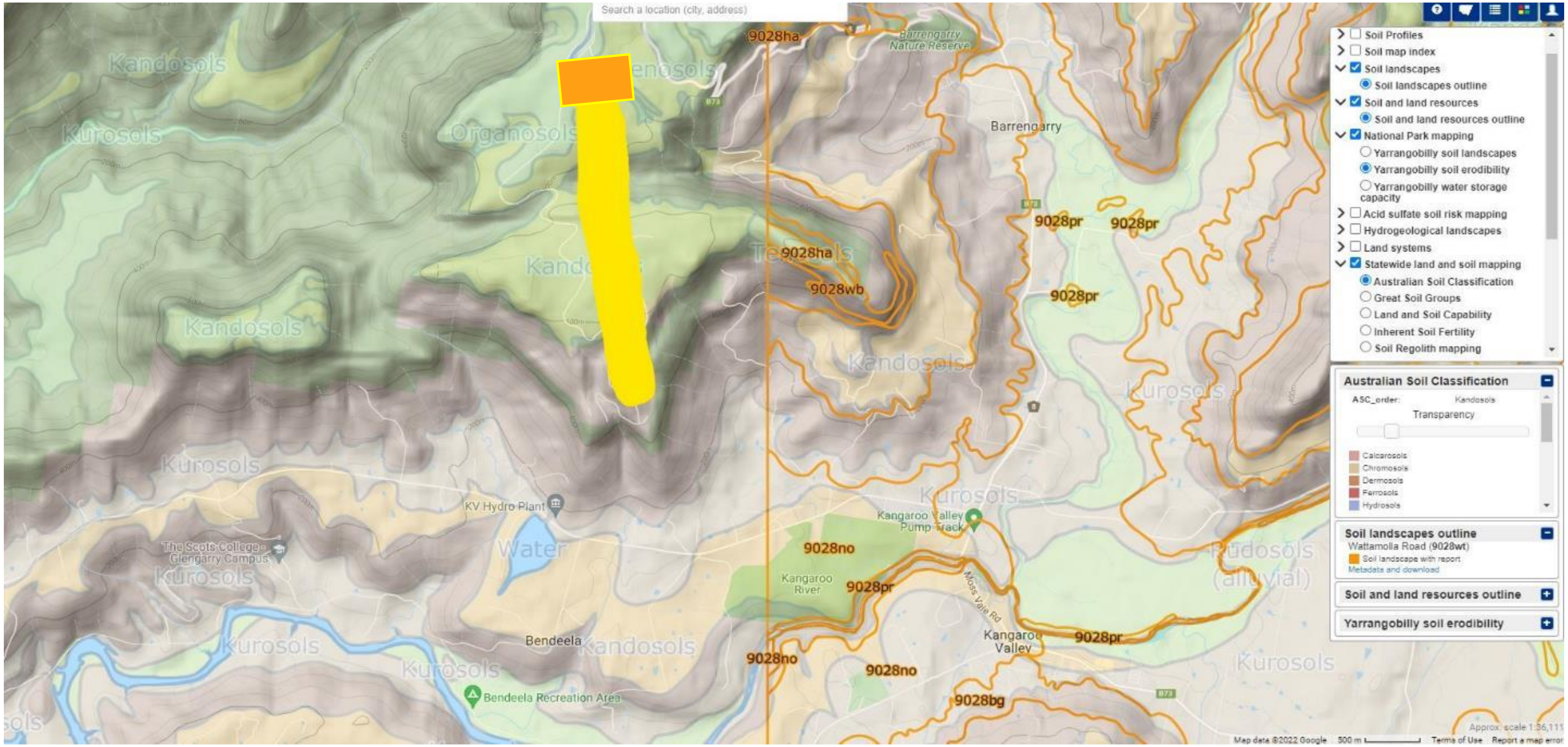
Figure G-1 – Soil Erodibility along the study area (denoted as the red area) (Estimated average Erodibility on this figure. k=0.045)



Appendix H Soil Landscapes for the site

Figure H-1 The soil profile over the study area is Wattamolla road (wt), Barrengarry (bg) and Nowra (no) Soil landscapes. **Figure H-1** shows the location of these soils. Further soil profile information on these soil profiles and soil landscapes is contained below this figure obtained from the NSW OEH eSpade which is sourced from the NSW Soil and Land Information System (SALIS) database:

- Wattamolla road (wt) soil profile along most of the pipeline area (denoted as the yellow area)
- Barrengarry (bg) soil profile along a small section of the upstream end of the pipeline near the upper canal (denoted as the orange area)
- Nowra (no) soil profile along the Kings Creek and stockpile areas (denoted as the blue area)



wt	WATTAMOLLA ROAD	Depositional

Landscape—long gently to moderately inclined sideslopes and undulating to rolling hills with broad benches on Budgong Sandstone. Relief <200 m. Slopes 5–15%. Extensively cleared with stands of tall open-forest.

Soils—moderately deep (50–100 cm) Red Podzolic Soils (Dr2.31) on upper slopes and benches. Yellow Podzolic Soils (Dy5.31) on mid and lower slopes.

Limitations—rock outcrop, run-on, mass movement (localised), hardsetting, high organic matter, low wet bearing strength, strongly acid, sodicity.

LOCATION

Long, gently to moderately inclined sideslopes and undulating to rolling hills on sandstone in the Kangaroo Valley. Examples include along the lower reaches of Wattamolla Road, Woodhill/ Berry Road and the crest and midslopes of Coolongatta Mountain.

LANDSCAPE

Geology

Budgong Sandstone—red brown and grey volcanic lithic sandstone.

Topography

Long, gently to moderately inclined sideslopes and undulating to rolling hills. Relief <200 m. Slope gradients generally 5–15% with isolated steep slopes >40%. Broad flat benches and crests <400 m wide recur throughout the landscape. Drainage lines are incised with rock outcrop. Terracettes and slumping and scattered boulders occur on steeper slopes.

Vegetation

Extensively cleared with scattered stands of tall open-forest. Common species include rough-barked apple (*Angophora floribunda*), cabbage gum (*Eucalyptus amplifolia*), brown barrel (*Eucalyptus fastigata*), mountain grey gum (*Eucalyptus cypellocarpa*), forest red gum (*Eucalyptus tereticornis*), isolated stands of scribbly gum (*Eucalyptus racemosa*) and bangalay (*Eucalyptus botryoides*).

Existing Erosion

On steeper slopes minimal terracettes, slumping and minor gullying occur.

Included Soil Landscapes

Small areas of Barrengarry **(bg)** soil landscape and Cambewarra **(ca)** soil landscape occur.

SOILS

Dominant Soil Materials

wt1—Hardsetting brownish black fine sandy loam (topsoil)

Colour	brownish black (5YR 3/1) to greyish brown (7.5YR 4/2) with occasional bleaching at depth
Texture	fine sandy loam
Structure	moderately pedal, 2–5 mm polyhedral peds
Fabric	rough-faced, porous
pH	6.0
Stones	<2% 2–6 mm
Roots	abundant, ex-ped

wt2—Friable brown silt loam (topsoil)

Colour	brown (7.5YR 4/3) to dull brown (7.5YR 4/6) with occasional bleach
Texture	silt loam
Structure	weakly pedal <2 mm polyhedral peds
Fabric	rough-faced, porous
pH	5.5
Stones	nil
Roots	common, ex-ped

wt3—Mottled brown light clay (subsoil)

Colour	brown (7.5YR 4/3) yellowish brown (10YR 5/4) red mottles (50%)
Texture	light clay
Structure	weakly to moderately pedal, 10–20 mm polyhedral to sub-angular blocky peds
Fabric	smooth-faced, dense
pH	5.5
Stones	nil
Roots	few, in-ped

wt4—Dark reddish brown strongly pedal light clay (subsoil)

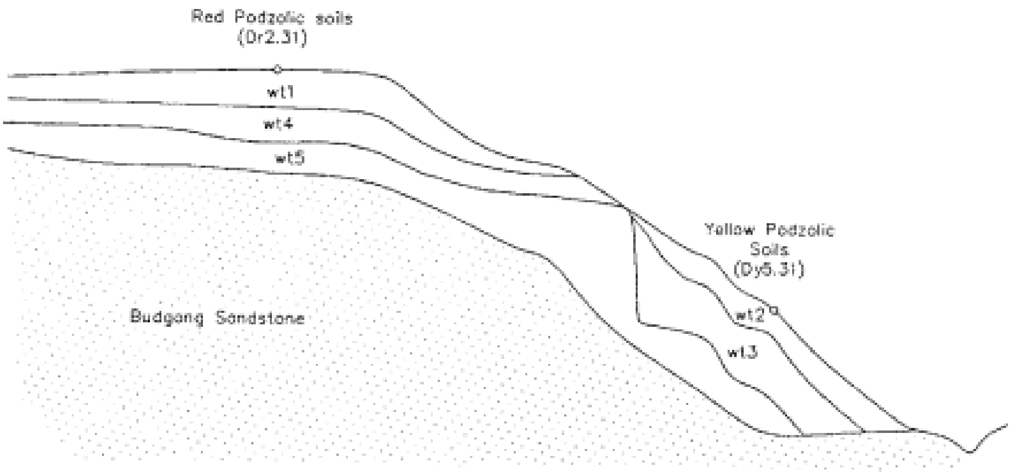
Colour	dark reddish brown (5YR 3/4)
Texture	light clay
Structure	strongly pedal, 10–20 mm sub-angular blocky peds
Fabric	rough-faced, porous
ph	5.5
Stones	nil
Roots	common, ex-ped

wt5—Mottled brown strongly pedal medium clay (subsoil)

Colour	brown (7.5YR 4/6) to yellowish brown (10YR 5/8) with red and grey mottles (50%) at depth
Texture	medium clay
Structure	strongly pedal, 20–50 mm polyhedral to sub-angular blocky peds
Fabric	rough-faced, porous
pH	4.5
Stones	nil
Roots	few, in-ped

Occurrence and Relationships

Upper slopes and benches. Up to 10 cm hardsetting brownish black fine sandy loam **(wt1)** overlies <25 cm dark reddish brown strongly pedal light clay **(wt4)** which overlies <60 cm mottled brown strongly pedal medium clay **(wt5).**



■ ***Schematic cross-section of Wattamolla Road soil landscape illustrating the occurrence and relationship of the dominant soil materials.***

Boundaries are clear [Red Podzolic Soils (Dr2.31)]. Total depth is <100 cm.

Mid and lower slopes. Up to 5 cm friable brown silt loam **(wt2)** overlies <20 cm mottled brown light clay **(wt3)** which overlies <80 cm **wt5.** Boundaries are clear [Yellow Podzolic Soils (Dy5.31)]. Total depth is <120 cm.

LIMITATIONS TO DEVELOPMENT

Soil Limitations

wt1 Hardsetting
Strongly acid
High organic matter

wt2 High organic matter
Low wet bearing strength
Sodicity
Strongly acid

wt3 Low wet bearing strength
Sodicity
Strongly acid

wt4 High permeability
Sodicity
Strongly acid

wt5 Low permeability
Low wet bearing strength
Sodicity

Fertility

Moderate to high fertility. Moderately pedal with moderate CEC. Very high to moderate base saturation **(wt1, wt2, wt3).** High organic matter **(wt1, wt2).**

Erodibility

The erodibility of the topsoils **(wt1, wt2)** is moderate. The erodibility of the subsoils **(wt3, wt4, wt5)** is high.

Erosion Hazard

Erosion hazard for non-concentrated flows is extreme. The calculated soil loss for the first 12 months of urban development ranges up to 150 t/ha for topsoils and 200 t/ha for exposed subsoils. The erosion hazard for concentrated flows is high.

Surface Movement Potential

The soil materials are generally stable.

Landscape Limitations

Steep slopes (localised)
Mass movement (localised)
Shallow soil (localised)
Rock outcrop
Water erosion hazard (localised)
Run-on

Urban Capability

Generally moderate limitations for urban development. High to severe limitations for urban development on steep slopes.

Rural Capability

Generally high to severe limitations for regular cultivation. Low to moderate limitations for grazing.

bg	BARRENGARRY	Depositional

Landscape—moderately inclined to steep 10–30% slopes with broad (100 m) benches on Berry Formation. Relief <300 m. Scattered rock outcrops similar to tors. Extensively cleared with scattered stands of tall open-forest.

Soils—deep (>150 cm) Krasnozems (Gn4.11) occur on benches and midslopes and Xanthozems (Gn3.71) occur on lower slopes. Lithosols (Um2.64) occur on steeper slopes.

Limitations—water erosion hazard, mass movement hazard (localised), run-on (localised), stoniness, high organic matter, high water-holding capacity, strongly acid.

LOCATION

Moderately inclined to steep slopes with broad benches on siltstone in the Kangaroo Valley. Examples occur at Barrengarry and along the Upper Kangaroo Valley Road.

LANDSCAPE

Geology

Berry Formation—light grey to dark grey micaceous siltstones, mudstones and shales with basaltic dykes.

Topography

Moderately inclined to steep slopes with hummocky sideslopes. Relief to 300 m. Slopes 10–30% locally ranging to 45%. Scattered broad colluvial benches up to 100 m wide with hummocky sideslopes that have occasional slumps and terracettes. Occasional gently inclined footslopes and narrow deeply incised drainage lines. Scattered rock outcrops resembling tors.

Vegetation

Extensively cleared with scattered stands of tall open-forest. Common tree species include sydney peppermint (*Eucalyptus piperita*), lemon-scented gum (*Eucalyptus citriodora*), rough-barked apple (*Angophora floribunda*), blue-veined stringybark (*Eucalyptus agglomerata*) and bangalay (*Eucalyptus botryoides*).

Land Use

Mostly cattle grazing on improved pastures.

Existing Erosion

Stable except for minor terracettes on the benches (localised) and rock fall from the benches after heavy rainfall. Occasional minor gullying along drainage lines.

Included Soil Landscape

Small areas of Wattamolla Road **(wt)** soil landscape occur.

SOILS

Dominant Soil Materials

bg1—Moderately pedal dull reddish brown sandy clay loam (topsoil)

Colour dull reddish brown (5YR 4/3)
Texture sandy clay loam
Structure moderately pedal, 2–5 mm granular peds
Fabric rough-faced, porous
pH 5.0
Stones <2% 2–6 mm angular, dispersed
Roots common, ex-ped

bg2—Dark reddish brown silty clay loam (subsoil)

Colour dark reddish brown (5YR 3/3)
Texture silty clay loam
Structure weakly to moderately pedal, 2–5 mm crumb to polyhedral peds
Fabric rough-faced, porous
pH 5.0
Stones nil
Roots common, ex-ped

bg3—Reddish brown silty clay (subsoil)

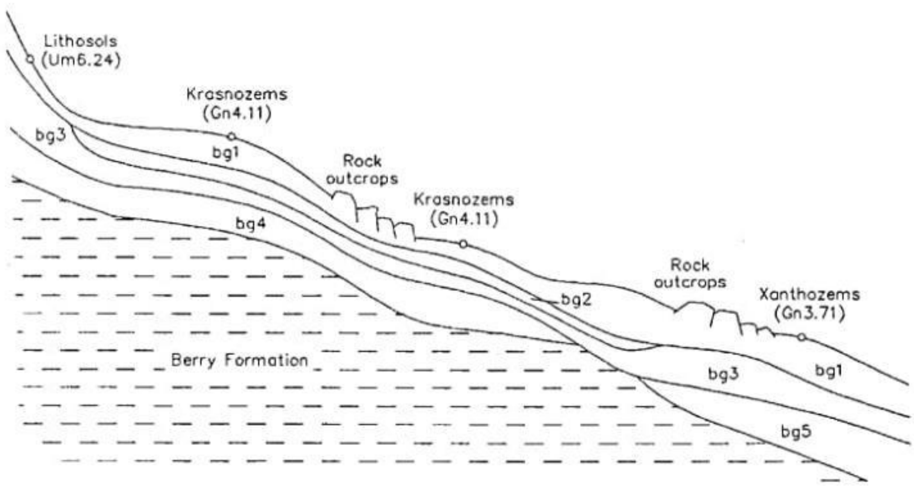
Colour reddish brown (2.5YR 4/6)
Texture silty clay to light clay
Structure moderately pedal, 5–10 mm sub-angular blocky to angular blocky peds
Fabric rough-faced, porous
pH 4.5
Stones nil
Roots few

bg4—Reddish brown medium clay (subsoil)

Colour reddish brown (2.5YR 4/6)
Texture medium clay
Structure strongly pedal, 10–20 mm angular blocky peds
Fabric rough-faced, porous
pH 4.0
Stones nil
Roots nil

bg5—Mottled bright brown medium clay (subsoil)

Colour bright brown (5YR 5/8) yellowish brown (10YR 5/6) red yellow and grey mottles (25%)
Texture medium to heavy clay
Structure strongly pedal, 10–20 mm angular blocky peds
Fabric rough-faced, porous
pH 3.5
Stones 10–20% 6–60 mm sub-angular to angular, dispersed
Roots nil



■ *Schematic cross-section of Barrengarry soil landscape illustrating the occurrence and relationship of the dominant soil materials.*

Occurrence and Relationships

A very complex geology pattern occurs within this landscape. The following soils materials sequences have been described.*

Benches. Up to 10 cm moderately pedal sandy clay loam **(bg1)** overlies <40 cm dark reddish brown silty clay loam **(bg2).** Up to 40 cm reddish brown silty clay **(bg3)** overlies <40 cm reddish brown medium clay **(bg4).** Boundaries are gradual [Krasnozems (Gn4.11)]. Total depth is <150 cm.

Steep slopes. Up to 40 cm **bg1** overlies bedrock [Lithosols (Um6.24)].

Midslopes. Up to 50 cm **bg1** overlies <70 cm **bg2** which overlies <50 cm **bg3.** Boundaries are clear to gradual [Krasnozems (Gn4.11)]. Total depth is 170–200 cm.

Lower slopes. Up to 50 cm **bg1** overlies <100 cm **bg3** which overlies <30 cm mottled bright brown medium clay **(bg5).** Boundaries are gradual [Xanthozems (Gn3.71)]. Total depth is >180 cm.

LIMITATIONS TO DEVELOPMENT

Soil Limitations

bg1 Stoniness
High organic matter
High available water-holding capacity
Shrink-swell

bg2 High organic matter
High available water-holding capacity
Shrink-swell

bg3 Strongly acid

bg4 Strongly acid

bg5 Low permeability
Low wet bearing strength
Strongly acid
Stoniness

Fertility

General fertility is moderate to high. The soils are deep except on steep slopes, well structured and well drained. The soils have a moderate CEC and are moderately to strongly acid.

Erodibility

The erodibility of the topsoil **(bg1)** is low and for the subsoils **(bg2** to **bg5)** is moderate.

Erosion Hazard

Erosion hazard for non-concentrated flows is ex-treme. The calculated soil loss for the first 12 months of urban development ranges up to 350t/ha for topsoils and 500 t/ha for exposed subsoils. The erosion hazard for concentrated flows is high.

Surface Movement Potential

bg1 and **bg2** are moderately reactive. **bg3** and **bg5** are slightly reactive.

Landscape Limitations

Steep slopes (localised)
Mass movement hazard (localised)
Water erosion hazard
Run-on (localised)

Urban Capability

Generally high to severe limitations for urban development with moderate limitations on benches.

Rural Capability

Generally high to severe limitations for regular cultivation. Low to moderate limitations for grazing but high to severe on steep slopes.

* Where the parent material is entirely shale and siltstone, highly dispersible Red and Brown Podzolics often occur.

no	NOWRA	Depositional

Landscape—moderately to gently undulating rises to low hills on Nowra Sandstone. Relief >40 m. Slopes >5%. Broad ridges and crests. Benched sandstone outcrops adjacent to drainage lines. Extensive to moderately cleared tall open-forest.

Soils—moderately deep (50–100 cm) Brown Podzolic Soils (Db1.11) occur on crests and upper slopes. Soloths (Dy3.21) and/or Yellow Earths (Gn2.61) occur midslope. Yellow Podzolic Soils (Dy5.11) occur on lower slopes and drainage lines.

Limitations—run-on, rock outcrop (localised), shallow soil (localised), stoniness, hardsetting, sodicity, low permeability, low wet bearing strength (subsoil).

LOCATION

Moderately to gently undulating rises to undulating low hills on sandstone on the Coastal Plain. Examples include Bomaderry and Falls Creek areas extending south and east of the township of Nowra.

LANDSCAPE

Geology

Nowra Sandstone—medium- to coarse-grained quartz sandstones which contain rounded pebbles scattered throughout the beds. Localised laterisation west of the village of Kangaroo Valley.

Topography

Moderately to gently undulating rises to undulating low hills. Relief >40 m. Slopes >5%. Broad ridges and crests with long, very gently inclined slopes, broad drainage areas with deeply incised channels. Benched sandstone outcrops adjacent to drainage lines.

Vegetation

Extensively to moderately cleared with stands of tall open-forest. Common species include turpentine (*Syncarpia glomulifera*), grey gum (*Eucalyptus punctata*), scribbly gum (*Eucalyptus sclerophylla*), sydney peppermint (*Eucalyptus piperita*), thin-leaved stringybark (*Eucalyptus eugenioides*), red bloodwood (*Eucalyptus gummifera*), forest oak (*Allocasuarina torulosa*) and blackbutt (*Eucalyptus pilularis*) with an understorey of flaky-barked tea-tree (*Leptospermum attenuatum*). Mountain devil (*Lambertia formosa*), hairpin banksia (*Banksia spinulosa*), pine-leaf geebung (*Persoonia pinifolia*) and burrawang (*Macrozamia communis*) grow on sandier soils.

Spotted gum (*Eucalyptus maculata*) and grey ironbark (*Eucalyptus paniculata*) grow on heavy soils. Decorative paperbark (*Melaleuca decora*) grows in drainage lines.

Land Use

Cattle grazing on improved pastures. State Forests including Nowra, Shoalhaven, Colymea, and Currambene. Urban—for example, Nowra—with small areas set aside as parks or undisturbed bushland.

Existing Erosion

Moderate rill erosion on batters.

Included Soil Landscape

Small areas of Greenwell Point **(gp)** soil landscape occur.

SOILS

Dominant Soil Materials

no1—Loose yellowish brown single-grained sand (topsoil)

Colour	greyish yellow brown (10YR 5/4) to yellowish brown (10YR 4/6)
Texture	sand to loamy sand
Structure	apedal, single-grained
Fabric	sandy
pH	4.0–6.5
Stones	nil
Roots	common

no2—Hardsetting gravelly massive yellowish brown clayey sand (topsoil and subsoil)

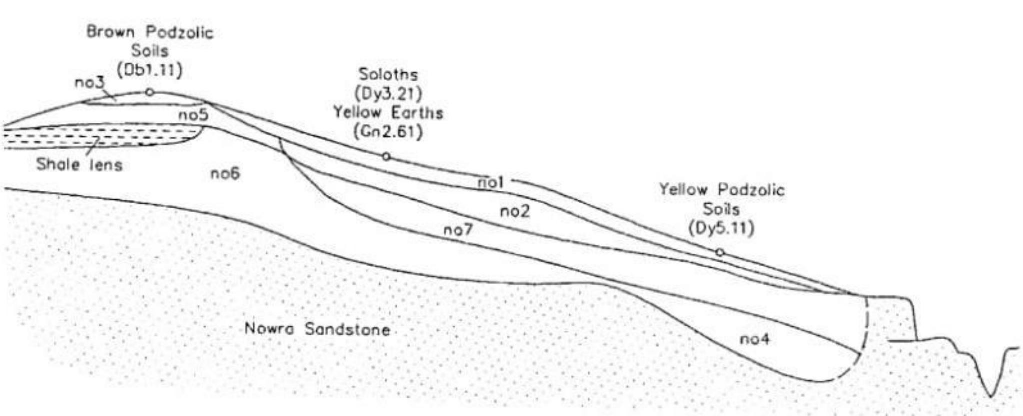
Colour	yellowish brown (10YR 5/6)
Texture	clayey sand to sandy loam
Structure	apedal massive
Fabric	sandy
pH	5.5
Stones	50–90% 6–20 mm sub-angular, stratified
Roots	common, in-ped

no3—Hardsetting dark reddish brown loam fine sandy (topsoil)

Colour	dark reddish brown (5YR 3/3)
Texture	loam fine sandy to silt loam
Structure	apedal massive
Fabric	earthy
pH	4.5
Stones	nil
Roots	common

no4—Mottled light clay (subsoil)

Colour	dull yellow orange (10YR 7/3) red and grey mottles (50%)
Texture	light clay with coarse sand
Structure	weak to moderate, 10–20 mm sub-angular blocky peds
Fabric	rough-faced, peds
pH	3.5
Stones	nil
Roots	nil



■ *Schematic cross-section of Nowra soil landscape illustrating the occurrence and relationship of the dominant soil materials.*

no5—Dark olive sandy clay (subsoil)

Colour	dark olive (5Y 4/4) to brown (10YR 4/6)
Texture	sandy clay
Structure	weak to moderately pedal, 2–20 mm round to sub-angular blocky peds
Fabric	smooth-faced, dense
pH	3.5–6.0
Stones	20–50% 6–20 mm rounded and sub-angular, dispersed
Roots	nil

no6—Bright brown moderately pedal light medium clay (subsoil)

Colour	bright brown (7.5YR 5/8) to dark olive (5Y 4/4)
Texture	light medium clay to medium clay
Structure	moderately pedal, 2–20 mm round to sub-angular blocky peds
Fabric	smooth-faced, dense
pH	3.5–5.0
Stones	10–20% 6–20 mm sub-rounded and sub-angular, dispersed
Roots	nil

no7—Brown sandy clay loam (subsoil)

Colour	brown (7.5YR 4/6)
Texture	light sandy clay loam to sandy clay
Structure	apedal massive
Fabric	earthy
pH	6.5
Stones	nil
Roots	few

Occurrence and Relationships

Crests and upper slopes. Up to 40 cm hardsetting dark reddish brown loam fine sandy **(no3)** overlies <30 cm dark olive sandy clay **(no5)** which overlies <30 cm bright brown moderately pedal light medium clay **(no6)**. Boundaries are clear [Brown Podzolic Soils (Db1.11)]. Total depth is <120 cm.

Midslopes. Up to 10 cm loose yellowish brown sand **(no1)** or hardsetting gravelly massive yellowish brown clayey sand **(no2)** overlies <20 cm brown sandy clay loam **(no7)** which overlies <100 cm **no6**. Boundaries are clear [Soloths (Dy3.21)] to gradual [Yellow Earths (Gn2.61)]. Occasionally **no1** does not occur. Total depth is <150 cm.

Lower slopes and drainage lines. Up to 15 cm **no1** overlies <15 cm **no7** which overlies <70 cm light clay with mottles **(no4)**. Boundaries are gradual to clear [Yellow Podzolic Soils (Dy5.11)]. Total depth is <120 cm.

LIMITATIONS TO DEVELOPMENT

Soil Limitations

no1 High organic matter
High permeability
Low available water-holding capacity
Sodicity

no2 Hardsetting
Stoniness
Low permeability
Sodicity
Low available water-holding capacity

no3 Hardsetting
Low permeability
Low wet bearing strength
Sodicity
Strongly acid
Low available water-holding capacity

no4 Low permeability
Strongly acid
Low wet bearing strength
Very high aluminium toxicity
Low available water-holding capacity

no5 Stoniness
Low permeability
Strongly acid (localised)
Sodicity
Low wet bearing strength
Low available water-holding capacity

no6 Stoniness
Strongly acid (localised)
Low permeability
Low wet bearing strength
Aluminium toxicity

no7 Low permeability
Low wet bearing strength
Very high aluminium toxicity

Fertility

General fertility is low to moderate. Topsoils **(no1, no2, no3)** are generally hardsetting. The soils are often moderately deep but are stony, strongly to moderately acid with generally low CEC.

Erodibility

Erodibility for the topsoil is generally low, but for the subsoils **(no4, no5, no6 and no7)** the erodibility is high.

Erosion Hazard

Erosion hazard for non-concentrated flows is moderate to high. The calculated soil loss for the first 12 months of urban development ranges up to 20 t/ha for topsoils and 60 t/ha for exposed subsoils. The erosion hazard for concentrated flows is low to moderate.

Surface Movement Potential

These soil materials are generally stable.

Landscape Limitations

Shallow soil (localised)
Rock outcrop (localised)
Run-on

Urban Capability

Generally low limitations for urban development.

Rural Capability

Generally low to moderate limitations for regular cultivation and grazing.