APPENDICES

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OVEN MOUNTAIN PUMPED HYDRO ENERGY STORAGE EIS

Surface water assessment

OVEN MOUNTAIN PUMPED HYDRO STORAGE

EMM creating opportunities

Oven Mountain Pumped Hydro

Surface water assessment

Prepared for OMPS Pty Ltd

May 2023

Oven Mountain Pumped Hydro

Surface water assessment

OMPS Pty Ltd

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Executive Summary

ES1 Introduction

OMPS Pty Ltd (OMPS) is proposing to develop the Oven Mountain Pumped Hydro Energy Storage Project (the Project), an off-river pumped hydro energy storage system (referred to as the 'pumped hydro system') located approximately half-way between Kempsey and Armidale adjacent to the Macleay River in northern New South Wales (NSW). The Project is located within the New England Renewable Energy Zone (REZ) and the Armidale Regional Local Government Area (LGA), proximate to its border with Kempsey Shire LGA.

At a basic level, the Project will consist of upper and lower water reservoirs, an underground waterway connecting them, and a pumped storage hydro-electric power station connected to the national electricity market (NEM) that is capable of generating or consuming electricity.

The Project has been declared by the NSW Government to be critical State significant infrastructure (CSSI) under the *NSW Environmental Planning and Assessment Act 1979* (EP&A Act). Infrastructure projects are declared to be CSSI if, in the opinion of the NSW Minister for Planning, they are essential to the State for economic, environmental, or social reasons. The Project will aid in the transition of the NEM towards cleaner, more reliable and affordable electricity by supporting around 1,600 megawatts (MW) of new renewable energy projects by providing up to 900 MW of electricity generating capacity, and up to twelve hours of dispatchable energy at full generation to be stored and made available to the NEM through the New England REZ. The expected operational lifespan of the Project is in excess of 100 years.

ES2 Report purpose

This surface water assessment is an appendix to the Project's Environmental Impact Statement (EIS) and should be read in conjunction with the EIS and other technical assessments referenced herein. It characterises the existing surface water environment, documents the water management approach built into the Project design to avoid and minimise impacts where possible, and assesses residual impacts resulting from construction and operation of the Project.

Project related impacts to the surface water environment will ultimately affect the Macleay River. Impacts to the Macleay River have the potential to affect the immediate receiving environment as well as environmental receptors and water users further downstream. A key focus of this report is to assess impacts to the Macleay River resulting from the Project.

There is significant complexity in navigating the relevant administrative water regulations and obtaining the required approvals and licences required to take water for pumped hydro projects. A key aspect of this surface water assessment is to establish water licensing requirements and demonstrate a feasible regulatory pathway is available to account for any water take that may occur due to the Project.

ES3 Water management approach

Water management during construction and operation of the Project will be a key factor in mitigating Project related impacts to the receiving surface water environment. A Project-specific water management approach has been developed with the aim to implement all practical measures to avoid or minimise Project related impacts.

The water management approach is based on the Project feasibility design prepared by SMEC (2022) and considers relevant industry standards and guidelines. Further refinement of the proposed water management approach will be undertaken in the future detailed design phase of the Project.

Key aspects of the proposed water management approach are summarised in Table ES1.

Table ES1 Water management summary

Key aspect	Management approach
Erosion and sediment control	Erosion and sediment control risks during construction will be managed via the implementation of Erosion and Sediment Control Plans (ESCPs) to be prepared within an overarching Project Soil and Water Management Plan (SWMP). The Project SWMP and ESCPs will be developed in accordance with best practice erosion and sediment control guidelines. The Project SWMP and associated ESCPs will be developed prior to the commencement of construction. Further detail on erosion risk and proposed management measures is provided in the Appendix O of the EIS (EMM 2022b).
Stormwater management	The stormwater management approach will vary based on the type of disturbance, construction activities and environmental factors such as topography. The stormwater management approach for each construction area will be documented within the SWMP and relevant ESCPs. The following measures are proposed: • management of clean water runoff from upslope areas and watercourses that traverse disturbance areas • sediment basins to capture and treat runoff from larger construction and disturbance areas • stormwater harvesting from sediment basins to reduce discharge volumes and frequency • source controls such as sediment traps or filters will be installed at discharge locations to reduce coarse sediment in runoff where sediment basins are not practical • source controls to isolate potentially polluting construction activities (i.e. concrete batching) from the stormwater system • measures to manage unforeseen events such as leaks and spills.
Process water management	The process water system aims to supply water (via the water supply system) to, and manage water produced by, construction activities. The following measures are proposed: • process water will be isolated from the stormwater system where practical to reduce the volume of water that requires management • process water will be collected, treated, and reused to reduce demand on the water supply system and discharge volumes • excess process water will be treated prior to discharge to the receiving environment.
Water supply system	A water supply system is proposed to supply water for potable water use, general construction water demand, initial fill of Project reservoirs and periodic operational top-up as necessary. The water supply system will extract water from the Macleay River via pump and pipeline. The following mitigation measures are proposed when extracting water at higher rates for initial storage fill and operational top-up: • extraction will only occur during high-flow (greater than 50th percentile) conditions • extraction will not occur during extended dry periods or drought • no extraction will occur during the first seven days of the first high-flow event following extended dry periods or drought to allow the river to recharge. Water extracted at lower pump rates (1 megalitre per day (ML/day)) for general construction purposes will be subject to the conditions and rules outlined in the relevant water sharing plan (WSP).
Wastewater management	• All wastewater (i.e. sewage) will be captured, treated and discharged in accordance with the relevant industry guidelines and standards.
Instream works	• Instream works and disturbance of waterfront land will be completed in general accordance with the NSW Department of Planning and Environment's (DPE) guidelines for controlled activities on waterfront land. • All instream structures and services will be designed by a suitably qualified professional in accordance with industry standards and guidelines. • All works to be documented within the SWMP and ESCPs and be completed in accordance with the management approach for erosion and sediment control and stormwater management.

Table ES1 Water management summary

Key aspect	Management approach
Flood risk management	• Flood risk management procedures during construction and operation will be documented within a Project specific Flood Management Plan (FMP) to be developed prior to the commencement of construction.

ES4 Residual impacts

ES4.1 Streamflow impacts

Residual impacts to the streamflow regime of the Macleay River are only anticipated to occur when extracting water for construction and operational purposes. The largest impact to streamflow will occur when extracting water for the initial fill of the Project dams and reservoirs. The following streamflow impacts are anticipated:

- The maximum annual water take for construction and the one-off initial storage fill (6,865 megalitres per year (ML/year)) represents 1% of the average annual streamflow volume adjacent to the Project area.
- The maximum predicted water take for operational top-up (710 ML/year) represents 0.07% of the average annual streamflow volume adjacent to the Project area while median (i.e. experienced in 50% of years) top-up volumes (131 ML/year) represent 0.01% of the average annual streamflow adjacent to the Project area. No operational top-up is predicted in 34% of years.
- Extraction for the initial storage fill and operational top-up will occur at a rate of up to 86.4 ML/day which results in a maximum streamflow reduction of 12.6% at the extraction point for short periods (several hours) of time just after extraction commences and just before extraction ceases. On average, an extraction rate of 86.4 ML/day results in a 6.1% reduction to streamflow based on the historical streamflow record.
- Extraction for initial storage fill and operational top-up is predicted to result in a maximum water level reduction of 0.05 m (or 5% of stream depth).
- Extraction at lower pump-rates (e.g. 1 ML/day) for general construction purposes is predicted to result in less than a 1% impact on the streamflow regime for 90% of Macleay River flow conditions adjacent to the Project area.
- Impacts to streamflow regime are predicted to decrease:
    - with increasing streamflow as the extraction volume makes up a smaller percentage of overall streamflow
    - moving downstream of the extraction location as additional catchment area contributes flow to the Macleay River.
- The initial storage fill is a one-off take and will occur for a relatively short period of time (i.e. 3–12 months) during construction while operational top-up is predicted to occur in 66% of years and for several days at a time. Hence, any residual impacts associated with water extraction will be short-term.

Impacts resulting from Project related discharges and the reduction in contributing catchment area due to impounding Fingerboard Crossing Creek are negligible given the relative size of the Macleay River catchment (7,596 km^2) upstream of the Project and relative magnitude of associated streamflow volumes (three to four orders of magnitude greater).

The streamflow regime in Fingerboard Crossing Creek will unavoidably be impacted as a result of the Project. Streamflow immediately downstream (i.e. at the toe of the dam wall) of the upper dam and reservoir is predicted to cease during operations. The impact to streamflow volumes gradually reduces moving further downstream with only a 13% reduction in streamflow at the lower dam and reservoir location.

A minor increase in baseflow is predicted to occur to several minor watercourses and the Macleay River during operation of the Project.

ES4.2 Water quality impacts

ES4.2.1 Stormwater discharges

During construction, runoff from disturbance areas (i.e. construction pads and access roads) may contain sediment and other contaminants associated with construction activities. Water quality risks during construction will primarily be mitigated through management measures to be documented in a SWMP and ESCPs.

Erosion and sediment controls are expected to effectively remove coarse sediment in runoff from disturbance areas. Where practical, sediment basins are proposed to capture and treat runoff from disturbance areas. The basins are expected to:

- prevent discharge of sediment laden water for rainfall events up to the design capacity
- during overflow conditions, provide sediment treatment, reducing the concentration of fine sediment entering receiving waters.

It is expected the proposed controls will mitigate most potential water management impacts. Some residual water quality impacts may be experienced as a result of sediment basin overflows during and following intense or prolonged periods of wet weather. Any residual impact is expected to be short-term (i.e. when the basin is overflowing) and nearfield as substantial dilution would occur downstream of the sediment basin under wet weather conditions.

For Project areas where the construction of sediment basins is not feasible due to terrain or other constraints, erosion and sediment controls may not effectively remove all fine dispersive sediments from disturbed area runoff. Stormwater discharges from construction areas entrained with fine and potentially dispersive sediments are expected to enter receiving waters during and shortly after rainfall. It is expected that any sediment laden water that enters the Macleay River will be significantly diluted by river flows and will rapidly dissipate.

Most of the surface infrastructure established to support construction activities will be decommissioned and rehabilitated in accordance with the Appendix P of the EIS (EMM, 2022d). This will substantially reduce the disturbance area and associated stormwater management risks from construction areas that are no longer required during operations. No material water quality impacts are anticipated due to stormwater discharges during operation of the Project.

ES4.2.2 Controlled discharges

Controlled discharges will occur from the process water and wastewater management systems during construction. Both process water and wastewater streams will be treated prior to discharge with the level of treatment dependant on the observed water quality. Treated water will be discharged to the nearest drainage line and ultimately the Macleay River.

The proposed treatment measures are expected to minimise water quality risks to the immediate receiving watercourse and the Macleay River. However, some residual risk may remain to the immediate receiving watercourse where concentrations of contaminants in treated water are above the water quality objectives (WQOs) and ambient receiving water values.

Residual water quality impacts to the Macleay River are anticipated to be minor and localised given typical streamflow values in the river are three to four orders of magnitude greater than the estimated discharge rates and substantial mixing and dilution will occur.

ES4.2.3 Spoil emplacements

A large volume of excavated rock and soil will be produced during construction of the Project. A portion of the material excavated by these actions will be used as aggregate for the construction of the reservoir dam walls. The material which is not suitable for this purpose will be disposed of in engineered spoil emplacements.

Discharge from the spoil emplacements is predicted to primarily occur as a result of direct rainfall which percolates through the rock matrix and discharges at the toe of each emplacement as seepage. Water that passes through the spoil emplacements has the potential to leach metals and other constituents from the rock.

Geochemical testing indicates waste rock from the Project may leach elevated levels of aluminium (between 2.4 milligrams per litre (mg/L) and 4.2 mg/L) and iron (between 1.0 mg/L and 5.9 mg/L). The actual concentrations within seepage from the emplacements may vary from the values observed in the leachate testing. Hence, the leachate testing results have been used to identify water quality risks associated with the spoil emplacements rather than as a predictor of expected water quality. The following potential changes to water quality are possible:

- The water quality immediately downstream (i.e. at the toe) of the spoil emplacements may have elevated concentrations of aluminium and iron compared to the WQOs and ambient water quality of receiving watercourses. The relative water quality impact is expected to decreased moving downstream due to dilution.

- Any seepage that enters the Macleay River would be significantly diluted and is therefore unlikely to materially change the existing water quality. It is noted that seepage is most likely to occur during and following rainfall when flows in the Macleay River are already elevated.

The spoil emplacement areas in the mid and upper reaches of Watercourse 1 represent approximately 18% of the total watercourse catchment area. The spoil emplacement area in the upper reaches of Watercourse 2 represents approximately 5% of the total watercourse catchment area. It is estimated that seepage from the Watercourse 1 and Watercourse 2 emplacement areas may be diluted by up to five and 20 times respectively before discharging to the Macleay River.

The total emplacement area in Watercourse 1 and Watercourse 2 represents less than 0.01% of the Macleay River catchment upstream of the Project area. Streamflow in the Macleay River is anticipated to be three to four orders of magnitude greater than the local catchment inflows during and following rainfall, when seepage is most likely to occur. Hence, any residual elevated metals concentrations within inflows to the Macleay River from Watercourse 1 and Watercourse 2 are expected to rapidly mix and dissipate.

ES4.2.4 Operational discharges

The Project will be operated so that inflows to the system in excess of the available storage capacity will overflow to the downstream portion of Fingerboard Crossing Creek and the Macleay River via the lower dam and reservoir spillway. Discharges may also be required from a low-level outlet at the base of the Lower dam and reservoir to facilitate emergency dewatering.

Discharges from the Lower dam and reservoir are expected to have similar water quality to the Macleay River (which is the source of water for initial storage fill and operational top-up) and Fingerboard Crossing Creek (which is impounded by the Project). Any residual risk to water quality will be managed through operational procedures. Hence, no downstream water quality impacts are anticipated due to Project overflows during operations.

ES4.3 Water availability

Extracting water for construction, the one-off initial storage fill, and operations is not expected to impact the security of water supply to downstream water users, or availability of water to environmental receptors as:

- The maximum annual extraction volume (6,865 ML/year) represents on average 1% of the annual streamflow volume in the Macleay River adjacent to the Project area and hence water available to downstream users. The maximum predicted water take for operational top-up (710 ML/year) represents 0.07% of the average annual streamflow volume adjacent to the Project area.

- High-flow-only access rules to be applied to the initial storage fill and operational top-up means there will be a minimum of 597 ML/day available for downstream users when extraction is occurring at higher pump rates. Extraction at lower pump rates (e.g. 1 ML/day) is expected to result in less than 1% reduction in available streamflow under most conditions.

- Only general construction water will be extracted (at rates of up to 1 ML/day) when streamflow is below the 235 ML/day used to define Kempsey Shire Council town water supply restrictions. Hence, an increase in the time and frequency water restrictions occur is not expected as a result of the Project.

- The maximum estimated water level reduction of 0.05 m (or 5% of stream depth) in the Macleay River is anticipated to have minimal impacts on local habitat availability.

- For species that rely on elevated streamflow cues (i.e. greater than 50th percentile), the maximum streamflow reduction is 12.6% which generally only occurs just after extraction commences and just before extraction ceases. Streamflow events that have low peak flow rates experience the largest impacts as the maximum extraction volume represents a greater portion of streamflow. Typically, the observed streamflow peak is substantially larger than the maximum extraction volume which may be as little as 1% of the observed streamflow peak.

The proportion of annual streamflow extracted, and associated impacts to downstream water availability decrease with distance downstream of the extraction site as the contributing catchment increases.

ES4.4 Flooding

Impacts to flooding in the Macleay River will primarily occur as a result of constructing infrastructure within the existing limit of flooding and due to water released from the Project dams and reservoirs in the event of a dam break. Most of the Project infrastructure is located above the 0.01% (1 in 10,000-year) annual exceedance probability (AEP) Macleay River flood level and therefore has a low risk of causing flood impacts.

A low-level bridge is proposed across the Macleay River to provide site access. The low-level bridge is anticipated to be inundated once a year on average for approximately 20 hours duration. During higher flow events, the bridge deck will be inundated allowing flood flows to pass the bridge relatively unimpeded. Localised increases to flood level are expected immediately upstream of the bridge crossing with localised decreases likely to occur immediately downstream. Flood level increases are expected to be minor and are not anticipated to result in a material increase in flood inundation on adjoining properties or Kempsey-Armidale Road. Impacts of the crossing are expected to reduce in scale with the increase in flood magnitude.

A preliminary dam break assessment was undertaken for the Project feasibility design (SMEC, 2022), to provide an initial understanding of dam break risk. The assessment concluded the volume of water from a dam break is comparatively small relative to a natural flood and thus becomes significantly attenuated as it travels further downstream. An attenuated dam break flood is approximately equal to natural flooding (1% AEP and less) in the Macleay River and is therefore unlikely to affect the downstream communities of Lower Creek and Bellbrook. The Macleay River is predicted to return to normal flow conditions approximately one hour after a dam break occurrence.

ES4.5 Geomorphology

The upper and lower dams and reservoirs will retain all coarse bed material generated within Fingerboard Crossing Creek, denying this natural contribution of sediment to the reaches downstream of the reservoirs, and from Fingerboard Crossing Creek to the Macleay River.

The section of Fingerboard Crossing Creek immediately downstream of the upper dam and reservoir will become geomorphologically dormant as streamflow and sediment transport to this section of creek will cease. Impacts to the remainder of Fingerboard Crossing Creek are expected to minor as the creek is characterised as having low geomorphic fragility which means potential impacts will be limited by the creek's natural resistance to change.

The reduction in sediment transport from Fingerboard Crossing Creek to the Macleay River is considered negligible at the catchment scale and minor at the local scale near the junction of Fingerboard Crossing Creek with the Macleay River.

Alterations to streamflow regime as a result extracting water for the initial storage fill and operational top-up are anticipated to have a minor short-term impact (i.e. when extraction is occurring) and negligible long-term impact on sediment transport process within the Macleay River.

ES5 Water licensing

ES5.1 Project water requirements

The estimated volumetric water requirements for the Project include:

- 365 ML/year over approximately five years for construction activities such as road and site establishment, site facilities (including potable water), processing areas, dust suppression, concrete batching, and firefighting.
- 6,500 ML for the one-off initial storage fill. This will occur once during the latter stages of construction.
- 838 ML/year (for 100 plus years) for operational top-up and runoff intercepted by the Project dams and reservoirs.

Water requirements will be met primarily from surface water sources, with the main source for the initial storage fill being unregulated flows from the Macleay River.

ES5.2 Project surface water sources

Surface water sources in the Project area are managed under the *Water Sharing Plan for the Macleay Unregulated and Alluvial Water Sources 2016* (Macleay WSP). The Project area straddles four surface water sources with all the main pumped hydro-electric and generation works (PHGW) infrastructure (i.e. reservoirs, tunnels, power station, intake and outlet structures) located within the Macleay Gorges Water Source.

The primary water sources relevant to the Project are the Macleay Valley and Macleay Gorges water sources. While sections of the Project area are in the Georges River and Dyke Creek water sources, no water take that requires licensing is proposed and so these water sources are not addressed further in this assessment. Most of the Project surface water take will occur from the Macleay Gorges Water Source.

ES5.3 Water licensing strategy

It is proposed to licence the water required for construction and initial storage fill via a specific purpose access licence (SPAL), as provided for in the NSW *Water Management (General) Regulation 2018* (Water Regulation). The remaining Project surface water take will primarily be licensed via trade of existing unregulated river access entitlements under the rules of the Macleay WSP.

A summary of the Project water licensing strategy for the construction, operation and decommissioning of the Project is presented in Table ES2.

Table ES2 Summary of water access licence requirements

Water source	Water take	Licensing pathway	Volume
Construction phase			
Macleay Gorges Water Source	General construction water and initial storage fill	Specific Purpose Access Licence as provided for in Part 2, Division 1 of the WM Act.	10,000 ML[1]
	Streamflow losses due to groundwater drawdown	Trade from existing unregulated river access entitlements.	33 ML/year
Macleay Valley Water Source	Eastern access road construction water	Trade from existing unregulated river access entitlements.	Up to 1 ML/day
Operational phase			
Macleay Gorges Water Source	Operational top-up	Trade from existing unregulated river access entitlements.	226 ML/year
	Local catchment runoff intercepted by upper dam and reservoir	Harvestable rights[2]	67 ML/year
	Local catchment runoff intercepted by lower dam and reservoir	Trade from existing unregulated river access entitlements.	545 ML/year
Decommissioning			
Macleay Gorges Water Source	Incidental interception of local catchment runoff	Licences obtained to account for the interception of local catchment runoff to be maintained to account for passive water take by retained reservoirs.	545 ML/year[3]

Notes: 1. Total SPAL volume includes estimated required volume of 8,325 ML plus 20% contingency to account for potential losses or an extended construction program.
2. Water take under harvestable rights is exempt from licensing requirements.
3. It is assumed the 67 ML/year intercepted by the upper dam and reservoir will be exempt under harvestable rights following decommissioning.

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1 Introduction

1.1 The Project

OMPS Pty Ltd (OMPS) is proposing to develop the Oven Mountain Pumped Hydro Energy Storage Project (the Project), an off-river pumped hydro energy storage system (referred to as the 'pumped hydro system') located approximately half-way between Kempsey and Armidale, adjacent to the Macleay River in northern NSW. The Project is located within the New England Renewable Energy Zone (REZ) and the Armidale Regional Local Government Area (LGA), proximate to its border with Kempsey Shire LGA.

Figure 1.1 and Figure 1.2 provide the regional and local context of the Project respectively.

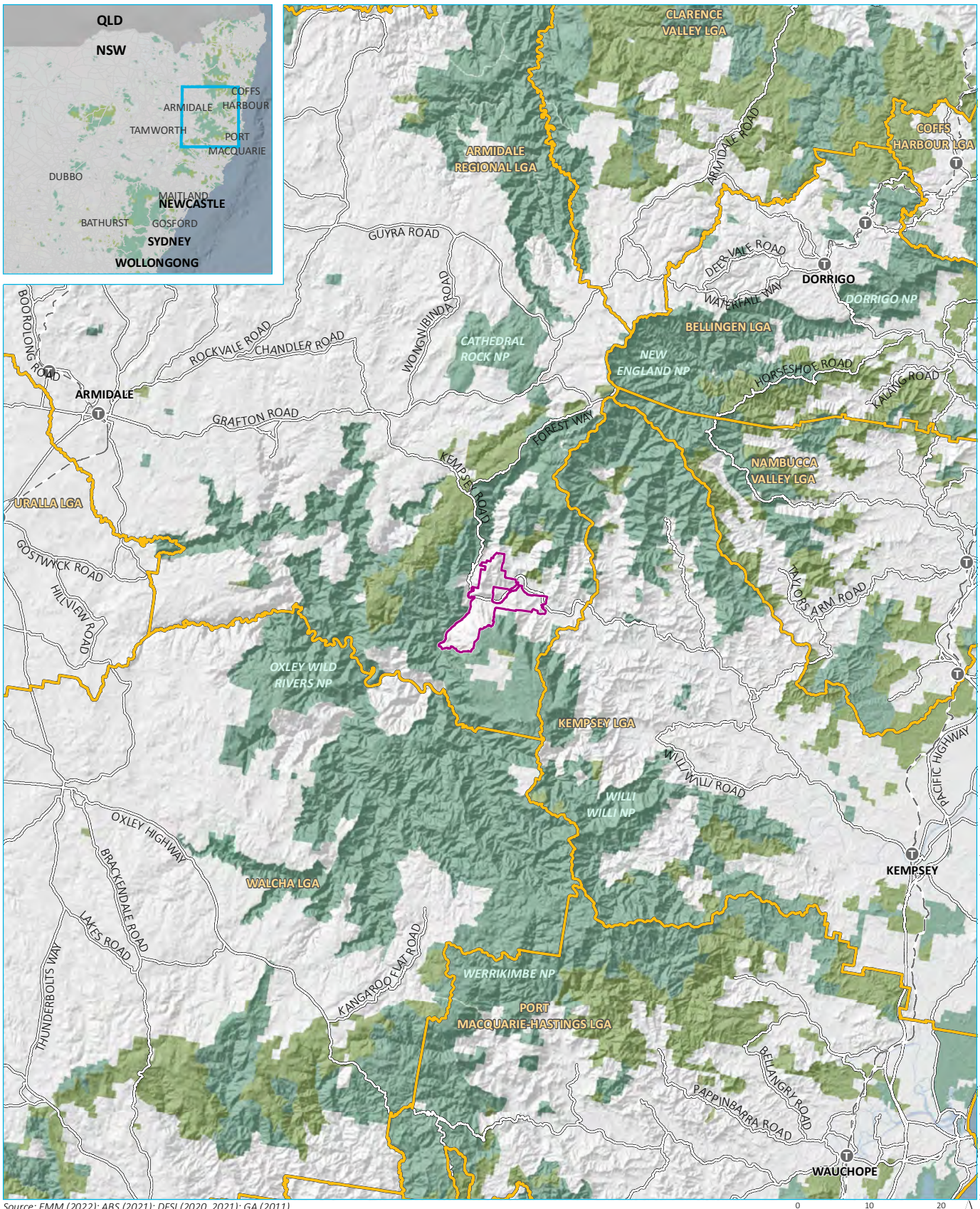
At a basic level, the Project will consist of upper and lower water reservoirs and an underground waterway connecting them via a hydro-electric power station.

The Project has been declared by the New South Wales (NSW) Government to be critical State significant infrastructure (CSSI) under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). Infrastructure projects are declared to be CSSI if, in the opinion of the NSW Minister for Planning, they are essential to the State for economic, environmental, or social reasons. By providing up to 900 MW of electricity generating capacity, the Project will aid in the transition of the NEM towards cleaner, more reliable and affordable electricity. It will also provide up to between eight and 12 hours of dispatchable energy at full generation to be stored and made available to the National Electricity Market (NEM) through the New England REZ. The expected operational lifespan of the Project is in excess of 100 years.

The Project will utilise the highly favourable natural terrain of the site on which it sits to allow electrical energy from the main grid to be stored by pumping water from the lower reservoir to the upper reservoir. Energy can then be generated when needed by allowing water to flow back down to the lower dam and reservoir via the hydro-electric power station, effectively enabling the Project to act as a large battery.

1.2 Proponent

OMPS (ABN 22 160 259 174) is developing the Project and is located in Kempsey at 2/28 Clyde Street, Kempsey NSW 2440.



Source: EMM (2022); ABS (2021); DFSI (2020, 2021); GA (2011)

0 10 20 km

GDA 1994 MGA Zone 56

N

KEY

- Project area
- Train station
- Rail line
- Major road
- Named waterbody
- Local government area
- NPWS reserve
- State forest

INSET KEY

- Major road
- NPWS reserve
- State forest

Regional setting

Oven Mountain Pumped Hydro Energy Storage Project
Surface water assessment
OMPS Pty Ltd
Figure 1.1

EMM creating opportunities

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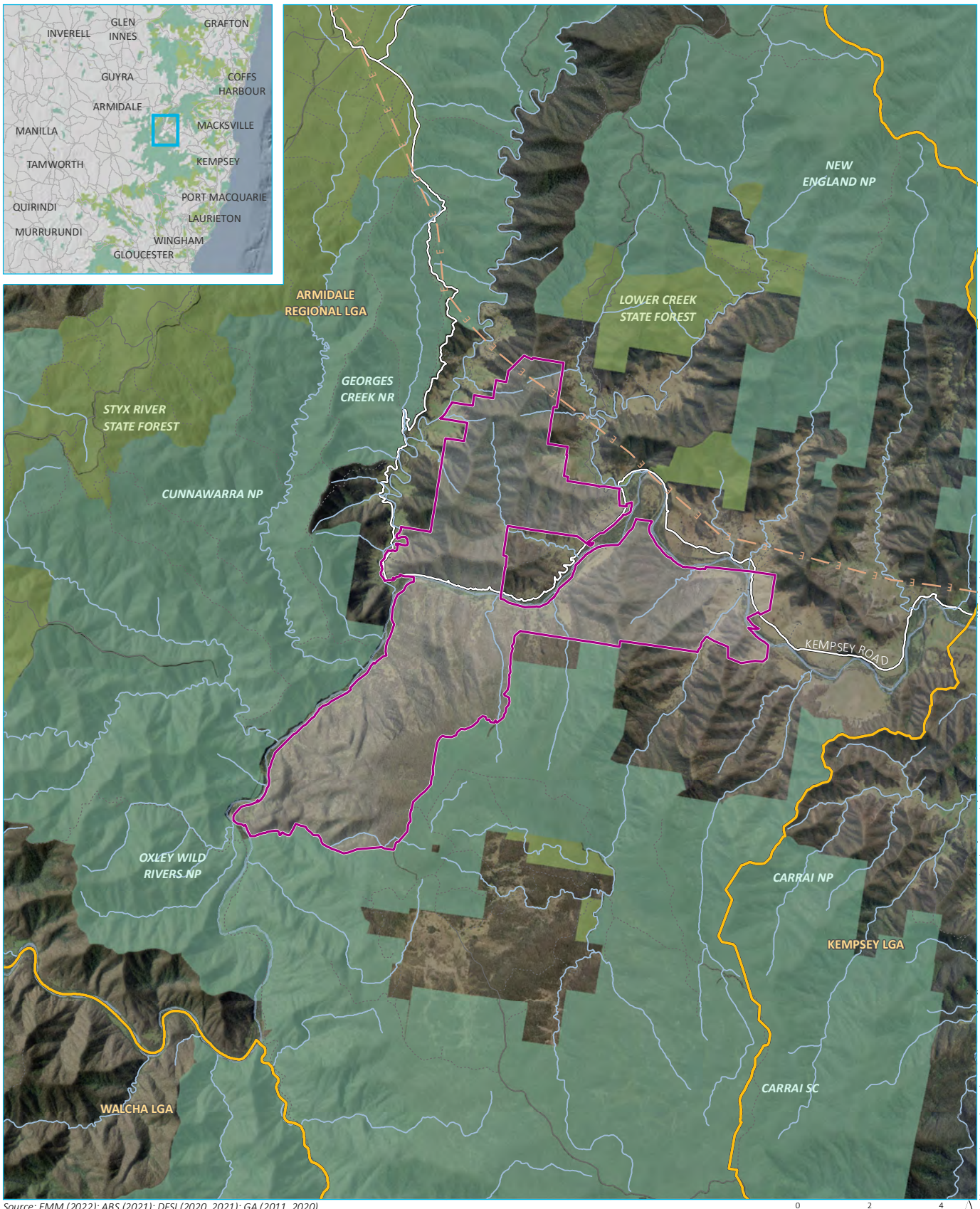

Source: EMM (2022); ABS (2021); DFSI (2020, 2021); GA (2011, 2020)

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KEY

- Project area
- Existing transmission line
- Major road
- Minor road
- Vehicular track
- Named watercourse
- Named waterbody
- Local government area
- NPWS reserve
- State forest

INSET KEY

- Major road
- NPWS reserve
- State forest

The Project area - local context

Oven Mountain Pumped Hydro Energy Storage Project
Surface water assessment
OMPS Pty Ltd
Figure 1.2

EMM creating opportunities

1.3 Purpose of this report

This surface water assessment is an appendix to the Project's Environmental Impact Statement (EIS) and should be read in conjunction with it. It characterises the existing surface water environment, documents the water management approach built into the Project design to avoid and minimise impacts, and assesses residual impacts resulting from construction and operation of the Project. A water licensing strategy is also presented to account for any water take that may occur due to the Project.

This report consists of the following sections:

- Chapter 2 provides a description of the Project
- Chapter 3 summarises relevant legislation, guidelines, plans and policies considered in this assessment
- Chapter 4 describes the existing surface water environment and surface water users
- Chapter 5 describes the proposed water management approach during construction and operation of the Project
- Chapter 6 assesses the impact of the Project on the surface water environment during construction
- Chapter 7 assesses the impact of the Project on the surface water environment during operation
- Chapter 9 provides an indicative surface water monitoring plan to be implemented during construction and operation of the Project
- Chapter 10 addresses water licensing and approval requirements and presents a water licensing strategy for the Project.

1.4 Assessment guidelines and requirements

This surface water assessment report has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) issued by the NSW Department of Industry, Planning and Environment (DPIE) (now the NSW Department of Planning and Environment (DPE)) on 10 June 2022. This assessment also considers relevant governmental assessment requirements, guidelines and policies, and consultation with the relevant government agencies, including the NSW DPE Water and the NSW Department of Primary Industries (DPI) Fisheries.

Table 1.1 lists the matters relevant to this assessment and where they are addressed in this report.

Table 1.1 Relevant matters raised in SEARs

Requirement	Section addressed
A detailed site water balance for the project, including the water take from each surface and groundwater source, any licensing requirements, and determine whether an adequate and secure water supply is available for the development.	Section 6.2, Section 7.2 and Chapter 10 Groundwater take is assessed in Appendix M of the EIS (EMM, 2022a)
An assessment of the impacts of the Project on:	
• the quantity and quality of the region's surface and groundwater	Chapter 6 and Chapter 7 Groundwater impacts are assessed in Appendix M of the EIS (EMM, 2022a)

Table 1.1 Relevant matters raised in SEARs

Requirement	Section addressed
• resources, including Macleay River and Fingerboard Crossing Creek	Chapter 6 and Chapter 7
• water security for local downstream receivers	Section 6.6 and Section 7.6
• hydrological flows on site, including any potential flooding impact	Section 7.8
• key water features on site, including potential impacts on riparian land	Section 5.9, Section 6.3 and Section 7.3
• type and extent of any dredging or reclamation activities within 'water land	No dredging or reclamation is proposed
• water-related infrastructure, basic landholder rights and the entitlements of water users.	Section 6.6 and Section 7.6
A description of the likely changes to the hydrological regime of the Macleay River, and any associated biodiversity impacts.	Section 6.3, Section 6.5, Section 7.5 and Section 7.3 Biodiversity impacts are assessed in Appendix I of the EIS (Stantec, 2022) and the Appendix H of the EIS (EMM, 2022b)
Where the Project involves works within 40 metres 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 *Guidelines for Controlled Activities on Waterfront Land* (DoI, 2018) and (if necessary) *Why Do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings* (Fairfull & Witheridge, 2003); and *Policy & Guidelines for Fish Habitat Conservation & Management* (DPI, 2013).	Section 5.9
A strategy to manage spoil and enhance any new landforms created.	A spoil management strategy is provided in Appendix O of the EIS (EMM, 2022c) and Appendix P of the EIS (EMM, 2022d)
Specific risks Hydrologic impacts on the Macleay River, including direct extraction and/or capture of groundwater or runoff that would have otherwise run into the river (aquatic and semi-aquatic species including frogs, fish, waterbirds, aquatic mammals, aquatic invertebrates such as crayfish). Management of runoff will be all the more important given that the referral indicates that the midstory and groundcover were burnt over much of the Project area. While it is noted that the Macleay River itself is not included in the World Heritage property where it borders the proposed Project area, its western tributaries would be.	Section 6.3 and Section 7.3

2 The Project description

2.1 Project overview

The Project involves building two 'off river' water containment structures to create an upper and a lower reservoir (referred to as 'the upper dam and reservoir' and 'the lower dam and reservoir'), on an ephemeral tributary of the Macleay River. An underground hydro-electric power station complex will be connected to the reservoirs by infrastructure including a power waterway and tunnels. During operation, the water will enable the generation of electricity as it passes through the underground power station while moving from the upper to the lower reservoir, from where it is pumped back up via the same waterway in a 'closed-loop circuit'. The pumped hydro system will be connected to the existing transmission network via new overhead high voltage transmission lines.

A detailed description of the Project and its strategic context is provided in the Project's EIS which should be read in conjunction with this report.

An overview of the key components and elements are provided below.

2.2 Key Project design elements

Broadly, the Project has been categorised into three key components, which are further broken down into the Project's key elements in Table 2.1 and shown in Figure 2.1:

- pumped hydro-electric and generation works (PHGW) – including:
  - new upper and lower water storage dams and reservoirs
  - a new underground pumped hydro-electric power station and transformer hall
  - water tunnels, access tunnels, portals and adits
  - tailrace
  - intake and outlet structures
  - associated gates, shafts and screens
- transmission connection works – including:
  - new electricity transmission lines to connect the PHGW to the existing electricity transmission network (Line 965)
  - new electricity transmission infrastructure
  - a new substation
- ancillary development – including but not limited to:
  - access roads, tracks and bridge
  - on-site quarries and related infrastructure
  - utilities and communications infrastructure
  - construction pads containing assets such as workshops, concrete batching plants (CBPs), and offices

- laydown and storage areas
- construction accommodation
- pumping infrastructure
- operational facilities such as offices, and camps for staff
- construction and operational power supply.

Table 2.1 Key Project elements

Project element	Description
PHGW	
Underground power station complex	An underground pumped hydro-electric power station located below the upstream end of the pumped hydro system to optimise the hydraulic arrangement of the Project. The power station complex consists of: • two main caverns comprising: – the machine hall – the transformer hall • interconnecting tunnels, the transformer hall tunnel and isolated phase busbar (IPB) tunnels.
Dams and reservoirs	Two concrete faced rockfill dams (CFRD) and reservoirs, referred to as the upper dam and reservoir and lower dam and reservoir, with the following specifications:
	Upper dam and reservoir: • CFRD approximately 70 metres (m) high and 780 m long • reservoir covering a total area of approximately 20 hectares (ha) and an inundation extent of approximately 16.7 ha • reservoir height of 881 m Australian Height Datum (AHD) at full supply level (FSL) and 830 m AHD at minimum operating level (MOL) • total reservoir storage capacity of around 5.1 gigalitres (GL) at FSL.
	Lower dam and reservoir: • CFRD approximately 70 m high and 280 m long • reservoir covering a total area of approximately 24.7 ha and an inundation extent of approximately 21.6 ha • reservoir height of 250 m AHD at FSL, 215 m at MOL and 205 m AHD at lowest operating level (LOL) • total reservoir storage capacity of around 6.5 GL at FSL.
Water intake structures	Two intake structures, one at each reservoir, including: • a morning glory, vertical-type intake structure situated at the upper dam and reservoir • a lateral intake structure, with head gates and stoplog slots, and an intake channel, at the lower dam and reservoir.
Spillway	Two concrete lined spillway chutes, one for each of the upper and lower dams and reservoirs. Both spillway crests will comprise of ungated ogee-shaped overflow weirs on the upstream ends of the spillway chutes.
Macleay River pump facility	A pump facility on the Macleay River, which will include duty and standby pumps for the first fill and for ongoing reservoir refills.

Table 2.1 Key Project elements

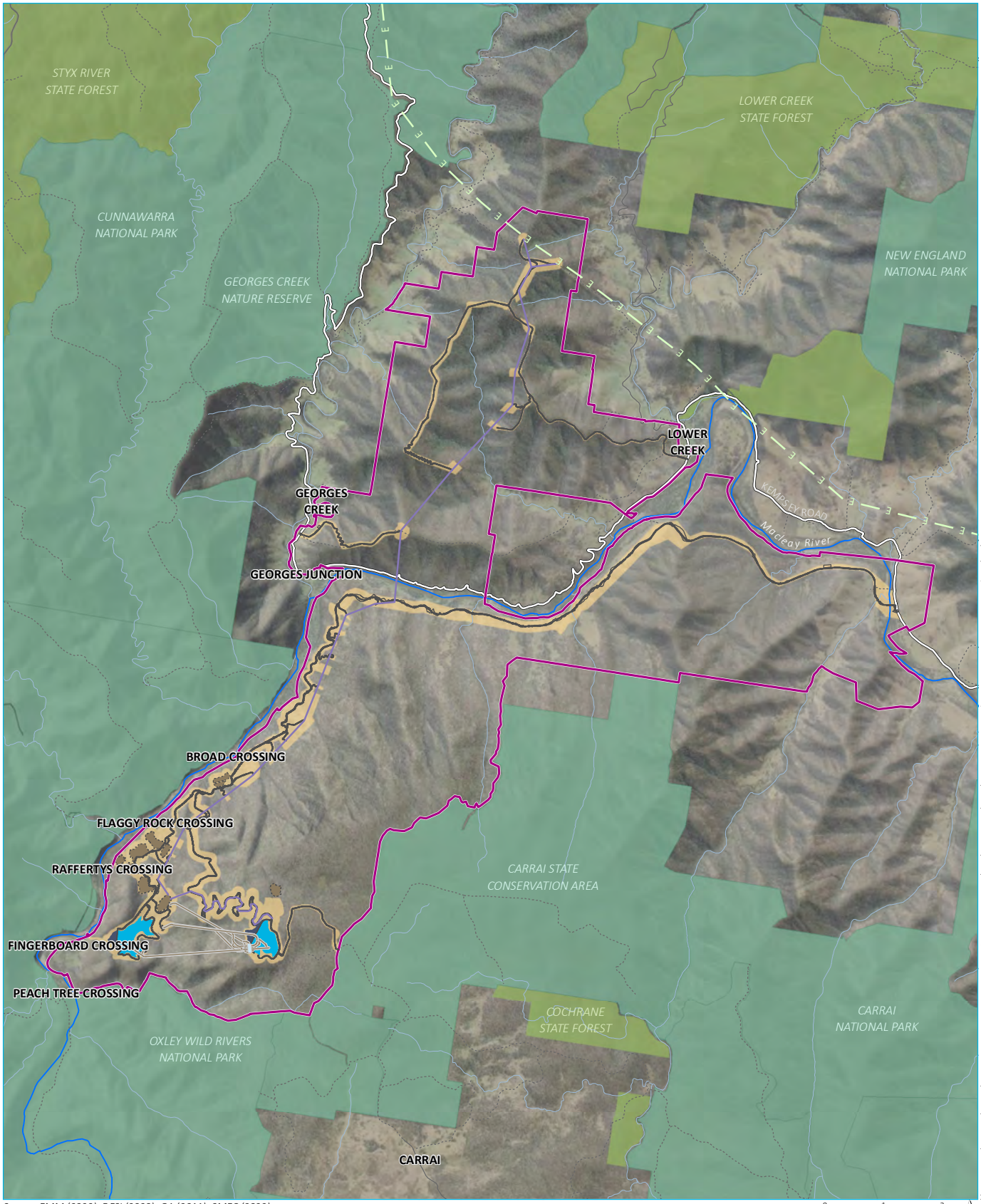
Project element	Description
Tunnels	Three main tunnels comprising of: • two main access tunnels (MAT1 and MAT2 • the emergency, cable, ventilation tunnel (ECVT). The MAT1 and MAT2 will provide loop access to the power station complex from the MAT portal. The ECVT will provide services access and egress between the switchyard portal and the transformer hall. The ECVT portal will contain the station switchyard, control rooms, ventilation and firefighting equipment, with blast walls separating important equipment.
Power waterway	The power waterway will consist of: • a 660 m deep, 5.1 m diameter vertical pressure shaft • 250 m concrete and steel lined high-pressure headrace tunnel • three or more 80 m long penstock tunnels • three or more 120 m long draft tube tunnels • an approximately 1,825 m long concrete lined tailrace tunnel.
Transmission connection works	
Connection works	The connection works will consist of: • an approximately 15km long transmission alignment comprising, at a maximum, double circuit single tower 330 kV overhead infrastructure and single circuit single tower 132 kV overhead infrastructure connecting to TransGrid Line 965 • Up to 25 transmission tower sites (approximately 50 m x 50 m) containing the 132 kV and 330 kV infrastructure • a transmission easement width of a maximum of approximately 105 m. Note: The upgrade of existing Line 965 will be the subject of a separate application.
Sub-station	Construction of a substation and associated connection infrastructure of up to 330 kV rating.
Switchyard	A high voltage connection linking the connection transmission lines to the cables exiting the underground power station complex. The outdoor air insulated switchyard will likely include: • switchgear and control room • cable potheads • disconnector/earth switches • capacitive voltage transformer (VT) • lightning protection • security fencing, lighting and surveillance • surge arrestor.
Ancillary development (construction and operation)	
Access roads, access tracks and bridge	A variety of road works to improve existing access, and construction of new permanent roads to enable construction access, temporary establishment and use of construction sites, and general access to the Project area including transmission line infrastructure.
	The proposed main access will be via the construction of a new unsealed two-lane access road located to the east of the site. The main access road will interface with the existing Kempsey-Armidale Road and will require the construction of one new single or two lane low-level bridge crossing over the Macleay River. A temporary bridge may be utilised prior to the construction of the permanent bridge.

Table 2.1 Key Project elements

Project element	Description
	There will be approximately 40 km of permanent roads connecting the dams, surface works, portals, transmission assets and spoil sites. Some of these roads are existing roads, however approximately 25 km will be newly constructed roads. The key road components include: • Main Access Road (approximately 4.7 km) • Eastern Access Road (up to approximately 11. 4 km) • Lower Dam Access Road (approximately 3.6 km) • Upper Dam Access Road (approximately 7.1 km) • access to portals and underground works • Upper Dam Emergency Egress Road (approximately 2.2 km). Access to the transmission infrastructure north of the Macleay River will be via two roads accessed from the Kempsey-Armidale Road. These two roads include the: • Northern Transmission Access Road (approximately 15 km) • Southern Transmission Access Road (approximately2.3 km). To support access along the transmission line easement south of the Macleay River and to each of the tower sites, a network of interconnecting access and maintenance tracks will be constructed, to a large extent utilising existing access tracks.
Surface works pads and facilities	There are four main construction pads in addition to surface portals which will be used temporarily during construction for different services (workers camp, construction site offices, workshop area, and laydown storage).
	Construction works will require the establishment of the following ancillary support infrastructure and areas: • Main accommodation camp(s), which will temporarily accommodate the majority of workers as required workers as required throughout the construction period • temporary or fly camps, which will temporarily accommodate the majority of workers as required throughout the construction period • two works areas including Works Area 1 and Works Area 2, which will contain ancillary facilities such as CBPs, mechanical and electrical workshops, a laboratory and various water treatment and wash areas • spoil emplacement areas • staging area • stockpiling areas • temporary site offices to be used during construction.
Communications	Communication infrastructure such as fibre optic cables are required for the operation of the Project and will be located: • on an overhead line linking the upper and lower dams and reservoirs (in conjunction with the electrical line) • buried in road corridors. The communication network will also include a communications tower near the upper dam and reservoir.
Utilities during construction	• Construction water will be supplied either via groundwater bores, or via pumping of water from the Macleay River to support camp operations, the CBP, dust suppressions and other activities across the site. • Construction power will be supplied primarily by use of portable diesel generators and supported where possible by leveraging off existing electricity distribution infrastructure running through the generation site.
Utilities for operation	Alignment and length of utilities (electricity, water, etc) will be combined into a single corridor (total length of about 5.4 km).

Table 2.1 Key Project elements

Project element	Description
Water diversion and water treatment facilities	• Site drainage will include a combination of cross drainage culverts, drainage pits and pipe, open channels/open drains (vegetated, rock-lined or concrete), levees/bunds, and detention basins. • Various water treatment plants will be used for construction drainage and water treatment facilities – for the main accommodation camp, temporary or fly camps, CBP, tunnel, etc. • Specific discharge locations are planned for stormwater and surface water runoff.
Laydown/stockpile areas	Temporary laydown/stockpile areas will be utilised across the Project area, with a total allocated stockpile area of around 114,000m^2.
Spoil emplacement areas	To accommodate spoil generated through excavation of the underground caverns and tunnels, three permanent spoil placement locations have been identified with a capacity to store around 2 million cubic metres (Mm^3) of material. Dead storage space within the reservoirs will also be used for spoil placement, with a capacity to store approximately 300,000–400,000 m^3.
Ancillary operational facilities	Primary operation of the Project can be undertaken remotely and will require minimal onsite operational staff, other than for maintenance activities. Operational facilities include maintenance housing, work area, car parking, workshop and storage, control room and switchgear, water treatment plant, office area, heating, ventilation and air conditioning (HVAC), backup generators and Macleay River pump facility.
Other	
Construction	• Construction duration of around four to five years. • Construction workforce of over 600 to approximately 1,000 workers at construction peak.
Rehabilitation	Rehabilitation of areas disturbed during pre-construction and construction will be undertaken progressively during all stages and phases of the Project. Progressive rehabilitation will occur over about 60 ha including spoil emplacement areas and areas used for construction ancillary facilities no longer needed during operation. At the end of the Project's life, 192 ha in total will be rehabilitated to native ecosystem (including native vegetation and rock landscape). Approximately 138 ha will be retained permanently for the water storages and access roads, subject to agreement with relevant landowners/land managers.
Operation	• The Project will provide up to 900 MW of electricity generating capacity and up to eight hours of energy storage at full generating capacity. • Maintenance and operational activities will include power station operations, infrastructure inspections, maintenance to assets, vegetation management, auditing and compliance and other activities. • It is expected that the operation of the new power station will require around 30–50 full-time workers, as well as additional contractors for regular and ad hoc maintenance and repairs.
Hours of operation	• Construction of the Project will be 24/7 and 365 days per year. • Operation of the Project will be 24/7 and 365 days per year.
Project timeline	The Project will involve the construction and operational stages, and numerous phases which are outlined in the Project's EIS.
CIV	Estimated to be about $1.8 billion.



Source: EMM (2022); DFSI (2020); GA (2011); SMEC (2022)

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KEY

- Project area
- Indicative generation component disturbance area

Project operational elements

- Power station
- Tunnels, portals, intakes, shafts
- Transmission overhead lines
- Permanent road
- Surface works
- Dam wall
- Reservoir

Existing environment

- Macleay River
- Watercourse/drainage line
- Major road
- Minor road
- Vehicular track
- Existing transmission line
- NPWS reserve
- State forest

Key Project elements

Oven Mountain Pumped Hydro Energy Storage Project
Surface water assessment
OMPS Pty Ltd
Figure 2.1

EMM creating opportunities

2.3 Project area terminology

Approval for the Project is being sought based on feasibility and concept designs as is common for projects of this size and scale. To accommodate minor changes and amendments to the design as it progresses, a 'Project area', 'construction envelope', 'disturbance footprint' and 'operational footprint' approach is being adopted for the Project. This approach is aimed at ensuring environmental impacts are assessed as accurately as possible, whilst accounting for the current level of design and the likelihood of design refinements occurring as the Project progresses towards construction. The terms are explained below.

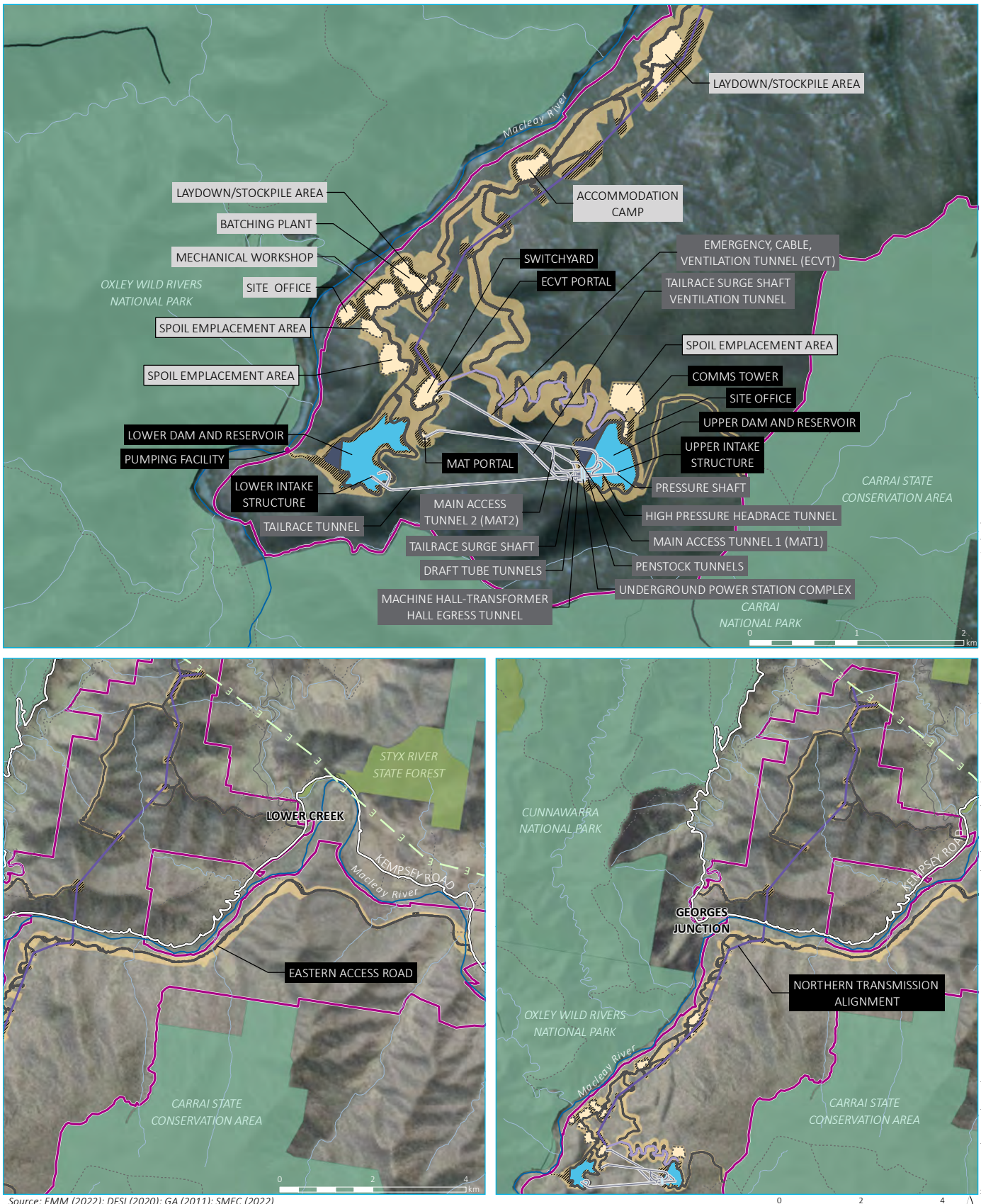
The *Project area* is the broader area within which the Project will be built and operated, and the extent within which direct impacts from the Project are anticipated. Importantly the Project area does not represent a footprint for the construction works, but rather indicates an area that was investigated during environmental assessments. The Project area has been further divided into different areas to facilitate the assessment of direct impacts from the Project.

The *construction envelope* represents the maximum extent of where disturbance may occur during the construction of the Project. In order to derive the construction envelope, buffers have been applied to the key Project elements and infrastructure. The buffers used to derive the final construction envelope area reflect the confidence around the current siting of the asset or infrastructure, and the likelihood that some minor amendments may be required prior to commencing the construction works as a result of the detailed design. The construction envelope for the Project covers an area of around 780 ha.

Located entirely within the bounds of the construction envelope sits the *disturbance footprint*, a smaller area that has been derived directly from the current level of design. The disturbance footprint represents the physical disturbance that can be expected as part of the construction works. As the design is refined, the final siting of the disturbance footprint can move within the construction envelope, subject to the recommended environmental management measures, and provided it does not exceed any limits as defined by the construction envelope. It is proposed that part of the disturbance footprint will be rehabilitated, and land formed at the completion of the Project. However, other parts will be retained after construction which is necessary for the ongoing operation and maintenance of the new power station (operational footprint). The disturbance footprint for the Project covers an area of around 330 ha.

Progressively and at the end of construction, temporary components that are required to support the construction of the Project will be rehabilitated and returned to a state representing their previous use. The exceptions to this are the areas required for the permanent operation of the Project, which would be retained (referred to as the *operational footprint*). The operational footprint of the Project covers an area of around 270 ha. Approximately 60 ha would be progressively rehabilitated during and following the completion of construction.

The Project area, construction envelope and disturbance footprint are shown in Figure 2.2.



Source: EMM (2022); DFSI (2020); GA (2011); SMEC (2022)

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KEY

- Project area
- Disturbance footprint
- Construction envelope
- Surface works

Project operational elements

- Underground power station complex
- Power and communications lines
- Transmission overhead lines
- Tunnels, portals, intakes, shafts
- Permanent road
- Reservoir
- Dam wall

Existing environment

- Macleay River
- Watercourse/drainage line
- Kempsey-Armidale Road
- Vehicular track
- Existing transmission line
- NPWS reserve

Label format

- SURFACE PERMANENT INFRASTRUCTURE
- UNDERGROUND PERMANENT INFRASTRUCTURE
- TEMPORARY INFRASTRUCTURE
- PERMANENT SPOIL EMPLACEMENT

Project areas overview

Oven Mountain Pumped Hydro Energy Storage Project
Surface water assessment
OMPS Pty Ltd
Figure 2.2

EMM creating opportunities

3 Assessment framework

3.1 Overview

This chapter provides a summary of relevant legislation, guidelines, plans and policies that have been considered in this surface water assessment.

3.2 Relevant legislation

3.2.1 Environmental Planning and Assessment Act 1979

The EP&A Act is the core legislation relating to planning and development activities in NSW and provides the statutory framework under which development proposals are assessed. The Project is declared CSSI under clause 20 of Schedule 5 of the *State Environmental Planning Policy (State and Regional Development) 2011*.

Division 5.2 of the EP&A Act sets out the assessment and approval framework for CSSI. The NSW Minister for Planning and Public Spaces is the determining authority for CSSI. This surface water assessment forms part of an EIS to support an application under Division 5.2 of the EP&A Act for the Project.

As the Project is CSSI, several water related exemptions apply under the EP&A Act (refer to Section 10.2.3i).

3.2.2 Water Management Act 2000

The primary legislation for managing water resources in NSW is the NSW *Water Management Act 2000* (WM Act), which provides for the sustainable and integrated management of the state's water for the benefit of both present and future generations. It sets the framework for providing water for basic landholder rights (domestic and stock, native title and harvestable rights) and for other licensed commercial uses within the context of protection of the state's water sources and their dependent ecosystems and culturally significant sites.

A key component of the WM Act is the separation of water licences from the land which facilitates opportunities for licence holders to trade water, subject to environmental protection considerations. The WM Act outlines the requirements for taking and trading water through water access licences (WALs), water supply work approvals and water use approvals.

The Project requires consideration against the WM Act because of the requirement to source water for construction, initial storage fill, and operations through WALs. Project water take has the potential to impact unregulated surface water sources and the water security of WALs within those sources.

Under the WM Act, access to water can only occur under exemption, certain rights, or access licences. Further detail on the legislation and policies relevant to water access, Project water licensing requirements, and the proposed water licensing strategy are provided in Chapter 10. This water licensing strategy has been developed in consultation with key regulators such as NSW DPE Water and NSW DPI Fisheries.

i Water Management (General) Regulation 2018

The NSW *Water Management (General) Regulation 2018* (Water Regulation) is the key regulation made under the WM Act. The regulation specifies important procedural and technical matters related to the administration of the WM Act, including the establishment of access licence categories, approval requirements and exemptions.

Part 2, Division 1 (10) of the Water Regulation was recently (October 2021) amended to include 'unregulated river pumped hydro-electricity generation (construction and initial storage fill) access licence' as a specific purpose access licence (SPAL) category. This SPAL category is applicable to water take for the Project construction and initial storage fill.

ii Water sharing plans

Water sharing plans (WSPs) are statutory documents developed under the WM Act that are designed to establish sustainable use and management of water resources at specific locations and for specific water resource types. WSPs establish the rules for sharing water between the environment and water users, and between competing extractive demands for water. WSPs apply to one or more water sources and establish overall limits to water take, environmental water rules, trading rules and mandatory licence conditions that apply to licence holders within each water source.

NSW has developed WSPs for all surface water and groundwater sources across the state, including a plan for each river system where major dams have been constructed for the purpose of regulating river flows (regulated rivers), plans that cover one or more water sources where major dams have not been constructed for the purpose of regulating flows (unregulated rivers), and plans for groundwater resources.

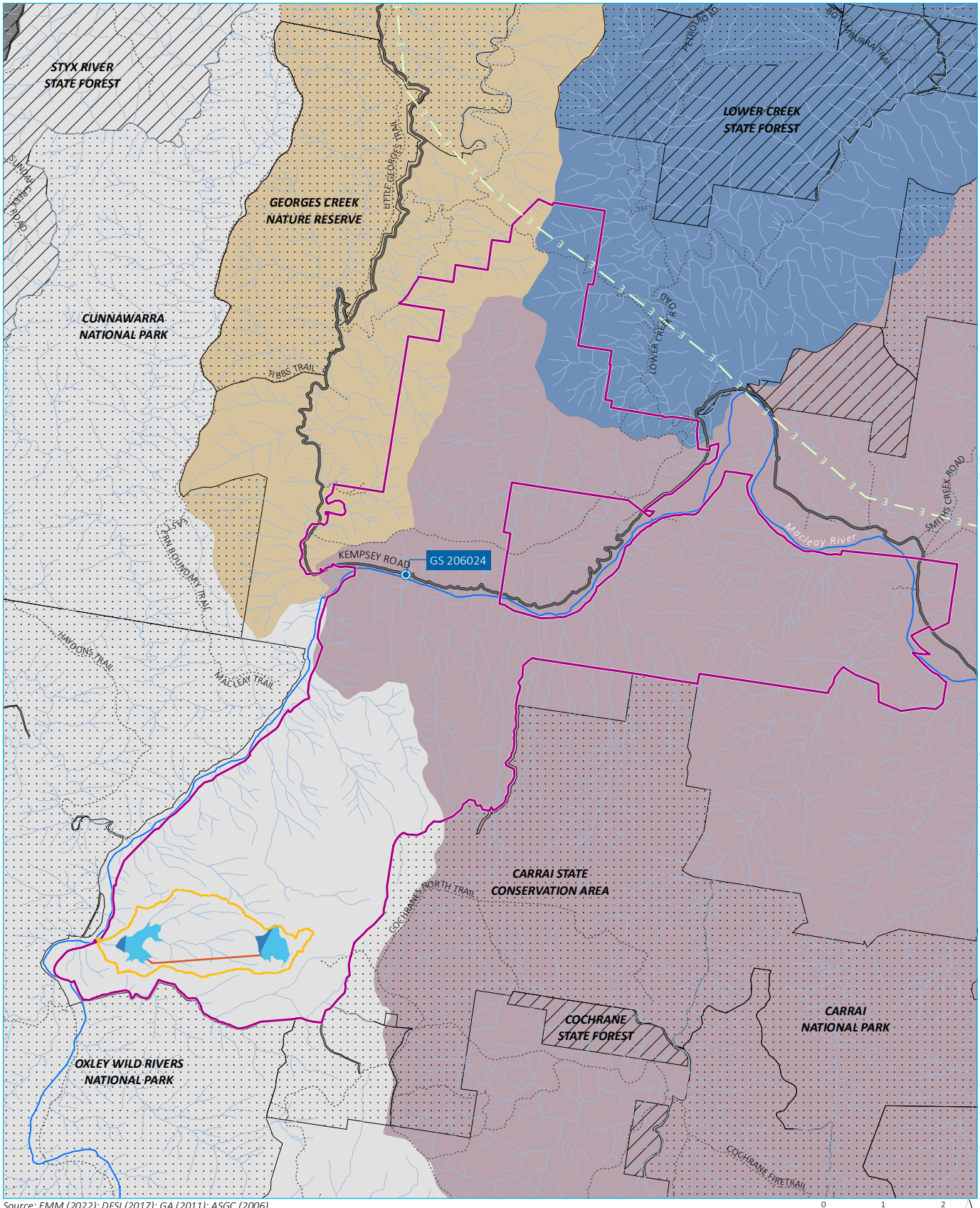
a Surface water

Surface water sources in the Project area are managed under the *Water Sharing Plan for the Macleay Unregulated and Alluvial Water Sources 2016* (Macleay WSP). This WSP covers 33 surface water sources (and connected alluvial groundwater) and one floodplain alluvial groundwater water source (DPI-Water, Water sharing plan for the Macleay Unregulated and Alluvial Water Sources: Background document, 2016a). The Project area straddles four surface water sources with all the main PHGW infrastructure (i.e. reservoirs, tunnels, power station, intake and outlet structures) located within the Macleay Gorges Water Source (refer to Figure 3.1).

All rivers and creeks within the Macleay WSP are classed as unregulated despite the presence of the Malpas Dam (on the Gara River in the upper north-west part of the catchment), which is the primary town water supply source for Armidale, and small dams and weirs that occur elsewhere (DPI-Water, Water sharing plan for the Macleay Unregulated and Alluvial Water Sources: Background document, 2016a). Water users within the catchment generally rely on natural flows for water supply.

The primary water sources relevant to the Project are the Macleay Valley and Macleay Gorges water sources. While sections of the Project area are in the Georges River and Dyke Creek water sources, no water take that requires licensing is proposed and so these water sources are not addressed further in this assessment.

Attachment A provides a summary of the available water entitlements, access rules, licence conversion rules, and dealing (trading) rules outlined in the Macleay WSP for water sources relevant to the Project.



Source: EMM (2022); DFSI (2017); GA (2011); ASGC (2006)

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KEY

- Project area
- Fingerboard Crossing Creek catchment
- Macleay River D/S Georges River Junction gauging station
- Road
- Track
- Watercourse/drainage line
- Macleay River
- NPWS reserve
- State forest

Indicative site layout

- Waterway alignment
- Reservoir
- Dam wall

Surface water sources within the Water Sharing Plan for the Macleay Unregulated and Alluvial Water Sources 2016

- Dyke River water source
- Georges River water source
- Macleay Gorges water source
- Macleay Valley water source
- Styx River water source

Macleay WSP water sources

Oven Mountain Pumped Hydro Energy Storage Project
Surface water assessment
OMPS Pty Ltd
Figure 3.1

EMM creating opportunities

b Groundwater

Groundwater sources in the Project area are managed under the *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* (Groundwater WSP) (DPI-Water, Water sharing plan for the North Coast Fractured and Porous Rock Groundwater Sources: Background document, 2016b). The Groundwater WSP covers 13 hard (fractured and porous) groundwater sources dispersed across several groundwater management areas from Gosford to the Queensland border. The Project area lies within the New England Fold Belt Coast (NEFBC) Groundwater Source.

Groundwater downstream of the Project area in alluvial systems is managed under the Macleay WSP (refer to Section 3.2.2iia). The Macleay WSP categorises alluvium as either being within 'upriver' alluvial water sources that are connected to adjacent unregulated surface water sources, or the Coastal Macleay Floodplain Alluvial Groundwater Source. Most alluvial groundwater is allocated for town water supply purposes and is extracted from Kempsey Shire Council's (KSC) bore field at Sherwood, 11 km west of Kempsey (APS, 2014).

Further details on the available water entitlements and water sharing rules outlined in the Groundwater WSP are provided in Appendix M of the EIS (EMM, 2022a).

3.2.3 Protection of the Environment Operations Act 1997

The NSW *Protection of the Environment Operations Act 1997* (POEO Act) provides the statutory framework for managing water pollution in NSW. It is supported by the NSW *Protection of the Environment Operations (General) Regulation 2021* (POEO Regulation), which among other functions prescribes certain matters for the purposes of the definition of water pollution.

The definition of 'water pollution' in the POEO Act sets out the general and specific circumstances that constitute pollution. At its broadest, water pollution means introducing any matter into waters which changes the physical, chemical, or biological condition of the water. It also includes placing any matter where it might fall, descend, be washed, be blown or percolate into any waters (e.g. soil which might wash into a waterway from land disturbance during construction of the Project).

Schedule 5 of the POEO Regulation includes a list of specific substances (prescribed matter) which, if they are introduced onto or into waters, are automatically assumed to constitute pollution of waters (i.e. animal matter, soil, thermal waste, any matter that contains faecal coliforms, pesticides, etc). Thermal pollution, relevant to potential cold water discharges from dams, is also addressed under Schedule 5 of the POEO Regulation.

Under the POEO Act, the NSW Environment Protection Authority (EPA) issues environment protection licences (EPLs) which regulate water pollution for projects and industrial operations. Licence conditions generally relate to pollution prevention and monitoring. An EPL will be required for both the construction and operational phases of the Project.

3.2.4 Fisheries Management Act 1994

The NSW *Fisheries Management Act 1994* (FM Act) provides for the sustainable management of fish and fish habitats and outlines approval processes for the activities that may impact on threatened fish species and habitats. Under Section 219 of the FM Act it is an offence to block the passage of fish. The FM Act requires a person who "constructs or alters a dam, floodgate, causeway or weir" to obtain a permit from the Minister.

As the Project is categorised as CSSI in accordance with the provisions of the EP&A Act, a permit is not required to construct the Project under the FM Act. Notwithstanding, potential impacts to fish and fish habitats have been considered for proposed works within watercourses that are outside of the dam and reservoirs, spillways, and inundation extents.

Impacts of the Project on aquatic ecosystems and species are addressed in Appendix I of the EIS (Stantec, 2022).

3.2.5 Dams Safety Act 2015 and Dams Safety Regulation 2019

The NSW *Dams Safety Act 2015* (DS Act) establishes Dams Safety NSW as an independent regulator charged with ensuring that any risks to public safety, the environment and economic assets that dams create are at an acceptable level to the community. Should the proposed dams be categorised by Dams Safety NSW as a 'declared dam' under Section 5 of the DS Act, OMPS (as the dam owner) will be required to comply with the relevant dams safety legislation and failure impact assessment requirements.

The NSW *Dams Safety Regulation 2019* (DS Regulation) applies to declared dams. A dam may be declared if it has a dam wall higher than 15 m, or if it would cause major or catastrophic damage or loss or endanger the life of a person if it failed. Based on this definition, the dams associated with upper and lower reservoirs may be a declared dam and subject to the regulation.

Under Part 3 of the DS Regulation, the owner of a declared dam must undertake a consequence assessment which describes the severity of damage and loss which may occur if the dam were to fail and provide this information to Dams Safety NSW.

Under Part 4 of the DS Regulation, a declared dam owner must create operations and maintenance plans and emergency management plans. The operation and maintenance plans describe details such as operating procedures, alarms and trigger levels, and security arrangements. The emergency management plans must describe the consequence category, dam construction, circumstances which may cause the dam to fail, descriptions of emergency warning systems, and emergency procedures. These plans must be delivered to Dams Safety NSW as soon as practical after construction and after any change.

A preliminary dam break assessment was completed as part of the Project feasibility design (SMEC, 2022). A comprehensive dam break study will be undertaken in future design stages to inform a consequence category assessment of the Project dams. Dams Safety NSW will be consulted to determine if the Project dams are to be declared dams.

3.3 Relevant NSW plans, policies, and guidelines

3.3.1 Water management policies

i Aquifer Interference Policy

The *NSW Aquifer Interference Policy* (DPI, NSW Aquifer Interference Policy: NSW Government policy for the licensing and assessment of aquifer interference activities, 2012) (AIP) sets out the licensing and assessment requirements for activities that may impact groundwater resources. For an aquifer interference activity, flow induced from the primary aquifer and connected water sources is considered a take of water. In all cases, a separate WAL is required for take from each water source. Groundwater licensing requirements associated with the AIP are addressed in Appendix M of the EIS (EMM, 2022a).

ii Harvestable rights

Owners or occupiers of a landholding are entitled to collect a proportion of the runoff from their property in one or more dams located on a minor stream or unmapped streams and use the water without the need for a licence or water supply work or water use approval. A minor stream is a first or second order stream defined using the Strahler system of stream ordering with reference to the Water Regulation 'hydroline' dataset. Harvestable rights orders are published in the NSW Government Gazette and specify the rules relating to harvestable rights.

For coastal draining catchments in the Eastern Division of NSW (where the site is located), landholders may capture, store and use:

- up to 10% of the average regional runoff from the property may be captured for any purpose

- up to an additional 20% (i.e. 30% total) of the average regional runoff from the property may be captured provided this is used solely for domestic consumption, stock watering and extensive agriculture.

The 10% threshold would apply to the Project.

The total capacity of all dams on a property allowed under the harvestable right is called the maximum harvestable right dam capacity (MHRDC). An MHRDC calculator is available on the WaterNSW website, which considers location, rainfall and variations in rainfall patterns.

If the total capacity of applicable dams on a property exceeds the maximum harvestable right volume, a licence and water use approval is required to authorise the take and use of water for the volume in excess of the MHRDC. In addition, a water supply work approval is required for dams that exceed the maximum harvestable right volume.

Harvestable rights cannot be applied to runoff captured in storages located on non-minor watercourses (defined as third order and above).

3.3.2 Guidelines for controlled activities on waterfront land

The WM Act defines waterfront land as the bed of any river, lake or estuary and any land within 40 m of the river banks, lake shore or estuary mean high water mark. Works undertaken on waterfront land generally require a controlled activity approval, unless defined as exempt.

Guidelines for controlled activities have been prepared by NSW Department of Industry (now DPE). These guidelines provide information on the design and construction of a controlled activity, and other ways to protect waterfront land.

The Project is categorised as CSSI in accordance with the provisions of the EP&A Act. A controlled activity approval to undertake work on waterfront land is not required for projects that are defined as CSSI. Hence, a controlled activity approval is not required for the Project. Notwithstanding, the guidelines for controlled activities have been considered for any proposed works on waterfront land.

3.3.3 Floodplain Risk Management Manual

The *Flood Risk Management Manual* (FRMM) (DPE, 2022a) is the NSW Government's primary guideline relating to the management of flood liable land in accordance with the NSW Flood Prone Land Policy and the NSW *Local Government Act 1993*. The FRMM and supporting toolkit updates the former *NSW Floodplain Development Manual* (DIPNR, 2005) and previous technical guidelines.

The FRMM provides for the development and implementation of sustainable strategies for managing human occupation and use of the floodplain. It provides for evaluation of strategies and formulation of plans that achieve effective flood risk management outcomes accounting for social, economic, ecological and cultural factors, together with community aspirations for the use of flood prone land.

3.3.4 NSW Water Quality and River Flow Objectives

The *NSW Water Quality and River Flow Objectives* (DECCW, 2006) provides water quality objectives (WQOs) that are consistent with the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000) water quality guidelines (refer to Section 3.4.1). The WQOs are "primarily aimed at maintaining and improving water quality, for the purposes of supporting aquatic ecosystems, recreation and where applicable water supply and the production of aquatic foods suitable for consumption and aquaculture activities" (DECCW, 2006).

The river flow objectives (RFOs) are the agreed high-level goals for surface water flow management. They identify the key elements of the flow regime that protect river health and water quality for ecosystems and human uses. Where WSPs have been made, RFOs informed the development of these plans but typically more detailed work and understanding of flow management objectives has since been derived to the extent that WSPs effectively supersede the RFOs.

WQO and RFOs are provided for catchments throughout NSW. The Project area is within the Macleay River catchment. Watercourses within the Project area, including the Macleay River, are classified as "uncontrolled streams" on the DECCW (2006) watercourse mapping.

3.3.5 Bunding and spill management

The NSW Government guideline *Storing and Handling Liquids: Environmental Protection: Participant's Manual* (DECC, 2007) describes best practice storage, handling, and spill management procedures for liquid chemicals. Bunding and spill management guidelines will be applied to the storage of liquid chemicals during Project construction and operation.

3.3.6 Erosion and sediment control

A key requirement for managing and mitigating environmental impacts of developments, particularly through the construction phase, is addressed through the preparation of a Soil and Water Management Plan (SWMP). The SWMP forms a key element of the overall Construction Environmental Management Plan (CEMP) and will be underpinned by Erosion and Sediment Control Plans (ESCPs), which are designed for use as a practical guide to manage risks to soil and water associated with specific construction activities for all discrete disturbance areas.

The content requirements of the SWMP and ESCPs are prescribed in the following guidelines and best practice documents:

- *Managing Urban Stormwater: Soils and Construction Volume 1* (Landcom, 2004)
- *Managing Urban Stormwater: Soils and Construction Volume 2A Installation of Services* (DECC, 2008a)
- *Managing Urban Stormwater: Soils and Construction Volume 2C Unsealed Roads* (DECC, 2008b)
- *Managing Urban Stormwater: Soils and Construction Volume 2D Main Road Construction* (DECC, 2008c)
- *Managing Urban Stormwater: Soils and Construction Volume 2E Mines and Quarries* (DECC, 2008d)
- *Best Practice Erosion and Sediment Control (BPESC) Books 1–6* (IECA, 2008).

The implementation of a SWMP and ESCPs to manage and mitigate potential impacts to the surface water environment during construction is described further in Section 5.2. Erosion and sediment control risks and proposed management measures are described more broadly in Appendix O of the EIS (EMM, 2022c).

3.4 Relevant Commonwealth policy and guidelines

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

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG, 2018) describe water quality objectives for freshwater and marine environments, aquatic ecosystems and primary industries within Australia and New Zealand. The ANZG (2018) guidelines are a revision to the 2000 version of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* published by the Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ).

The ANZG (2018) guidelines provide a framework for the development, assessment and implementation of water quality objectives to sustain current, or likely future community values for natural and semi-natural water resources. The ANZG (2018) guidelines include default guideline values (DGVs) that define ranges and maximum values for certain parameters that are suitable for the protection of specific water uses or values.

The DGVs do not make allowance for site-specific factors that may influence water quality. The DGVs may be superseded by site-specific trigger values (SSTVs) should sufficient baseline data (typically greater than 24 months) become available.

In accordance with the *NSW Water Quality and River Flow Objectives* (DECCW, 2006), the ANZG (2018) and (where relevant) ANZECC (2000) guidelines have been applied to establish environmental values and WQOs for watercourses that may be impacted by the Project (refer to Section 4.6.2).

3.4.2 Australian Drinking Water Guidelines

The *Australian Drinking Water Guidelines* (ADWG) (NHMRC, 2011) provide a framework for good management of drinking water supplies that, if implemented, will assure safety at point of use. The ADWG have been developed after consideration of the best available scientific evidence and 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.

Drinking water is defined as water intended primarily for human consumption, either directly, as supplied from the tap, or indirectly, in beverages, ice or foods prepared with water. Drinking water is also used for other domestic purposes such as bathing and showering.

The ADWG include two different types of guideline values:

- a health-related guideline value, which is the concentration or measure of a water quality characteristic that, based on present knowledge, does not result in any significant risk to the health of the consumer over a lifetime of consumption
- an aesthetic guideline value, which is the concentration or measure of a water quality characteristic that is associated with acceptability of water to the consumer (e.g. appearance, taste and odour).

The ADWG have been considered when establishing WQOs for watercourses that may be impacted by the Project (refer to Section 4.6.2).

3.4.3 Australian Rainfall and Runoff

Australian Rainfall and Runoff (ARR 2019) (Ball, et al., 2019) is a national guideline used for the estimation of design flood characteristics in Australia. The key objective of ARR 2019 is to provide the best available information on design flood estimation in a manner suitable for use by Australian practitioners. Ultimately, the outcomes aim to support provision of reliable and robust estimates of flood risk, support risk mitigation and community resilience.

4 Existing surface water environment

4.1 Overview

This chapter describes the existing surface water environment of the Project area and provides a baseline characterisation of local and regional climate, watercourses, water quality, water use, and flooding. The baseline conditions established in this section are used to assess Project-related impacts in Chapter 6 and Chapter 7.

4.2 Climate

4.2.1 Observed rainfall records

The climate of the Macleay River catchment ranges from subtropical in the lower coastal areas to temperate conditions in the higher elevation areas associated with the New England Tablelands (tablelands). A rainfall gradient exists decreasing from east to west with average annual rainfall totals ranging from approximately 1,250 millimetres per year (mm/year) at Kempsey to 750 mm/year at Armidale. Most of the annual rainfall typically occurs during summer and early autumn. However, large rainfall events may occur at any time of the year.

There are several Bureau of Meteorology (BoM) operated rainfall gauges that provide representative records for the Project area. Key information and statistical data for four gauges near the Project area are provided in Table 4.1. The rainfall gauges presented in Table 4.1 have been chosen based on proximity, length and completeness of record.

Daily rainfall data for the Project area was obtained as SILO grid point data from the Queensland Climate Change Centre of Excellence. SILO grid point data is based on historical data from BoM rainfall stations, where rainfall totals are interpolated at the point of interest (or grid location) from nearby station records. The daily rainfall data was obtained for the 1907 to 2022 period to coincide with available records for nearby BoM operated stations and is compared to the BoM operated stations in Table 4.1.

Table 4.1 Annual rainfall statistics

Statistic	Units	Jeogla Station (57011)	Uralla (Blue Nobby) (57091)	Lower Creek (Cedar Park) (57052)	Bellbrook (East Street) (59000)	SILO data (Project area)[1]
Rainfall record	-	1907 – present	1959 – present	1961–2017	1889–2017	1907 – present
Record completeness	-	99%	97%	89%	97%	-
Distance from Project area	-	25 km north-west	33 km west	8 km north-east	30 km east	0 km
Elevation	(m AHD)	950	1067	130	95	295
Average rainfall	(mm/year)	935	933	1,069	1,136	986
Lowest rainfall	(mm/year)	310	271	597	522	316
10th percentile rainfall	(mm/year)	666	676	715	753	662
Median rainfall	(mm/year)	904	952	1,049	1,057	960
90th percentile rainfall	(mm/year)	1,239	1,159	1,413	1,662	1,350
Highest rainfall	(mm/year)	1,781	1,397	1,724	2,052	1,728

Source: BoM website (climate data online).
Notes: 1. Rainfall data obtained as SILO patched point data at -30.75, 152.20.

The annual rainfall totals shown in Table 4.1 indicate rainfall generally increases from west to east with the highest annual rainfall totals experienced at the Bellbrook (East Street) gauge. The rainfall gradient follows the topography of the catchment with lower rainfall totals experienced on the tablelands and higher rainfall totals experienced towards the coast.

The annual average rainfall for the Lower Creek (57052) gauge is 1,069 mm/year. However, the Lower Creek rainfall record is only 89% complete and contains numerous data gaps, particularly between 2000 and 2017. The Lower Creek gauge was decommissioned in 2017 and therefore does not capture the drought that occurred in 2018 and 2019.

The annual average rainfall for the Jeogla Station (57011) gauge is 935 mm/year. The Jeogla Station gauge provides the most complete long-term record of rainfall near the Project area and includes extreme wet and dry years. It is noted that the Jeogla Station gauge is west of the Project area and is expected to experience less annual rainfall on average.

The annual rainfall statistics for the Project area (based on SILO data) are similar to the annual rainfall statistics for the Lower Creek (57052) and Jeogla Station (57011) gauges, indicating the SILO data is representative of the long-term rainfall record (both average and extreme conditions) near the Project area. The SILO data has been used to summarise historical rainfall trends for the Project area in Historical rainfall trend at the Project area (-30.75, 152.20). The deviation (11 year moving average) in the average annual rainfall total (986 mm/year) is also shown to identify extended wet and dry periods.

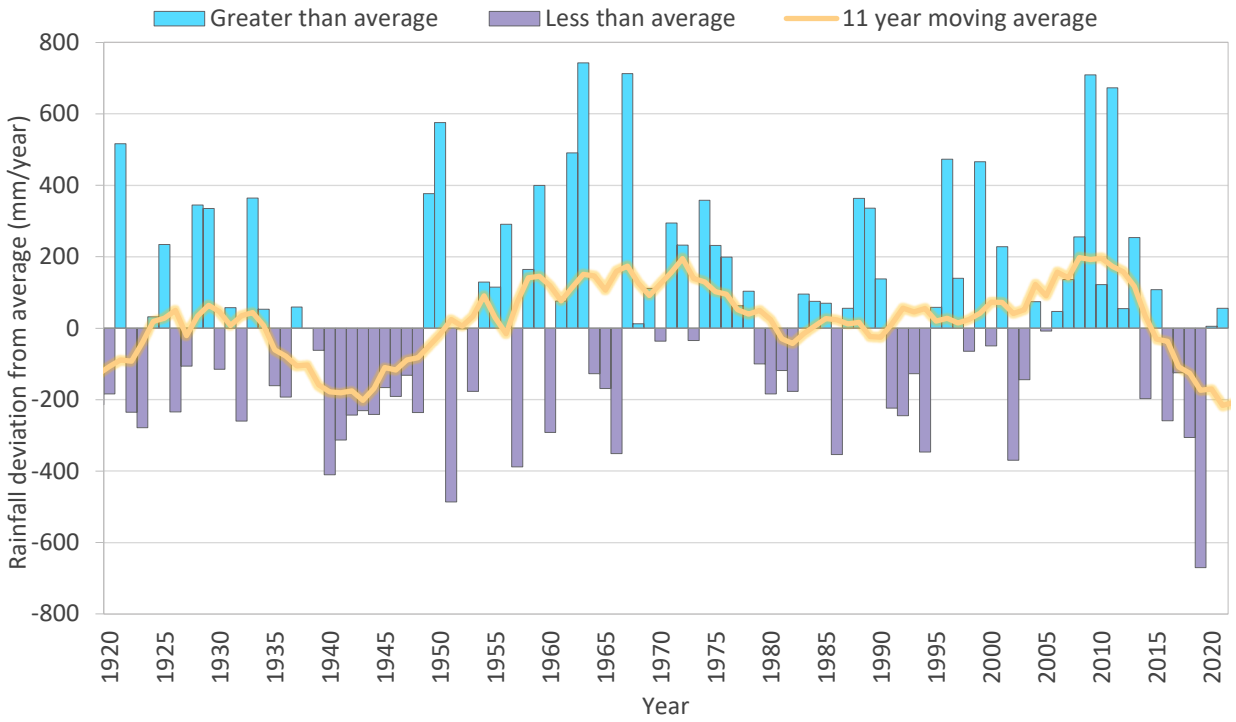


Figure 4.1 Historical rainfall trend at the Project area (-30.75, 152.20)

4.2.2 Seasonal trends

Monthly rainfall and pan evaporation statistics for the Project area have been calculated using the SILO data described in Section 4.2.1 and are presented in Figure 4.2.

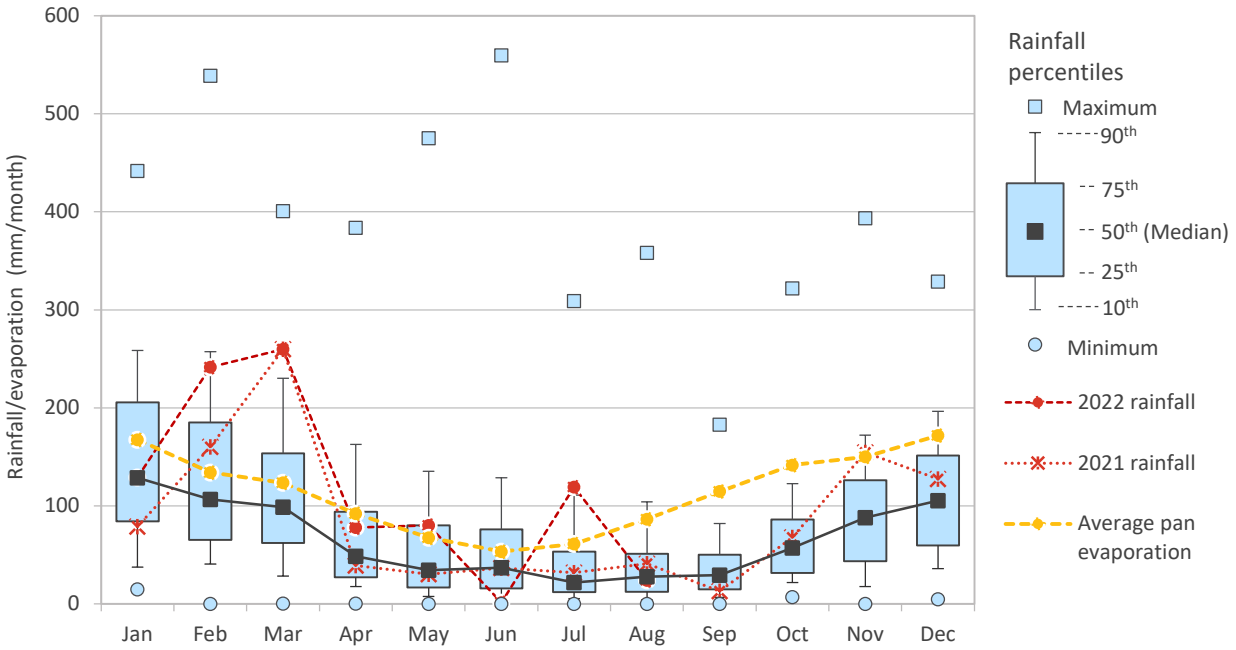


Figure 4.2 Monthly rainfall statistics for the Project area

The data presented in Figure 4.2 indicates greater rainfall totals are experienced in summer and early autumn. The larger difference between the 25th and 75th percentile values indicate greater rainfall variation also occurs during summer and early autumn. Less variation in rainfall occurs from May to September, however larger rainfall events may still occur during this period.

Average monthly pan evaporation totals are shown to be similar, although slightly higher, to median monthly rainfall totals from January to July. Average pan evaporation totals are shown to substantially exceed median rainfall totals from August to December. This is expected to be a result of lower rainfall and higher temperatures (and subsequently increased evaporation) that are experienced from August to December.

Summer and autumn rainfall increases towards the coastal portions of the catchment with monthly rainfall totals exceeding monthly evaporation totals from February to June. Greater rainfall deficits are experienced on the tablelands during summer and autumn compared to the Project area. However, rainfall is observed to marginally exceed evaporation during winter. The difference between monthly rainfall and evaporation totals is similar across the catchment in spring. Less of a rainfall deficit is experienced on the tablelands during spring compared to the rest of the catchment.

4.2.3 Recent weather

Recent rainfall and evaporation trends were calculated for the Project area using the SILO data described in Section 4.2.1. Observed rainfall and evaporation totals from 2018 to 2022 are compared against the long-term average monthly totals in Figure 4.3.

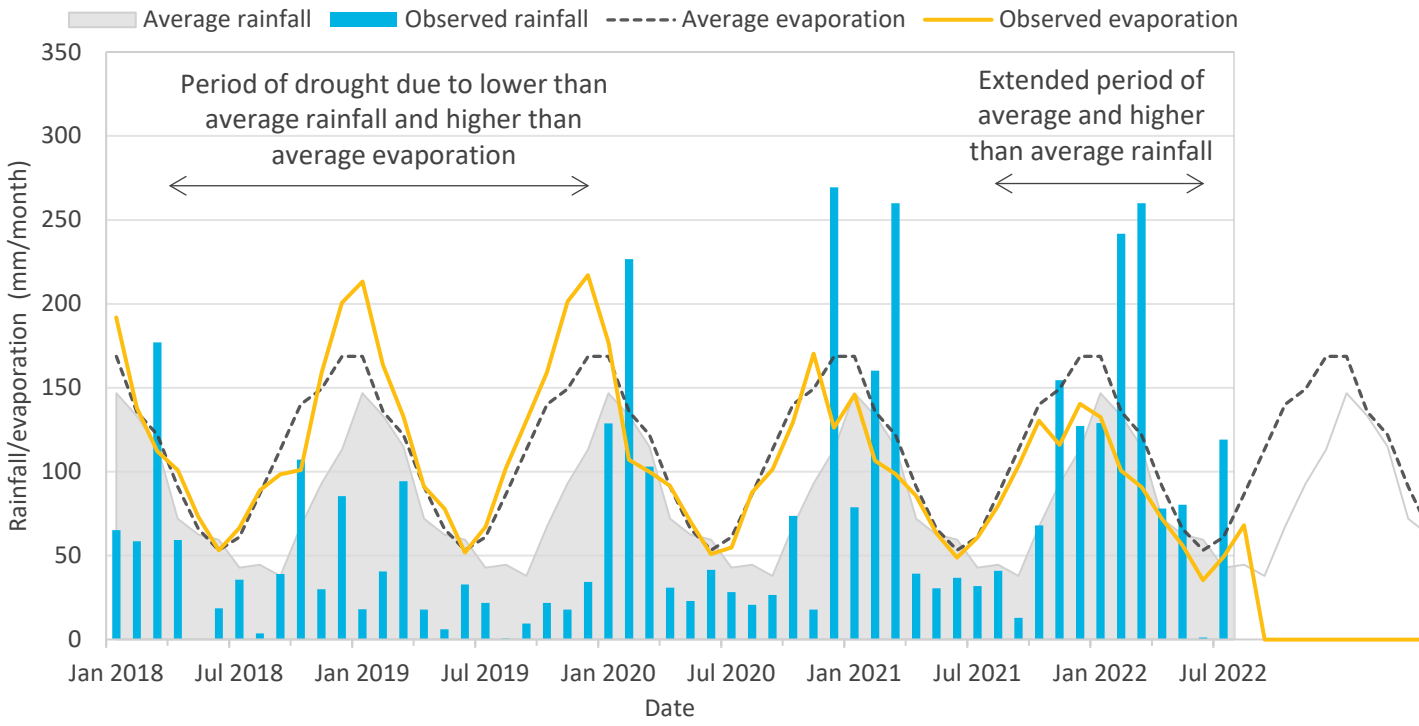


Figure 4.3 Recent weather conditions for the Project area

The rainfall and evaporation data shown in Figure 4.3 indicate:

- Below average rainfall and above average evaporation occurred through most of 2018 and 2019 resulting in some of the driest conditions observed in the Macleay River catchment historical record.
- Above average rainfall occurred in February and December 2020, and March 2021. Flooding was experienced in the downstream catchment near Kempsey in March 2021.
- An extended period of above average rainfall occurred from October 2021 to May 2022.

Data collected to inform the surface water assessment during 2021 and 2022 (refer to Section 4.6.1) was obtained during wetter than average conditions.

4.3 Watercourses

4.3.1 Local watercourses

i Physical setting

Numerous minor tributaries to the Macleay River traverse the Project area in proximity to the proposed works. Catchment characteristics across the Project area are generally uniform and are primarily comprised of steep bushland. Upland swamps are observed in the upper reaches of some watercourses while pockets of open grassland are observed at lower elevations. Elevations range from 120 m AHD at the Macleay River to 1,000 m AHD in the headwater catchments.

The Project dams and reservoirs will impound Fingerboard Crossing Creek, an intermittent third order tributary of the Macleay River. Fingerboard Crossing Creek has a catchment area of 3.3 square kilometres (km^2) and drains from the higher elevations of Carrai plateau in the eastern portion of the Project area to the Macleay River immediately west of the Project area. The Project is expected to impound approximately 94% (3.1 km^2) of the Fingerboard Crossing Creek catchment.

Peach Tree Creek is immediately south of the Fingerboard Crossing Creek catchment and forms the southern border of the Project area. Peach Tree Creek is a fourth order watercourse with an 8 km^2 contributing catchment. While the Project surface works are not anticipated to impact Peach Tree Creek, the proposed underground works have the potential to drawdown the watertable and indirectly impact the flow regime of the creek.

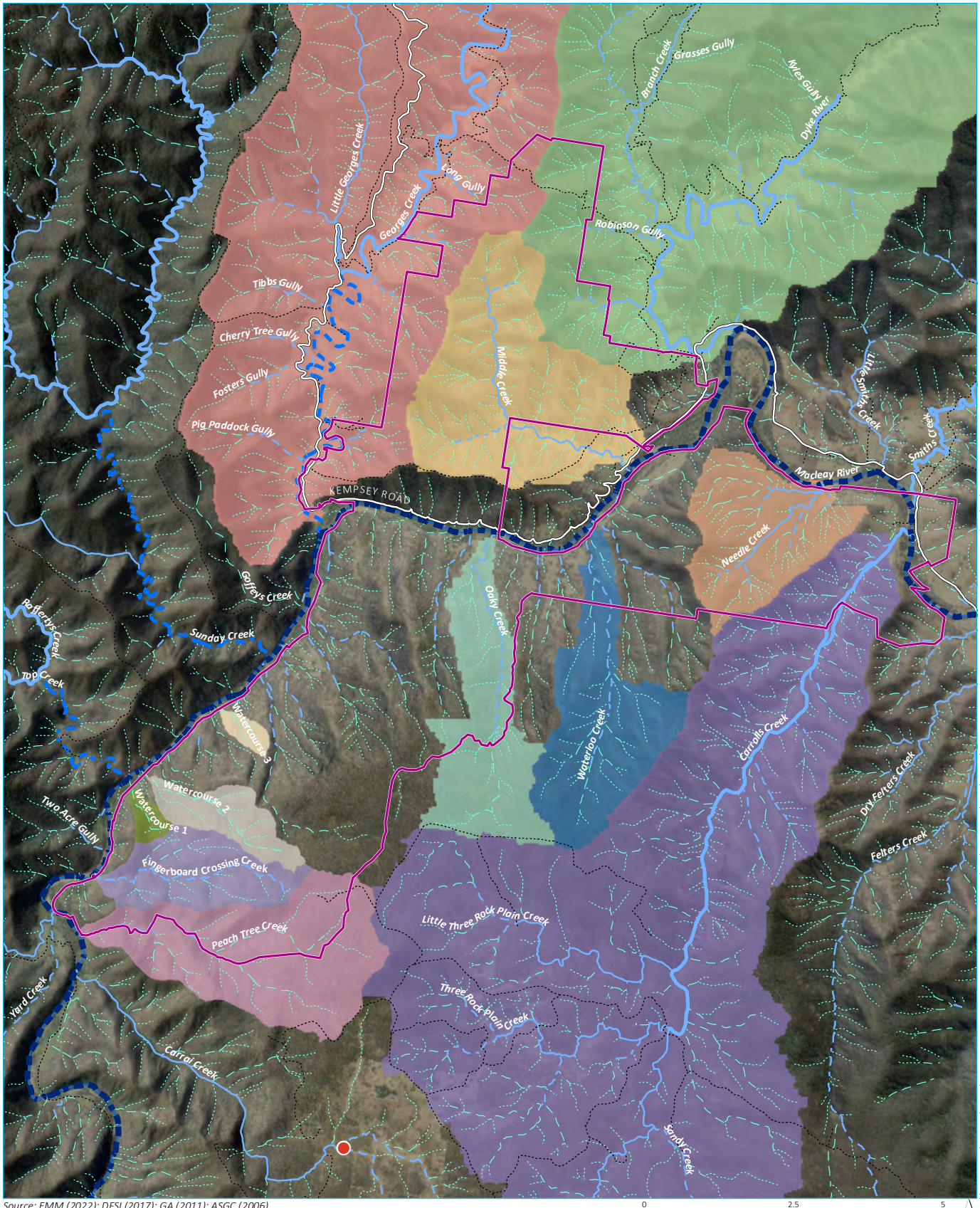
Several named watercourses (Oaky, Waterloo, Needle, and Carrolls creeks) will be traversed by the Eastern Access Road. The transmission line component crosses the Georges Creek, Middle Creek and Dyke River catchments. The remaining watercourses within the Project area are primarily unnamed first and second order streams.

The stream order, catchment area and flow regime of local watercourses are described in Table 4.2 and shown in Figure 4.4.

Table 4.2 Local watercourse characteristics

Relevant Project component	Watercourse	Stream order[1]	Catchment area	Flow regime[2]
PHGW	Watercourse 1	2nd order watercourse	0.4 km^2	Ephemeral
	Watercourse 2	2nd order watercourse	1.7 km^2	Ephemeral
	Watercourse 3	2nd order watercourse	0.3 km^2	Ephemeral
	Fingerboard Crossing Creek	3rd order watercourse	3.3 km^2	Intermittent
	Peach Tree Creek	4th order watercourse	8.0 km^2	Perennial
Eastern Access Road	Oaky Creek	3rd order watercourse	5.7 km^2	Intermittent
	Waterloo Creek	3rd order watercourse	6.4 km^2	Intermittent
	Needle Creek	5th order watercourse	5.2 km^2	Intermittent
	Carrolls Creek	5th order watercourse	75.0 km^2	Perennial
Transmission connection works	Georges Creek	6th order watercourse	149.9 km^2	Perennial
	Middle Creek	4th order watercourse	10.2 km^2	Perennial
	Dyke River	5th order watercourse	100.5 km^2	Perennial

Notes: 1. Stream order has been established using the Strahler system of ordering watercourses using information provided on a 1:25,000 topographic map.
2. Flow regimes have been estimated based on the NSW Spatial Services hydroline dataset (DCS, 2022) and site observations.



Source: EMM (2022); DFSI (2017); GA (2011); ASGC (2006)

0 2.5 5 km

GDA 1994 MGA Zone 56

N

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KEY

- Project area
- Carrai Waterholes (approximately)
- Road
- Track
- Macleay River

Project catchment
- Carrols Creek
- Dyke River
- Fingerboard Crossing Creek
- Georges Creek
- Middle Creek
- Needle Creek
- Oaky Creek
- Peach Tree Creek
- Watercourse 1
- Watercourse 2
- Watercourse 3
- Waterloo Creek

Strahler stream order
- 1st order
- 2nd order
- 3rd order
- 4th order
- 5th order
- 6th order
- 9th order

Local watercourses

Oven Mountain Pumped Hydro Energy Storage Project
Surface water assessment
OMPS Pty Ltd
Figure 4.4

EMM creating opportunities

ii Watercourse characterisation

Fingerboard Crossing Creek will be impounded by the Project dams and reservoirs. A geomorphology assessment (Gippel, 2022) was completed to characterise the existing condition of Fingerboard Crossing Creek and is provided in Attachment B.

Fingerboard Crossing Creek was characterised as moderately steep in the upper headwater reaches and very steep in the mid catchment reaches. The watercourse progressively declines in grade from the mid catchment to the outlet at the Macleay River. Bed material within Fingerboard Crossing Creek is primarily comprised of bedrock and boulders in the upper reaches and cobbles in the lower reaches of the creek.

Based on the observed bed material, channel morphology and vegetation, Fingerboard Crossing Creek was assessed to comprise of two River Styles:

- The upper creek from its headwaters down to the steep mid catchment reach was classified as confined valley setting headwater, good condition, low fragility, and conservation recovery potential.
- The lower creek, from the steep mid catchment reach to the junction at Macleay River, was classified as confined valley setting gorge, good condition, low fragility, and conservation recovery potential.

The entire Fingerboard Crossing Creek is classified as low fragility as it is formed within resistant bedrock rather than adjustable alluvium. An upstream and mid catchment reach of Fingerboard Crossing Creek are shown in Photograph 4.1 and Photograph 4.2, respectively.

Photograph 4.1 Fingerboard Crossing Creek upstream reach (looking upstream)

Photograph 4.2 Fingerboard Crossing Creek mid catchment reach (looking upstream)

4.3.2 Macleay River

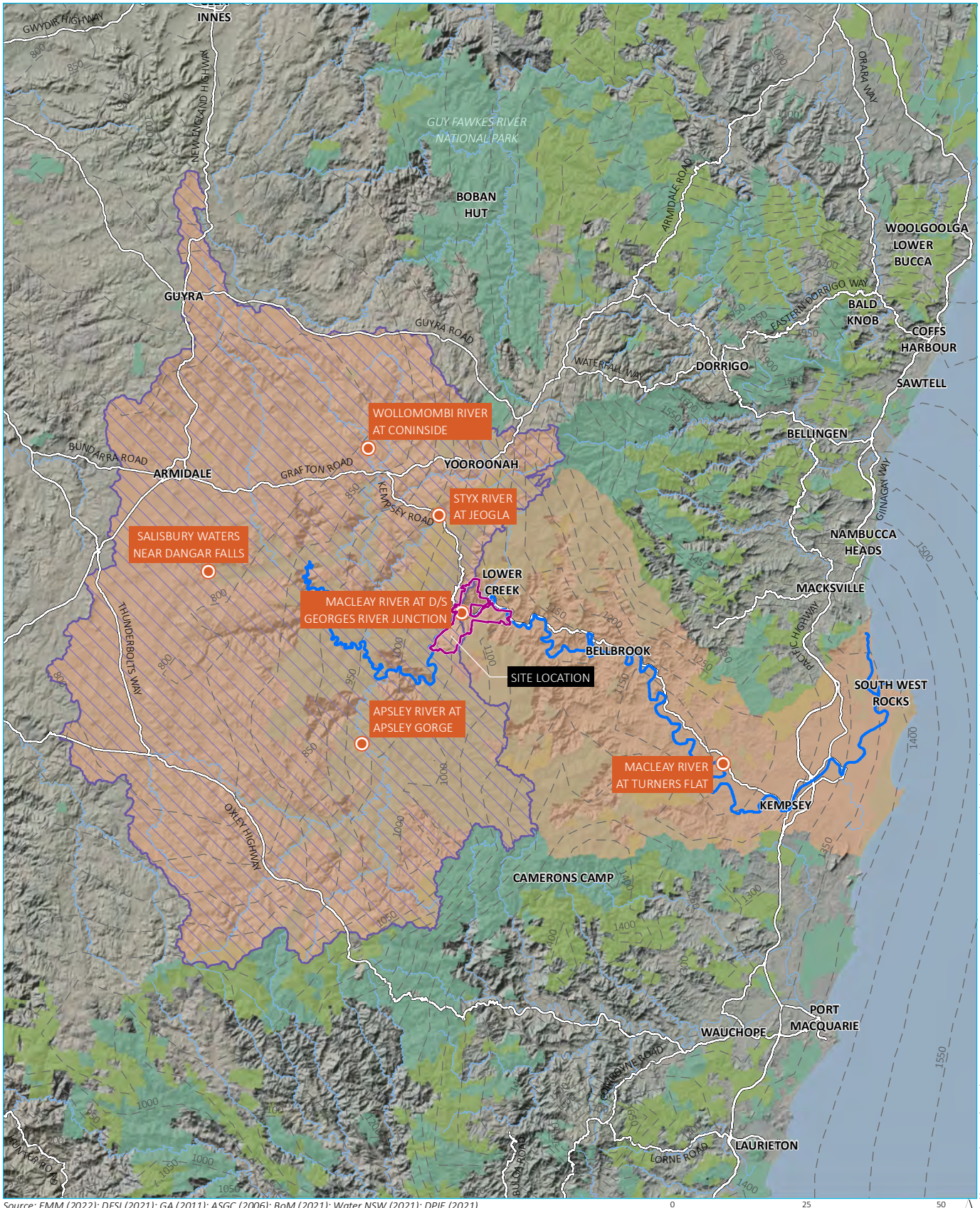
i Physical setting

The Macleay River is a perennial watercourse with a catchment area of approximately 11,400 km^2. The Macleay River catchment drains from the tablelands in the west to the Pacific Ocean in the east. The river rises at the edge of the tablelands where it descends through a series of steep gorges before emerging into an area characterised by lower elevation hills downstream of Georges Creek. The river then meanders for a further 140 km before reaching the tidal limit at Belgrave Falls, 10 km upstream of Kempsey (Ryder et al. 2016). The tidal portion of the Macleay River is characterised by coastal floodplains and coastal sandplains until it reaches the Pacific Ocean at South West Rocks.

Land use within the Macleay River catchment is diverse and includes fishing, cropping, grazing, mining, forestry, commercial, urban development, and national parks. The dominant land uses within the catchment are agricultural grazing (53%) and vegetated area (26%). Most of the vegetated area exists through the gorge and midland hill regions (Ryder et al. 2016).

The rivers and streams of the Macleay River catchment are largely unregulated, with only a small number of weirs, dams, and road crossings in the smaller head water tributaries (Bulter et al. 2016). However, several major dams are in operation for domestic water supply.

An overview of the Macleay River catchment, including annual average rainfall contours and the location of streamflow gauges described in Section 4.4, is shown in Figure 4.5.



Source: EMM (2022); DFSI (2021); GA (2011); ASGC (2006); BoM (2021); Water NSW (2021); DPIE (2021)

0 25 50 km

GDA 1994 MGA Zone 56

N

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KEY

- Project area
- Stream gauge
- Average annual rainfall contour
- Macleay River catchment
- Macleay River D/S Georges River Junction gauge contributing catchment

Existing environment

- Macleay River
- Rivers
- Major road
- NPWS reserve
- State forest
- Waterbody

Macleay River catchment overview

Oven Mountain Pumped Hydro Energy Storage Project
Surface water assessment
OMPS Pty Ltd
Figure 4.5

EMM creating opportunities

ii Watercourse characterisation

The Macleay River is characterised by a series of pool and riffle sections along the length of the Project boundary. The river channel typically varies from 20 m wide to more than 50 m wide. A substantial floodplain and associated alluvial material are present either side of the main channel.

The Macleay River in the vicinity of the Project area and for a distance 9.7 km downstream of the Fingerboard Crossing Creek junction, has been classified by the River Styles Spatial Layer for NSW (NOW, 2012) as partially confined valley setting bedrock-controlled gravel, good condition, moderate fragility, and conservation recovery potential. The classification of moderate fragility can be attributed to the corridor of adjustable alluvium in which the channel is formed (Gippel, 2022).

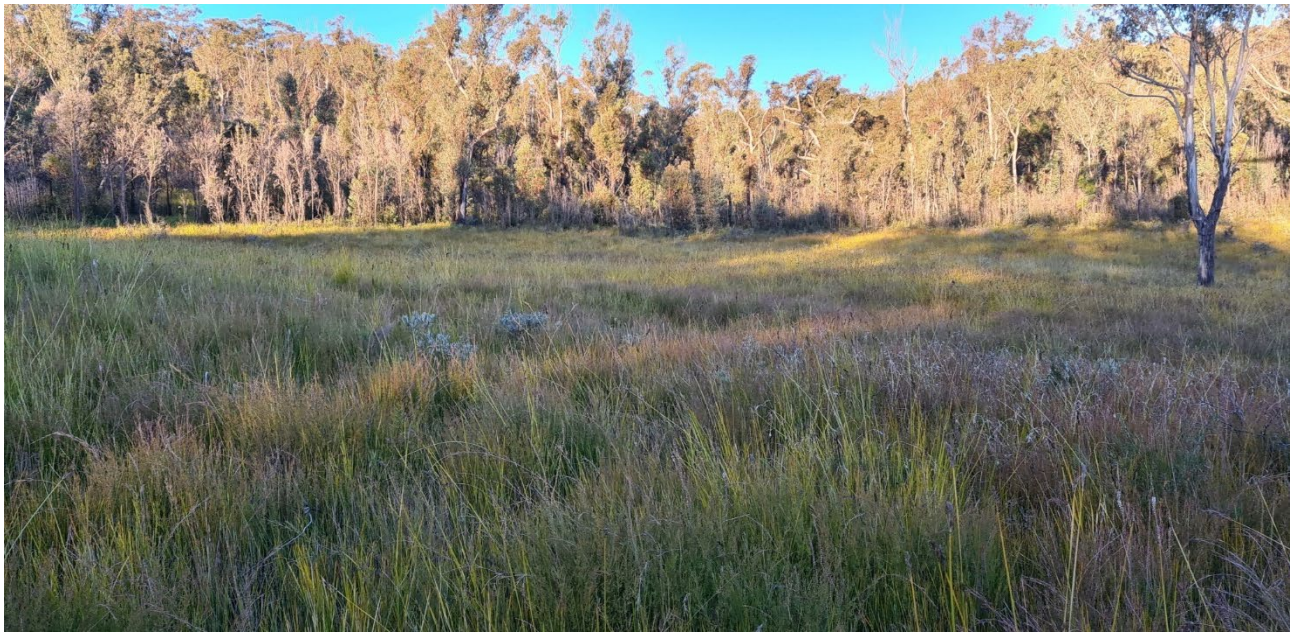
Typical sections of the Macleay River near the Project area are shown in Photograph 4.3 and Photograph 4.4.

Photograph 4.3 Macleay River looking downstream towards Fingerboard Crossing Creek confluence

Photograph 4.4 Macleay River looking upstream from near Georges Junction

4.3.3 Swamps and fens

Swamp areas (fens) occur in small, isolated pockets on the Carrai plateau. The fens are supported by the shallow groundwater system which recharges via direct rainfall. The shallow groundwater system discharges (via springs) into the fens for extended periods of time following rainfall and eventually supports the watercourses further downstream. The slow release of water (i.e. baseflow) from fens may be important in terms of sustaining semi-permanent to permanent aquatic ecological communities, as well as contributing baseflow to the Macleay River. A typical fen on the Carrai plateau is shown in Photograph 4.5.



Photograph 4.5 Carrai plateau fen (facing east)

4.4 Streamflow regime

This section characterises the streamflow regime of the Macleay River and Fingerboard Crossing Creek. The streamflow regime of other watercourses across the Project area has not been characterised due to a lack of available data. Furthermore, potential streamflow impacts are anticipated to be minimal for many of the watercourses and are therefore assessed qualitatively in this surface water assessment.

An emphasis is placed on characterising streamflow in the Macleay River due to the sensitivity of the receiving environment and significance of potential impacts associated with water extraction and discharges.

4.4.1 Fingerboard Crossing Creek

Fingerboard Crossing Creek is an ungauged watercourse and therefore does not have a historical streamflow record. The streamflow regime of Fingerboard Crossing Creek has been characterised using a catchment specific hydrologic model developed as part of the water balance described in Attachment D. The hydrologic model has also been used to assess streamflow impacts in Chapter 7.

The annual streamflow volume in Fingerboard Crossing Creek is highly variable and dependant on the prevailing climate conditions. For example, annual streamflow discharging to the Macleay River is predicted to range between 100 megalitres per year (ML/year) and 1,150 ML/year for the 10th and 90th percentile years, respectively. The median annual streamflow volume is estimated at 236 ML/year which represents approximately 0.03% of the median annual streamflow in the Macleay River (refer to Section 4.4.2i).

Flow duration curves provide a statistical representation of the frequency of various flow rates. The hydrologic model was used to develop a daily flow duration curve for Fingerboard Crossing Creek which is shown in Figure 4.6.

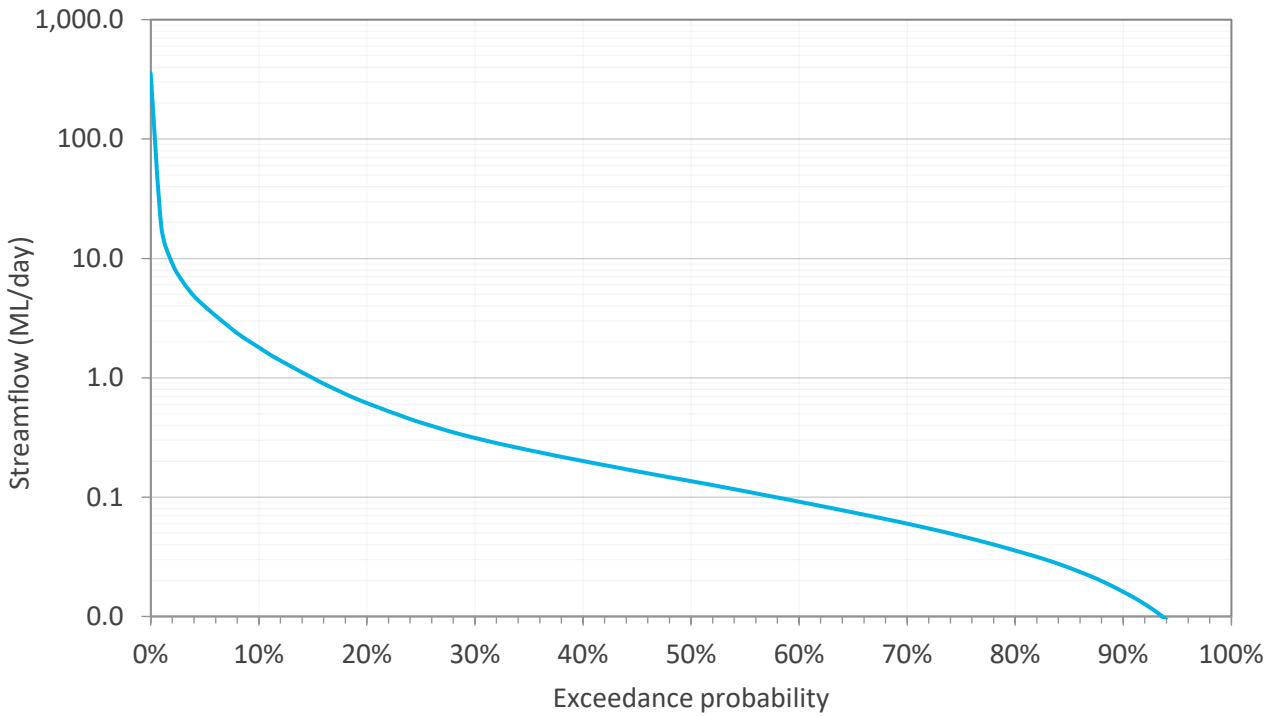


Figure 4.6 Modelled flow duration curve – Fingerboard Crossing Creek

Daily streamflow totals within Fingerboard Crossing Creek are shown to be relatively small with streamflow less than 1 megalitre per day (ML/day) occurring 85% of the time. Streamflow totals that are less than 0.1 ML/day (about 40% of the time) are interpreted to represent periods where flow is occurring within the interstitial space between the rocks and alluvium that form the creek bed and would not be visible as surface flow.

It should be noted the above flow duration curve has been developed using a hydrologic model and that the actual streamflow regime of Fingerboard Crossing Creek may be different. However, the modelled flow duration curve is considered adequate for the purpose of assessing streamflow impacts to Fingerboard Crossing Creek as a result of the Project.

4.4.2 Macleay River

Streamflow in the Macleay River catchment is recorded at several WaterNSW operated gauges. Most of these gauges are located on tributaries in the upper catchment (refer to Figure 4.5). The Macleay River downstream (D/S) Georges River Junction (station no. 206024) streamflow gauge, located within the Project area and approximately 8 km downstream of Fingerboard Crossing Creek (the watercourse impounded by the Project) is representative of streamflow conditions adjacent to the Project area. The Macleay River D/S Georges River Junction gauge is used to characterise streamflow in the Macleay River.

i Annual streamflow characteristics

Streamflow statistics for several key gauges in the Macleay River catchment are provided in Table 4.3. The statistics are presented as annualised totals that have been calculated from available gauge records. Years with more than 10% of the streamflow record missing have been excluded from the statistics in Table 4.3. The specific mean discharge and average annual runoff coefficient at each gauge was calculated using streamflow data post 1970 to align with the available streamflow record at Macleay River at D/S Georges River Junction gauge. The location of each streamflow gauge is shown in Figure 4.5.

Table 4.3 Annual streamflow statistics

	Styx River at Jeogla	Macleay River at Turners Flat	Wollomombi River at Coninside	Macleay River at D/S Georges River Junction	Salisbury Waters Near Dangar Falls	Apsley River at Apsley Gorge
Stream gauge information						
Station number	206001	206011	206014	206024	206025	206033
Record	1918 – present	1945 – present	1948 – present	1969 – present	1972 – present	1981 – present
Record available	99.5%	91.6%	98.6%	98.6%	98.6%	97.9%
Distance from Project area	22 km north (upstream)	56 km south-east (downstream)	38 km north-west (upstream)	8 km (downstream of PHGW)	47 km west (upstream)	26 km south-west (upstream)
Catchment area	163 km^2	9,980 km^2	376 km^2	7,930 km^2	594 km^2	2,406 km^2
Annual streamflow statistics (GL/year)[1]						
Average	106	1,355	35	953	24	223
Minimum	12	37	1	27[3]	0	31
10th percentile	39	335	5	241	0	45
25th percentile	53	528	9	304	2	68
Median	89	920	23	793	11	158
75th percentile	151	1,807	45	1,435	26	292
90th percentile	198	3,261	84	2,103	85	482
Maximum	294	3,736	242	3,062	134	946
General streamflow statistics – post 1970						
Specific mean discharge[2] (ML/year/km^2)	581	142	79	120	41	93
Average annual runoff coefficient[4]	53%	13%	9%	13%	5%	11%

Notes:
1. Years where more than 10% of days are missing streamflow data have been excluded from the annualised statistics.
2. Specific mean discharge calculated as the average annual streamflow post 1970 divided by the stream gauge catchment area.
3. Minimum value occurred in 2019 where approximately 11% of streamflow record is missing due to low flows not registering at the gauge.
4. Average annual runoff coefficient calculated as average annual streamflow post 1970 divided by the average annual rainfall total for the contributing catchment. Average annual rainfall was estimated from the rainfall contours in Figure 4.5.

The specific mean discharge statistics presented in Table 4.3 indicate the volume of streamflow generated per square kilometre of catchment generally increases from west to east in line with the rainfall gradient described in Section 4.2. The Styx River at Jeogla gauge is shown to have a specific mean discharge of 581 megalitres per year per square kilometre (ML/year/km^2), which is substantially larger than the other gauges presented in Table 4.3. Historical records from several discontinued BoM operated rainfall gauges (57016, 57017) in the upper Styx River catchment suggest annual rainfall totals may be up to twice that of surrounding rainfall gauges to the west and south. Higher annual rainfall totals in the upper catchment may be a contributing factor to the increased specific mean discharge experienced at the Styx River at Jeogla gauge. The elevated (compared to surrounding gauges) rainfall totals and specific mean discharge appear to be localised to the headwaters of the Styx River, Georges River and Five Day Creek catchments. There is also a possibility the gauging and ratings data for the Styx River at Jeogla gauge are inaccurate and therefore measuring higher streamflow totals than observed.

The percentage of rainfall that converts to streamflow is similar across the mid to lower catchment with both Macleay River gauges having an average annual runoff coefficient of 13%. Average annual runoff coefficients are lower in the upper catchment indicating less rainfall converts to streamflow on the tablelands compared to the gorges area and lower catchment. As with specific mean discharge, the Styx River at Jeogla gauge runoff coefficient is substantially larger than the other gauges.

The Macleay River at D/S Georges River Junction stream gauge has been in operation since 1969 and is the primary gauge used to describe streamflow characteristics of the Macleay River adjacent to the Project area. Streamflow at the Macleay River at D/S Georges River Junction gauge typically ranges between 241 gigalitres per year (GL/year) (10th percentile) and 2,103 GL/year (90th percentile). The median annual streamflow volume at the gauge is 793 GL/year. A time series of historical streamflow at the Macleay River at D/S Georges River Junction gauge is shown in Figure 4.7.

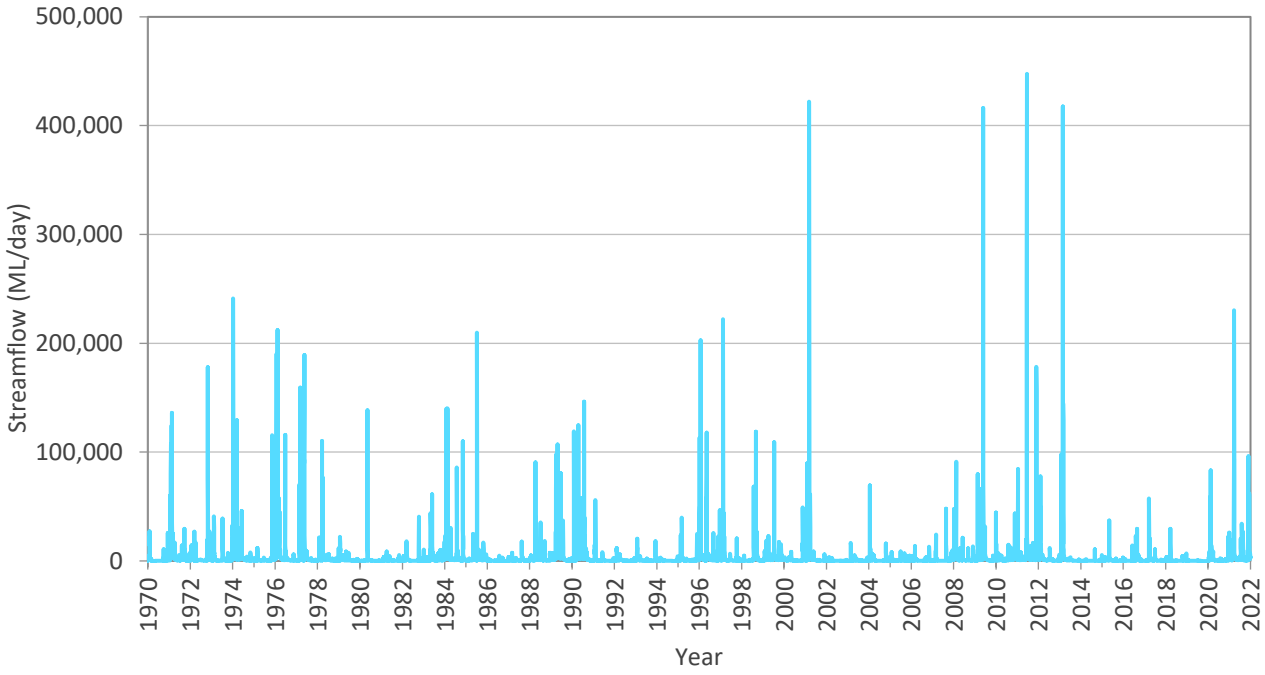


Figure 4.7 Historical streamflow record – Macleay River at D/S Georges River Junction

Annual streamflow trends at the at Macleay River at D/S Georges River Junction gauge since 1970 are presented in Figure 4.8. Historical flood and low rainfall years, along with documented periods of drought in NSW (BoM, 2022a), are also identified on Figure 4.8. Flood years are defined as years when the major flood level of 10 m (BoM, 2022b) was exceeded at least once at the Macleay River at D/S Georges River Junction gauge. Low rainfall years have been characterised as years with 'very much below average' rainfall on the east coast of NSW as defined by the BoM rainfall deciles map (BoM, 2022c).

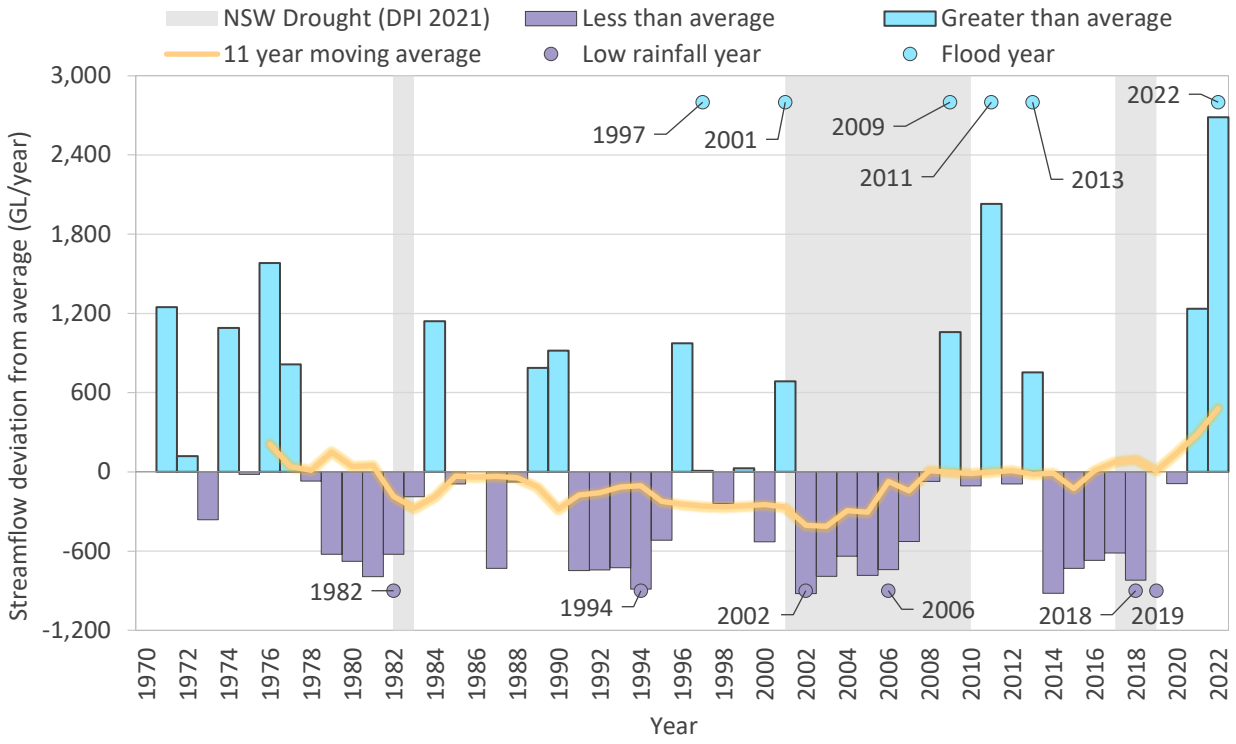


Figure 4.8 Annual streamflow trends – Macleay River at D/S Georges River Junction

The Macleay River has experienced periods of both lower and higher than average streamflow. Higher than average streamflow is shown to have occurred through most of the 1970s, between 2008–2013 and during 2021 and 2022. It should be noted the streamflow total for 2022 is presented from January to November and does not include the full year record. Regardless, 2022 is shown to have the highest streamflow total on record.

Flood years are shown to coincide with higher than average streamflow years. Lower than average streamflow occurred between 1979–1983, 1991–1995, 2002–2007, and 2014–2019. Lower than average streamflow occurs due to both very low rainfall years and extended (multiple years) periods of low to average rainfall.

Data collected to inform the surface water assessment during 2021 and 2022 (refer to Section 4.6.1) was obtained during higher than average streamflow conditions.

ii Seasonal and monthly streamflow characteristics

Flow duration curves were developed for the Macleay River at D/S Georges River Junction gauge based on the historical record. Flow duration curves were developed on a seasonal (summer, autumn, winter, spring) as well as annual basis and are presented in Figure 4.9.

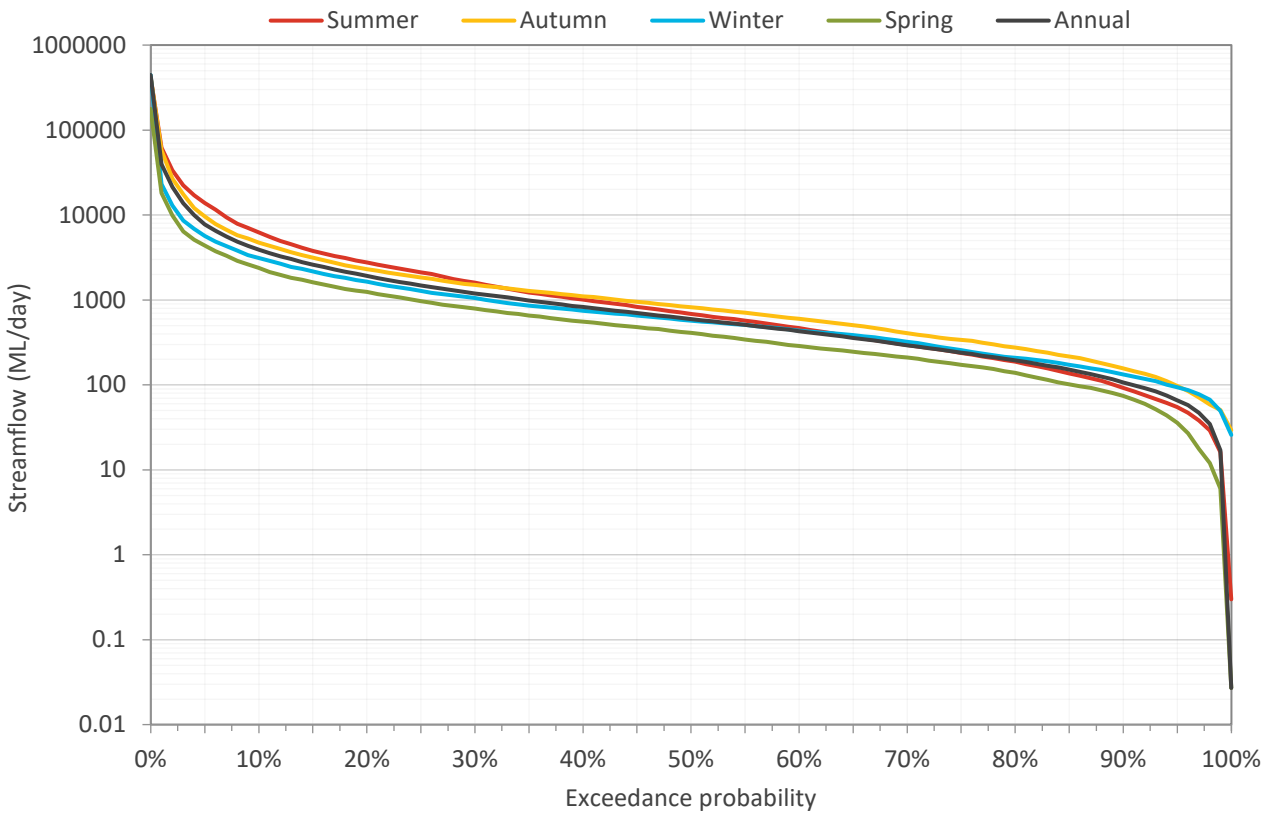


Figure 4.9 Seasonal flow duration curve – Macleay River at D/S Georges River Junction

The seasonal flow duration curves presented in Figure 4.9 indicate:

- The lowest streamflow occurs during spring when monthly rainfall totals are lower, and evaporation is shown to exceed rainfall by the largest margin (refer to Figure 4.2). These factors result in reduced streamflow as:
  - there is less rainfall which can produce runoff and eventually streamflow
  - higher evaporation rates increase losses to catchment runoff prior to streamflow occurring
  - higher evaporation rates increase transmission losses within watercourses due to increased evaporation rates from the water surface and increased evapotranspiration rates from vegetation within the watercourse, and at the edge of watercourse banks.
- During winter, elevated streamflow (between 0% and 50% exceedance probability) values are lower than during summer, autumn and on an annual basis. Streamflow during winter is shown to exceed summer and annual values at the lower end of the flow duration curve. Higher low flows during winter may be a result of lower runoff and transmission losses due to reduced evaporation rates, particularly on the tablelands where average monthly rainfall is expected to exceed average monthly evaporation during winter.
- The highest streamflow totals (between 0% and 25% exceedance probability) occur in summer as a result of elevated rainfall and the occurrence of flood producing runoff events. Streamflow totals during summer decrease to below autumn and winter values at the lower end of the flow duration curve. This is likely due to increased evaporation losses to catchment runoff and streamflow transmission (as described above) during years that experience low seasonal rainfall during summer.

- Autumn produces higher streamflow at the lower end of the flow duration curve (between 50% and 100% exceedance probability) compared to the other seasons. This is likely due to the occurrence of higher rainfall totals (particularly in March) compared to winter and spring and lower potential for system losses as evaporation rates are similar to rainfall.

- Streamflow is generally observed 100% of the time, indicating a perennial flow regime and constant baseflow contributions. Higher low flow values during autumn and winter suggest baseflow contributions are greater during these seasons.

Monthly streamflow statistics for the Macleay River at D/S Georges River Junction gauge between 1969 and 2021 are presented in Figure 4.10. The minimum values presented in Figure 4.10 represent the minimum recorded values excluding cease to flow conditions. Cease to flow conditions are described in Section 4.4.2iv.

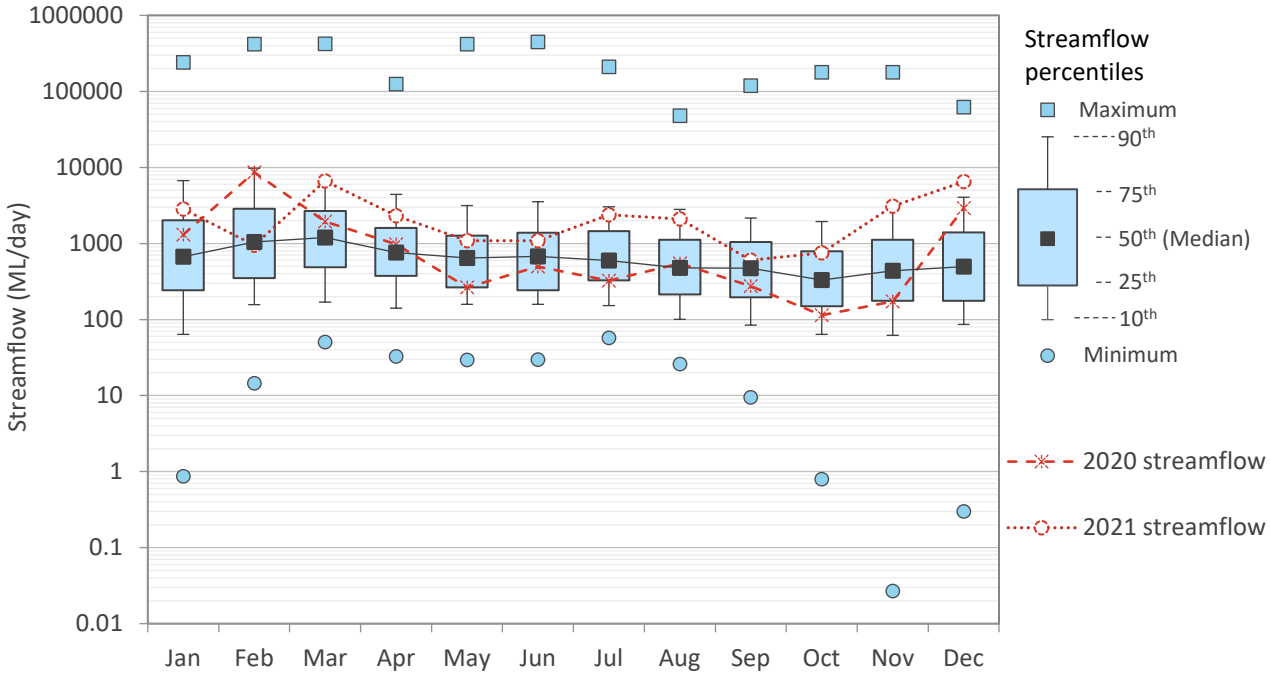


Figure 4.10 Monthly streamflow statistics – Macleay River at D/S Georges River Junction

The streamflow statistics presented in Figure 4.10 are in agreement with the seasonal flow duration curves provided in Figure 4.9, with larger daily streamflow totals occurring in summer and autumn compared to winter and spring. The maximum daily streamflow totals indicate significant streamflow may occur at any time of the year. However, the largest streamflow rates have historically occurred in summer, autumn, and early winter. Minimum daily streamflow totals are shown to be greater from March to August (autumn and spring) compared to September to February (spring and summer).

The greatest daily streamflow totals typically occur between January and March with median daily streamflow ranging from 671 ML/day in January to 1,193 ML/day in March. Streamflow during March is almost twice the annual median daily streamflow of 597 ML/day. On average, 40% of annual streamflow occurs in the three months from January to March. However, the January to March contribution to annual streamflow is highly variable and ranges from as little as 4% of annual streamflow up to 91% of annual streamflow depending on annual rainfall distribution.

The lowest daily streamflow totals typically occur in October which has a median streamflow of 332 ML/day. This is approximately 44% less than the annual median daily streamflow of 597 ML/day.

iii Baseflow contributions

Baseflow contributions at the Macleay River at D/S Georges River Junction gauge were estimated using the Lyne and Hollick digital filtering methodology. The baseflow analysis was undertaken using five passes of the digital filter for a range of recession constants (k) over the 1970 to 2021 period. The resulting annual baseflow index estimates are presented in Table 4.4.

Table 4.4 Lyne and Hollick baseflow separation – Macleay River at D/S Georges River Junction

Recession constant k	Annual baseflow index
0.90	22%
0.92	**20%**
0.95	17%

Notes: **Bold** denotes the adopted baseflow index.

The Macleay River at D/S Georges River Junction baseflow index is shown to range between 17% and 22% for a recession constant range of 0.90 to 0.95. The best fit k value of 0.92 results in a baseflow index of 20%. The estimated baseflow contribution to the Macleay River at D/S Georges River Junction gauge for the June 2020 to June 2021 period is shown in Figure 4.11. This period of the streamflow record was chosen as it includes both periods of relatively dry weather (August to November 2020) and a major runoff event (March 2021).

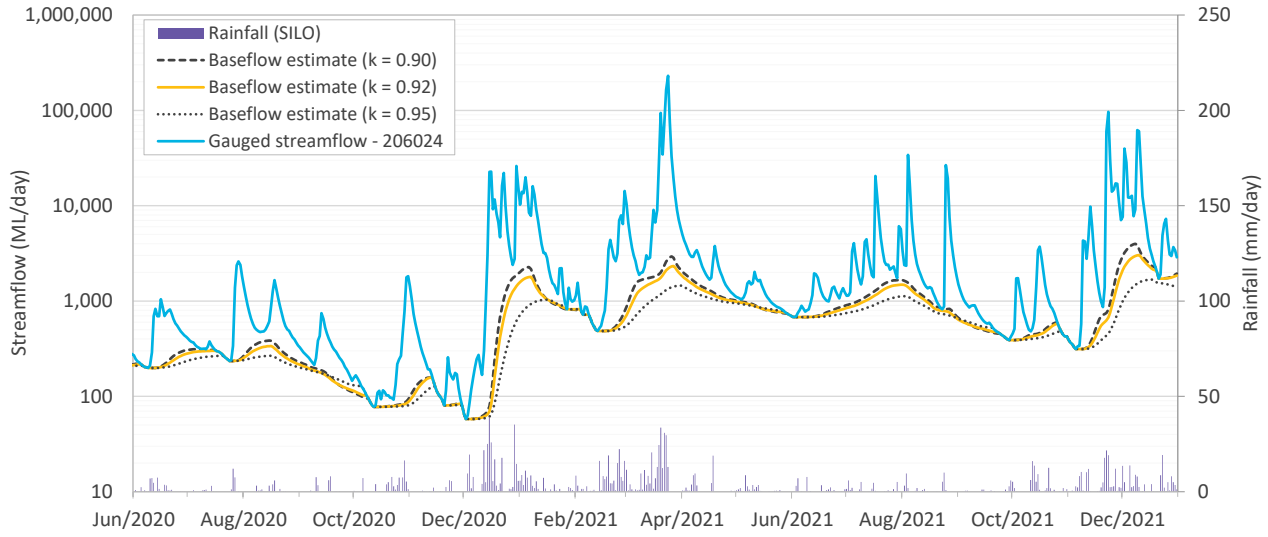


Figure 4.11 Baseflow separation – Macleay River at D/S Georges River Junction

Figure 4.11 shows streamflow within the Macleay River catchment generally rises steeply following a rainfall event. Runoff contributions from the upper catchment (i.e. tablelands), and the spatial and temporal variation of rainfall across the catchment, can result in streamflow continuing to rise for several days following a rainfall event. The falling limb of the streamflow hydrograph recedes more gradually due to the slower release of water from the catchment via interflow and other slow-release processes. The slower runoff response from the upper catchment means it can take several days to weeks for streamflow to return to a predominantly baseflow fed regime following rainfall events.

The adopted recession constant of 0.92 provides a reasonable estimate of baseflow contributions with the baseflow hydrograph generally re-joining the streamflow hydrograph after quickflow contributions have passed (i.e. when baseflow provides the primary contribution to streamflow). Baseflow peaks are also shown to experience a delay compared to streamflow peaks associated with quickflow processes.

iv Low flow and drought conditions

The Macleay WSP defines very low flow conditions at the Macleay River at D/S Georges River Junction gauge as occurring when streamflow at the gauge recedes to 13 ML/day. The Macleay WSP notes 13 ML/day corresponds to a flow rate at the gauge that is estimated to be exceeded 97% of the time during the month of November (the critical month). The flow duration curves presented in Figure 4.9 indicate a streamflow of 13 ML/day or less occurs less than 1% of the time over the historical record.

The Macleay River at D/S Georges River Junction gauge has recorded very low flow (less than 13 ML/day) conditions on a total of 181 days over the historical record. Periods of very low flow are identified from the historical streamflow record in Figure 4.12. Low rainfall years (refer to Figure 4.8) are also identified in Figure 4.12.

Very low flow conditions are shown in Figure 4.12 to have occurred over the following general periods:

1. October 1980 – January 1981
2. October – November 1994
3. November 2002 – January 2003
4. September 2019 – January 2020.

Cease to flow conditions (water level at gauge less than 0.27 m) also occurred for 39 days during the September 2019 – January 2020 very low flow period.

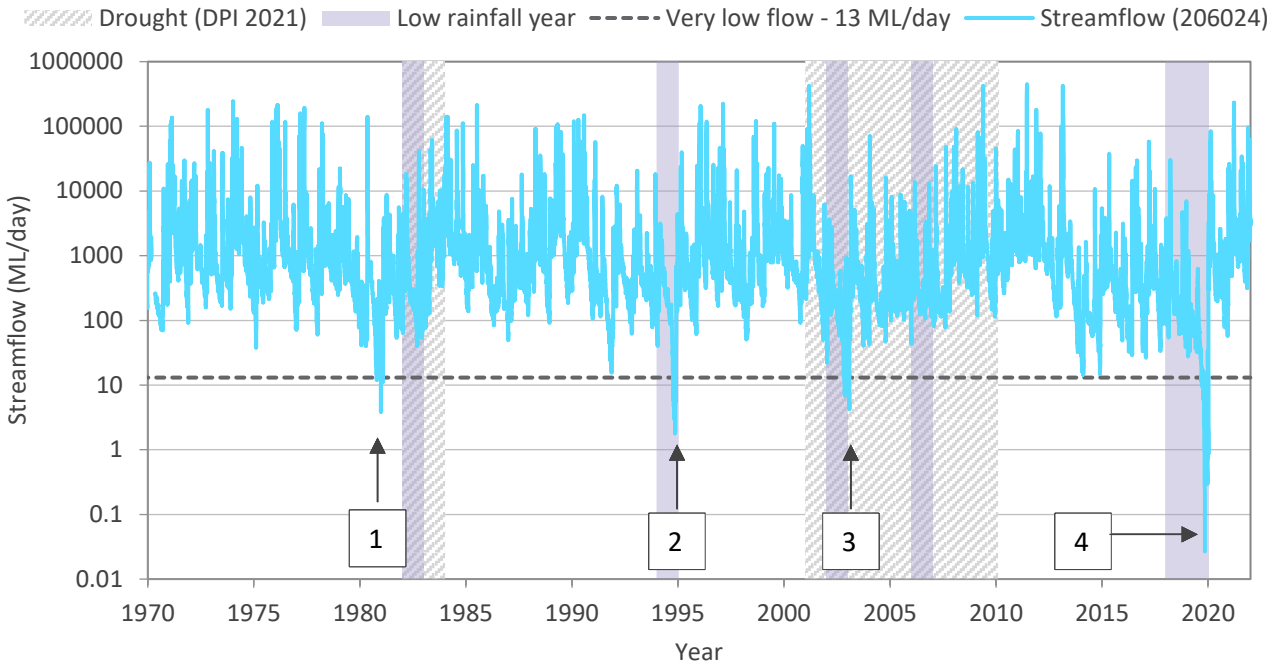


Figure 4.12 Very low flow conditions – Macleay River at D/S Georges River Junction

The streamflow time series in Figure 4.12 shows very low streamflow conditions generally occur during or relatively shortly after low rainfall years (period 2, 3 and 4). Longer-term (multiple years) drying conditions (as indicated by downward trending streamflow) are observed to precede all four occurrences of very low flow conditions at the Macleay River at D/S Georges River gauge, indicating antecedent dry conditions may be a more significant contributing factor to very low streamflow conditions than low rainfall years in isolation.

A low flow frequency analysis was undertaken to further characterise low flow conditions at the Macleay River at D/S Georges River Junction gauge. The frequency analysis involved calculating the minimum cumulative streamflow volume over a 7, 14, 30 and 90-day period from 52 years (1970–2021) of historical streamflow data. The minimum volume from each year was then ranked from smallest to largest to obtain the average recurrence interval (ARI) of a particular low flow magnitude occurring. Periods with missing data or cease to flow conditions were excluded from the low flow frequency analysis. The frequency and magnitude of low flows at the Macleay River at D/S Georges River Junction gauge is presented in Figure 4.13.

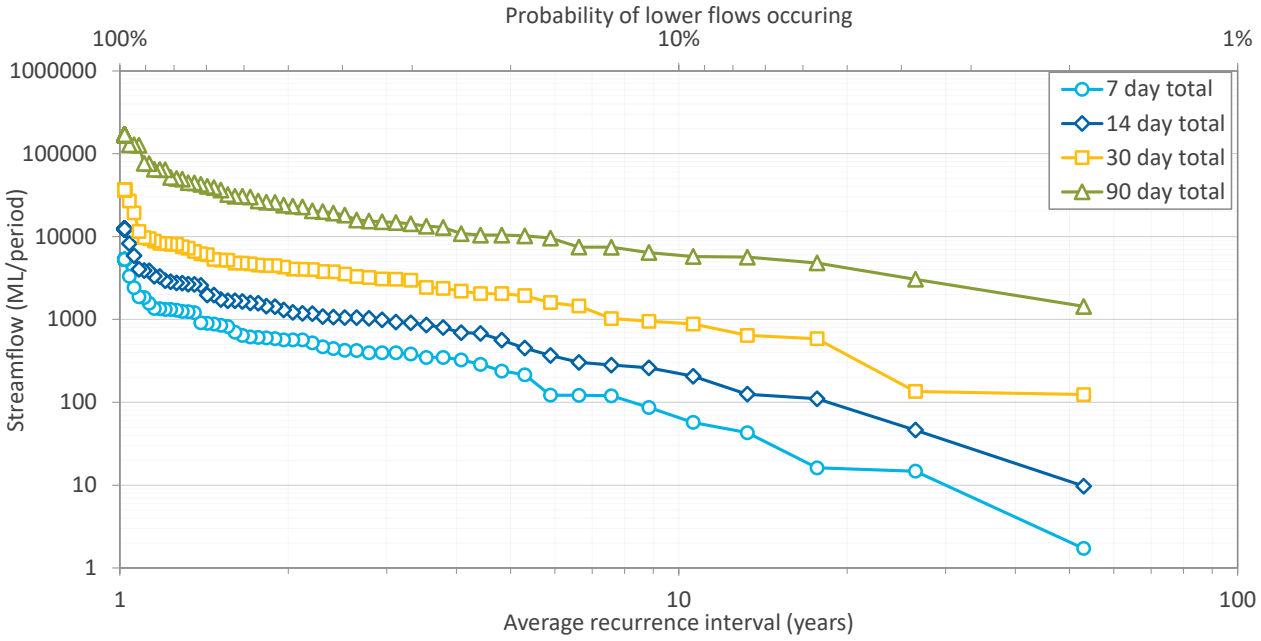


Figure 4.13 Low flow frequency analysis – Macleay River at D/S Georges River Junction

The low flow frequency curves presented in Figure 4.13 are solely based on the historical streamflow record values and have not been extrapolated to account for the possibility that observed events within the 52 year record are of a rarer nature than a 1 in 52-year recurrence. Streamflow totals for a 2, 5 and 10 year ARI low flow event are summarised in Table 4.5.

Table 4.5 Summary of low flow frequency analysis

	Streamflow (ML/period)		
Low flow period	**2 year ARI**	**5 year ARI**	**10 year ARI**
7 day	566	215	57
14 day	1,213	451	206
30 day	4,044	1,936	880
90 day	23,237	10,228	5,751

4.5 Existing surface water users

The Macleay WSP outlines water access rights at the time of plan commencement (refer to Attachment A). Trading of water entitlements has likely occurred since the commencement of the Macleay WSP. A search of the NSW Water Register (WaterNSW, 2021a) indicates currently (2021/2022 water year):

- One WAL is listed for the Macleay Gorges Water Source – a unregulated river licence with a two-unit share component (i.e. 2 ML). There has been no recorded use of the entitlement on the NSW Water Register since it was first listed in the 2016/2017 water year, although given its size, metering of extraction is not currently mandatory.

- 79 WALs are listed for the Macleay Valley Water Source comprising:

    - five aquifer category WALs with a total of 281 unit shares

    - five domestic and stock category WALs with a total of 8 ML/year

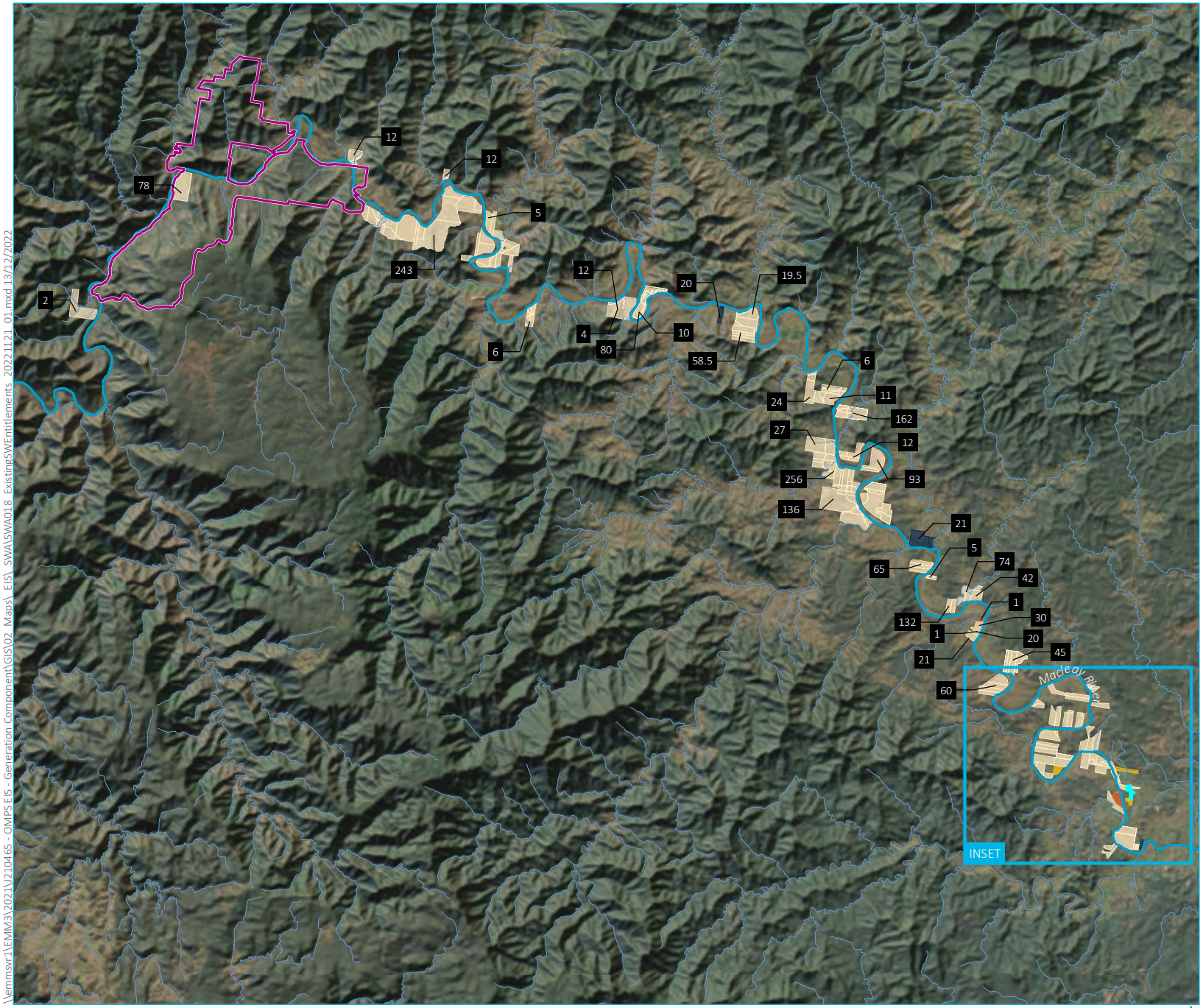
    - two local water utility groundwater category WALs with a total of 10,100 ML/year

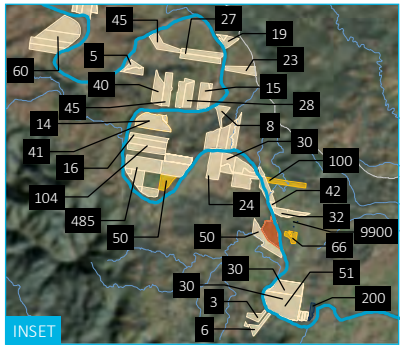
    - two local water utility unregulated category WALs with a total of 41 ML/year

    - 65 unregulated river category WALs with a total of 3,379 unit shares.

Of the 13,809 ML made available to users of the Macleay Valley Water Source, approximately 17% (2,351 ML) was recorded to have been used in the 2020/2021 water year. Noting that 10,141 ML is allocated for town water of which 2,313 ML (23%) was used (i.e. 23% usage of town water) and 3,668 ML is tradeable water, of which 38 ML (2%) was used. It should be noted the above usage numbers are based on recorded values. At this stage, metering for most take in this water source is not mandatory, so the reported use is likely to be an understatement of actual use.

The spatial distribution of existing water entitlements in the Macleay Gorges and Macleay Valley water sources is shown in Figure 4.14.





KEY

- Project area
- Macleay River
- Named watercourse

Water access licence category (labelled by volume ML/year)

- Aquifer
- Domestic And Stock
- Domestic And Stock[Domestic]
- Local Water Utility
- Unregulated River

Source: EMM (2022); DFSI (2020); ESRI (2022); GA (2011)

0 5 10 km

GDA 1994 MGA Zone 56

N

\\emmsvr1\EMM3\2021\210465 - OMPS EIS - Generation Component\GIS\02 Maps\ EIS\ SWA\SWA018 ExistingSWEntitlements 20221121 01.mxd 13/12/2022

Existing surface water entitlements – Macleay Gorges and Macleay Valley water sources

Oven Mountain Pumped Hydro
Energy Storage Project
Surface water assessment
OMPS Pty Ltd
Figure 4.14

EMM
creating opportunities

4.6 Surface water quality

4.6.1 Water quality monitoring

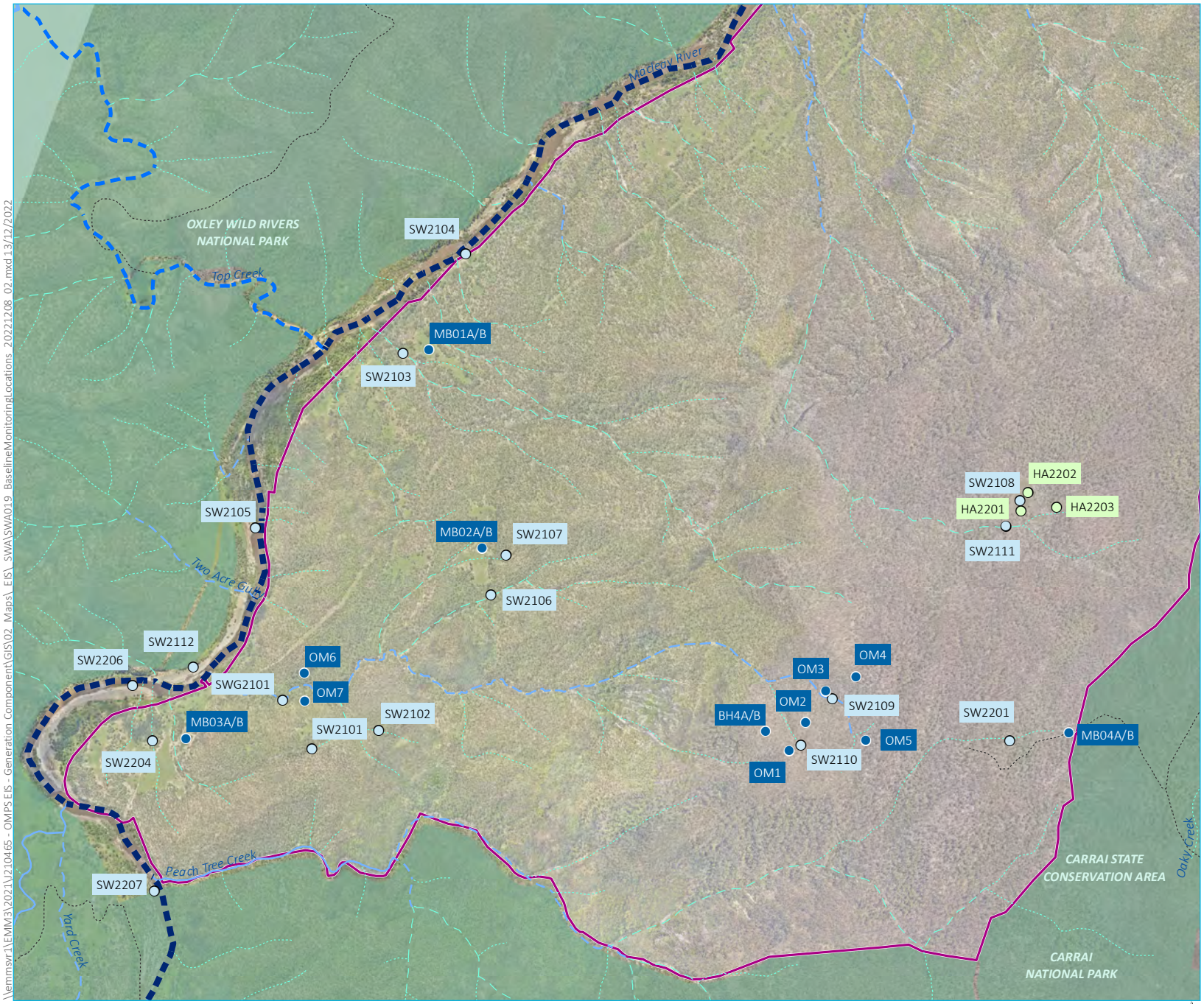
No historical water quality data is available for Fingerboard Crossing Creek and other local watercourses that may be impacted by Project activities. Historical data is available for the Macleay River and is primarily in the form of technical studies and investigations. A baseline monitoring program was conducted to:

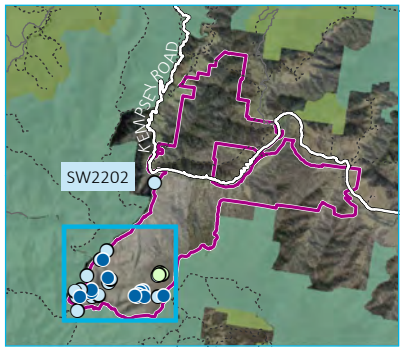
- inform a characterisation of minor watercourse quality across the Project area
- confirm the Macleay River water quality adjacent to the Project area is consistent with historical studies and investigations.

The baseline monitoring program for the Project commenced in August 2021 and is ongoing. The data collection program includes surface water and groundwater monitoring as well as several field surveys. Surface water data collected up to the beginning of August 2022 (i.e. 12 months of data) is documented in Attachment C.

Groundwater data that was collected as part of the baseline monitoring program is described in Appendix M of the EIS (EMM, 2022a).

Surface water quality data was collected from the Macleay River, Fingerboard Crossing Creek, and several minor watercourses within the Project area. Surface water monitoring locations are shown alongside the groundwater monitoring network in Figure 4.15.





KEY

- Project area
- Major road
- Vehicular track
- NPWS reserve
- Fen monitoring bore
- Groundwater bore
- Surface water site

Strahler stream order

- 1st order
- 2nd order
- 3rd order
- 4th order
- 5th order
- 6th order
- 9th order

Source: EMM (2022); OMPS (2020); BoM (2017); DFSI (2017); GA (2011)

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Baseline monitoring program locations

Oven Mountain Pumped Hydro
Energy Storage Project
Surface water assessment
Figure 4.15

EMM creating opportunities

4.6.2 Water quality objectives

i Macleay River catchment environmental values

The *NSW Water Quality Objectives* (DECCW, 2006) provide WQOs for catchments throughout NSW. The WQOs for a water resource are dependent on the community and environmental values of that resource. The environmental values of a water system are related to its use, from both a human and environmental perspective.

Activities associated with the Project have the potential to impact the water quality of the Macleay River as well as several named and unnamed tributaries that traverse the Project area. Watercourses in proximity to the Project area, including the Macleay River, are classified as "uncontrolled streams". The environmental values and associated WQOs for uncontrolled streams within the Macleay River catchment are summarised in Table 4.6.

Table 4.6 Application of NSW water quality objectives

Environmental value	Objective	Application to the Project
Aquatic ecosystems	Maintaining or improving the ecological condition of water bodies and their riparian zones over the long term.	The Macleay River adjacent to and downstream of the Project area supports a wide range of aquatic ecosystems. Some minor watercourses adjacent to and downstream of the Project area may support aquatic ecosystems.
Visual amenity	Aesthetic qualities of waters.	Several viewpoints and waterfront properties exist which overlook the Macleay River.
Secondary contact recreation	Maintaining or improving water quality for activities such as boating and wading, where there is a low probability of water being swallowed.	The Macleay River adjacent to and downstream of the Project area supports secondary recreational activities.
Primary contact recreation	Maintaining or improving water quality for activities such as swimming in which there is a high probability of water being swallowed.	The Macleay River adjacent to and downstream of the Project area supports primary recreational activities.
Livestock water supply	Protecting water quality to maximise the production of healthy livestock.	Downstream users extract water from the Macleay River for livestock watering. Livestock may also drink directly from some minor watercourses within the Project area and the Macleay River.
Irrigation water supply	Protecting the quality of waters applied to crops and pasture.	Downstream users extract water from the Macleay River for irrigation purposes.
Homestead water supply	Protecting water quality for domestic use in homesteads, including drinking, cooking and bathing.	Downstream users may extract water from the Macleay River for domestic purposes.
Drinking water	Refers to the quality of drinking water drawn from the raw surface and groundwater sources before any treatment	Downstream users extract water from the Macleay River unregulated river and groundwater sources for town water supply.
Aquatic foods (cooked)	Refers to protecting water quality so that it is suitable for the production of aquatic foods for human consumption and aquaculture activities.	Aquatic foods (e.g. fish) are caught and consumed from the Macleay River adjacent to and downstream of the Project area.

ii Default guideline values

The DGVs applicable to each environmental value are provided in the *NSW Water Quality Objectives* (DECCW 2006). The DGVs vary depending on the environmental value, with the trigger values for the protection of aquatic ecosystems generally being the lowest. The level of protection applied to aquatic ecosystems is dependent on the current conditions of the water resource. The Macleay River is considered a slightly to moderately disturbed watercourse due to catchment land use practices including urban development, agriculture, and mining. Many of the minor watercourses within the Project area are also considered slightly to moderately disturbed due to historical vegetation clearing and livestock grazing.

The *NSW Water Quality Objectives* provide DGVs for physical and chemical stressors and reference ANZECC (2000) for toxicant DGVs. The ANZECC (2000) toxicant DGVs have since been replaced by ANZG (2018) (refer to Section 3.4.1). Hence, the ANZG (2018) DGVs for slightly to moderately disturbed ecosystems are used in this assessment for toxicants and are supplemented by the ADWG values where relevant. DGVs for physical and chemical stressors provided by the *NSW Water Quality Objectives* and ANZECC (2000) have been applied in this assessment as these parameters have not yet been updated by ANZG (2018).

The DGVs for each environmental value applicable to the Project are provided in Table 4.7. Where more than one DGV is available for a particular parameter, the most stringent value from all environmental values has been applied as the WQO value in the remainder of this surface water assessment. It should be noted the WQO values do not make allowance for site specific factors that may influence water quality. Site-specific guideline values may be developed during later stages of the Project (when more baseline data is available).

Table 4.7 Water quality objectives – default guideline values

Indicator	Units	Aquatic ecosystem[1]	Visual amenity	Secondary contact	Primary contact	Livestock water supply	Irrigation water supply	Aquatic foods (cooked)	ADWG (health)	ADWG (aesthetic)
Physico-chemical										
pH	-	**6.5–8.5**	-	-	5.0–9.0	-	6.5–8.5	-	-	6.5–8.5
Temperature	°C	-	-	-	15–35	-	-	**<2 °C change over one hour**	-	-
Dissolved oxygen	%	**85–110**	-	-	-	-	-	-	-	>85
Electrical conductivity	µS/cm	**200–300[2]**	-	-	-	3,582[3]	<950[4]	.	<896[3]	-
Turbidity	NTU	50	-	-	6	-	-	-	-	**5**
Nutrients										
Oxidised nitrogen	µg/L	**40**	-	-	-	-	-	-	-	-
Ammonia	µg/L	**20**	-	-	-	-	-	-	-	500
Total nitrogen	µg/L	**350**	-	-	-	-	25,000–125,000	-	-	-
Reactive phosphorus	µg/L	**20**	-	-	-	-	-	-	-	-
Total phosphorus	µg/L	**25**	-	-	-	-	800–12,000	-	-	-
Chemical contaminants/toxicants										
Aluminium	µg/L	**55**	-	As per ADWG aesthetic	As per ADWG health	5,000	5,000	-	-	200
Arsenic	µg/L	13[5]	-			500	100	-	**10**	-
Antimony	µg/L	9[6]	-			-	-	-	**3**	-
Cadmium	µg/L	**0.2**	-			10	10	-	2	-

Table 4.7 Water quality objectives – default guideline values

Indicator	Units	Aquatic ecosystem[1]	Visual amenity	Secondary contact	Primary contact	Livestock water supply	Irrigation water supply	Aquatic foods (cooked)	ADWG (health)	ADWG (aesthetic)
Chromium	µg/L	**1.0**[7]	-			1,000	100	-	50	-
Copper	µg/L	**1.4**	-			1,000	200	5	2,000	1,000
Iron	µg/L	-	-			2,000	**200**	-	-	300
Lead	µg/L	**3.4**	-			100	2,000	-	10	-
Manganese	µg/L	1900	-			-	200	-	500	**100**
Mercury	µg/L	**0.06**	-			2	2	1	1	-
Nickel	µg/L	**11**	-			1,000	200	-	20	-
Zinc	µg/L	8	-			20,000	2,000	**5**	-	3,000
Other chemical contaminants/toxicants	-	As per ANZG (2018)	-			As per Table 4.3.2 ANZECC	As per Table 4.2.10 ANZECC	-	As per ADWG (2011)	As per ADWG (2011)
Biological										
Chlorophyll-a	µg/L	**5**	-	-	-	-	-	-	-	-
Algae & blue-green algae	Cells/mL	-	-	<15,000	<15,000	<11,500	Not visible	-	**<2,000**	-
Faecal coliforms	Col./100 mL	-	-	<1,000	<150	<100	**<10**	2.3 MPN/g	**0**	**0**
Enterococci	Ent. /100 mL	-	-	<230	**<35**	-	-	-	-	-

Notes:
1. Contaminant/toxicant DGVs for slightly to moderately disturbed ecosystems as per ANZG (2018). All other indicators for lowland (less than 150 m AHD) rivers as per DECCW (2006).
2. Values typical of NSW low land rivers as described in Table 3.3.3 of ANZECC (2000).
3. Derived from a total dissolved solids concentration by using the following equation electrical conductivity x 0.67 = total dissolved solids (ANZEC 2000).
4. For sensitive crops as defined in Table 4.2.4 of ANZECC (2000).
5. As for Arsenic (V).
6. Unknown reliability value.
7. As for Chromium (VI).

Bold denotes adopted WQO.

4.6.3 Local watercourse water quality

Historical water quality data is not available for local watercourses within the Project area. To characterise local watercourse water quality, EMM collected and analysed water samples from Fingerboard Crossing Creek and several other minor watercourses over a period of 12 months (refer to Section 4.6.1).

The monitoring program did not cover every watercourse within the Project area. However, the watercourses that were sampled are considered representative of water quality across the broader Project area. It is important to note the limitations of short-term (12 months) monitoring data in characterising water quality, which can be highly variable under normal conditions. Local watercourse water quality is characterised as:

- Water temperature varies seasonally with colder temperatures in winter and warmer temperatures in summer. Water temperature was observed to range from 6.1 degrees Celsius (°C) to 25.2 °C during the monitoring period.

- Electrical conductivity was below the WQO value of 300 microsiemens per centimetre (µS/cm) at all sampling locations except for two sites on a minor tributary to Fingerboard Crossing Creek, which may reflect the groundwater system that feeds this watercourse during low flow periods.

- pH is neutral to slightly acidic with lower (more acidic) pH values generally occurring in the upper reaches of watercourses. pH was outside the WQO range (6.5–8.5) in 15 of 24 minor watercourse samples and 6 of 28 samples on Fingerboard Crossing Creek.

- Turbidity concentrations exceed the WQO value of 5 nephelometric turbidity units (NTU) in approximately half the local watercourse samples. Turbidity concentrations are still considered to be relatively low in these watercourses with most results being below the DGV for aquatic ecosystem protection (50 NTU). Higher turbidity was generally observed in smaller watercourses that received runoff from historically disturbed areas.

- Nitrogen and phosphorus concentrations exceeded the WQO values in approximately 50% of the minor watercourse samples and 25% of the Fingerboard Crossing Creek samples. Higher nutrient concentrations were typically observed in the upper catchment, within or downstream of the fen described in Section 4.3.3.

- All dissolved metals concentrations were below WQO values except for:

    - aluminium and iron concentrations exceeded WQO values in approximately 50% of samples and were typically higher in the upper reaches of watercourses

    - copper concentrations exceeded the WQO values in four out of 51 samples

    - antimony and zinc concentrations exceeded the WQO values in one out of 51 samples each.

- Hydrocarbons were generally below detection limits in all samples except for one sample on a tributary to Fingerboard Crossing Creek and one sample within the Carrai plateau fen identified in Section 4.3.3. It is not clear whether the hydrocarbon detects are naturally occurring or anthropogenic (due to contamination of sampling equipment).

Results for water quality parameters that frequently exceeded the WQO values are presented as box and whisker plots in Figure 4.16, where the WQO range is represented by a grey band. Water quality statistics are presented for both local watercourses (minor watercourses and Fingerboard Crossing Creek) and the Macleay River.

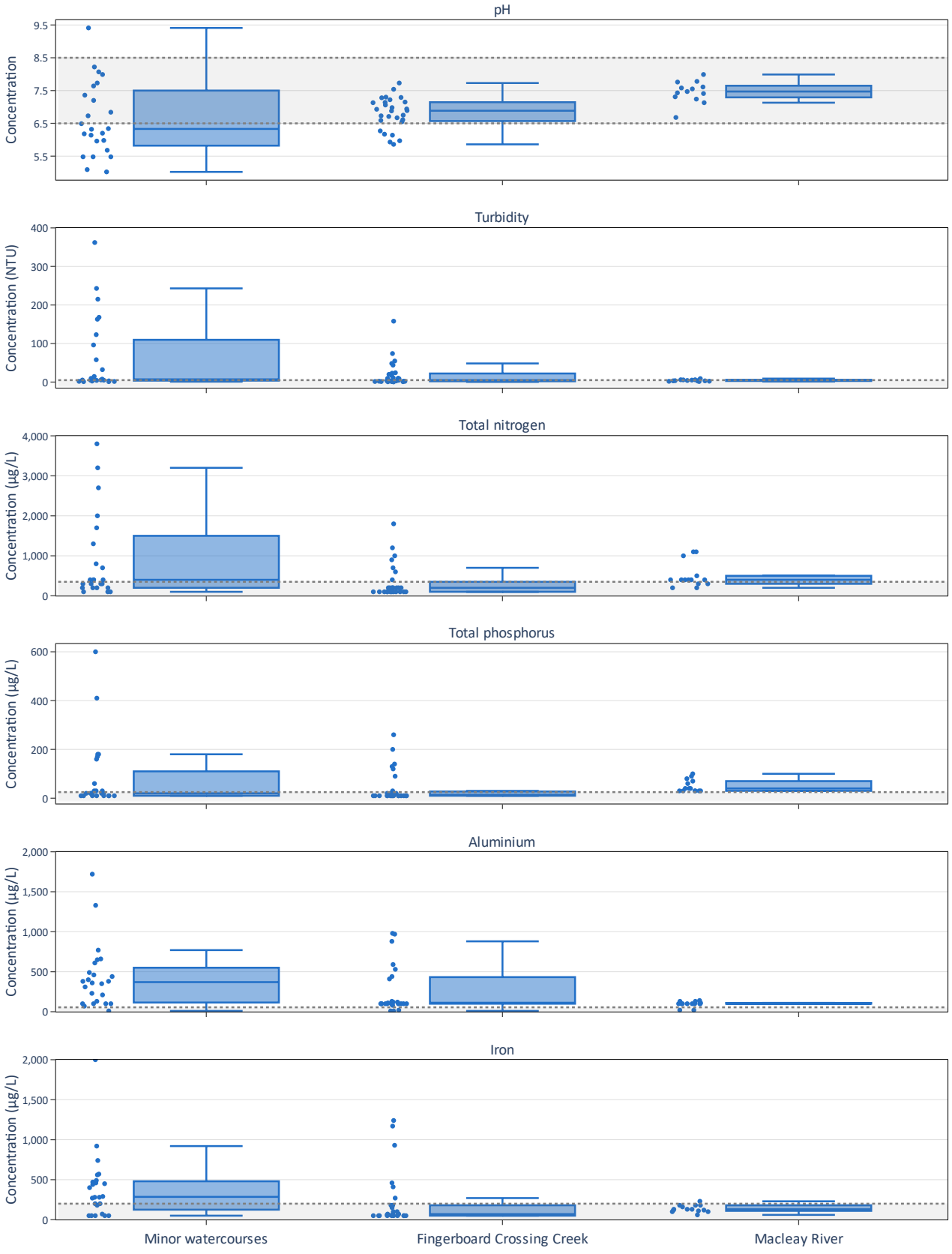


Figure 4.16 Surface water quality box and whisker plots

While antimony and arsenic were detected within local watercourses, concentrations were generally low and below the WQO value. It should be noted most antimony results were subject to laboratory detection limits (10 micrograms per litre (µg/L)) greater than the WQO value of 3 µg/L. The actual concentration of these samples is unknown. Hence, it is possible a larger number of antimony results exceeded the WQO values than represented in the water quality data described above. However, the antimony results that used a lower detection limit generally had concentrations of less than 1 µg/L, indicating that antimony concentrations within local watercourses are generally in line with background concentrations (Ashley, Graham, Tighe, & Wolfenden, 2007) and are not subject to the contamination issues experienced elsewhere in the Macleay River catchment. Arsenic and antimony contamination within the Macleay River catchment is discussed further in Section 4.6.4iii.

4.6.4 Macleay River water quality

i Overview

Water quality across the Macleay River catchment varies both spatially and temporally. Lower water quality is generally observed in the tableland tributaries, driven by low dissolved oxygen, elevated pH, and high nutrient concentrations (Ryder, Mika, Vincent, Burns, & Schmidt, 2016). The main channel of the Macleay River typically displays better water quality than the tablelands and adjoining tributaries. However, nutrient concentrations are still observed to frequently exceed WQOs.

Historical mining practices within the catchment have resulted in elevated metals concentrations occurring in the sediment and water column of serval major tributaries to the Macleay River, along with the Macleay River main channel and downstream floodplain (GHD, 2016; Ashley, Graham, Tighe, & Wolfenden, 2007; Johnston, et al., 2020).

This section characterises water quality in the Macleay River in the context of the WQOs defined in Section 4.6.2. The characterisation is based on the water quality data obtained for the Project and described in Attachment C, as well as historical water quality information gathered and presented by others (Ryder, Mika, Vincent, Burns, & Schmidt, 2016; Johnston & Maher, Drought, megafires and flood - climate extreme impacts on catchment-scale river water quality on Australia's east coast, 2022; Ashley, Graham, Tighe, & Wolfenden, 2007; GHD, 2016).

ii Water quality characterisation

The water quality of the Macleay River is characterised as:

- Water temperature varies seasonally with colder temperatures in winter and warmer temperatures in summer. Water temperature adjacent to the Project area has historically ranged between 14 °C and 29 °C (Ryder, Mika, Vincent, Burns, & Schmidt, 2016).

- Electrical conductivity typically ranges between 100–200 µS/cm in response to changes in streamflow. Higher electrical conductivity concentrations are typically experienced with decreasing streamflow rates (Johnston & Maher, Drought, megafires and flood - climate extreme impacts on catchment-scale river water quality on Australia's east coast, 2022). Regardless, electrical conductivity is generally below the WQO value of 300 µS/cm.

- pH is neutral to slightly alkaline and occasionally exceeds the upper bound WQO value of 8.5 (Ryder, Mika, Vincent, Burns, & Schmidt, 2016). Sampling completed by EMM suggest pH is primarily neutral with no upper or lower bound exceedances observed.

- Turbidity increases moving downstream (Ryder, Mika, Vincent, Burns, & Schmidt, 2016) and occasionally exceeds the WQO of 5 NTU. Turbidity concentrations are still considered to be relatively low in the Macleay River with all results being below the DGV for aquatic ecosystem protection (50 NTU).

- Dissolved oxygen generally falls between the WQO range of 85–110% and is observed to improve moving downstream along the Macleay River (Ryder, Mika, Vincent, Burns, & Schmidt, 2016).
- Total nitrogen, total phosphorus, and oxidised nitrogen exceed the WQO values in almost all EMM samples and most of the samples reported in Ryder et al. (2016). The elevated nutrient concentrations may be attributed to widespread agricultural practices across the tableland portion of the Macleay River catchment (Johnston, et al., 2020).
- The characterisation of metals within the Macleay River has historically been focused on known arsenic and antimony contamination which is discussed further in Section 4.6.4iii. The EMM monitoring program at or near the Project area indicated all dissolved metals concentrations were below WQO values except for:
    - aluminium and antimony which each exceeded the WQO values in four of 14 samples
    - copper which exceeded the WQO values in two of 14 samples
    - zinc which exceeded the WQO values in one of 14 samples
- Hydrocarbon concentrations were below detection limits in all Macleay River samples.

When compared to the local watercourses across the Project area, the Macleay River generally has more neutral pH, lower turbidity, and lower dissolved metals concentrations. Nutrient concentrations are also generally lower but are more likely to exceed WQO values. Macleay River water quality is compared against local watercourse water quality and the WQOs for several key parameters in Figure 4.16.

iii Antimony and arsenic contamination

The Macleay River catchment contains many areas with naturally occurring elevated concentrations of metals including gold, arsenic, and antimony (GHD, 2016). The presence of these metals has resulted in a long (more than 140 years) mining history within the catchment. Because of the long mining history, large volumes of mine waste and tailings have been produced. Historical (pre-1970) waste disposal practices have led to most of this material being dumped or washed into adjoining watercourses and ultimately the Macleay River (Ashley, Graham, Tighe, & Wolfenden, 2007; GHD, 2016).

The historical disposal of mine waste has resulted in high levels of antimony and arsenic contamination of stream sediments adjacent to and downstream of legacy mining areas. The transport of this material during flood events has resulted in antimony and arsenic rich sediments being dispersed along the full length of the Macleay River, hundreds of kilometres downstream of the original source. The concentration of antimony and arsenic within the Macleay River sediments decreases moving downstream, away from the contamination source (Ashley, Graham, Tighe, & Wolfenden, 2007).

As streamflow passes through and over the contaminated sediment, antimony and arsenic enter the water column via adsorption to suspended solids or dissolution. The transfer of contaminants from bed sediment to the water column is understood to be the primary mechanism leading to elevated antimony and arsenic concentrations within watercourses of the Macleay River catchment (Ashley, Graham, Tighe, & Wolfenden, 2007; GHD, 2016).

Seepage from mine openings, tailings dams, and mine-waste dumps also provide a source of dissolved antimony and arsenic into watercourses. Although the seeps are observed to have high concentrations (2–3 orders of magnitude above WQOs) of these metals, the overall discharge volumes are relatively low and hence are understood to only contribute a small amount of the overall antimony and arsenic load within the catchment (Ashley, Graham, Tighe, & Wolfenden, 2007).

The largest source of Antimony and arsenic contamination is attributed to mining within the Bakers Creek catchment, approximately 50 km upstream of the Project area. Antimony and arsenic contamination have also been attributed to mining within the Chandler River, Commissioners Waters and Aspley River catchments, as well as from non-mining catchments that have naturally elevated antimony and arsenic levels (GHD, 2016).

Antimony and arsenic concentrations in Bakers Creek have historically been 1–2 orders of magnitude greater than the WQOs (Ashley, Graham, Tighe, & Wolfenden, 2007; GHD, 2016). Concentrations rapidly decrease moving downstream with significant dilution occurring at the Macleay River junction (Ashley, Graham, Tighe, & Wolfenden, 2007; Johnston, et al., 2020). However, both antimony and arsenic concentrations remain elevated compared to background and WQO values for at least another 80 km downstream of the Macleay River/Bakers Creek confluence (Ashley, Graham, Tighe, & Wolfenden, 2007). Antimony is observed to be more mobile in the Macleay River system than arsenic (Johnston, et al., 2020) and hence elevated concentrations of antimony generally extend further downstream. This is in line with the Project monitoring results (refer to Section 4.6.4ii) which were sampled approximately 80 km downstream of the Macleay River/Bakers Creek confluence and recorded occasional exceedances of the WQO for antimony but no exceedances for arsenic.

Contaminated sediments within Bakers Creek and other impacted watercourses are anticipated to provide a continuous source of antimony and arsenic into the Macleay River system for many (100–1,000s) years to come (Ashley, Graham, Tighe, & Wolfenden, 2007).

iv Influence of catchment bushfires

The Macleay River catchment, including most of the Project area, experienced widespread bushfires in late 2019 followed by substantial rainfall and moderate flooding in early 2020. Bushfires can alter hydrologic flow paths and increase the rate of erosion and sediment transport from the landscape. When rainfall occurs on a bushfire impacted area, there is an increased risk of the resulting runoff mobilising nutrients, major ions, carbon, suspended sediments, and trace metals into receiving watercourses. At a catchment scale, the water quality response following bushfires is extremely variable and dynamic over time (Johnston & Maher, Drought, megafires and flood - climate extreme impacts on catchment-scale river water quality on Australia's east coast, 2022).

The impact of the 2019 bushfires on the water quality of the Macleay River was assessed by Johnston and Maher (2022). The following impacts to Macleay River water quality were observed:

- Sulphate, calcium, magnesium, potassium, dissolved organic carbon, total suspended solids, nitrogen, and phosphorus concentrations were significantly greater during the initial post-fire streamflow events compared to pre-fire conditions.
- The largest spike in concentration was experienced by phosphorus and nitrogen which had post-fire median concentrations that were 22 and 21 times greater respectively than pre-fire median concentrations.
- Concentrations of the above parameters were generally elevated compared to background values during the first 12 months following the fires with most of the load occurring during the first two months.
- Water quality returned to background values within 3–14 months post-fire, suggesting the acute impacts were relatively short lived. The return to background values likely reflects catchment properties that change over time following a fire including soil erodibility, vegetation ground cover, and the rapid depletion of fine, easily transportable sediments.

The results of Johnston and Maher (2022) indicate the greatest water quality impacts occurred immediately post-fire with the tested water quality parameters having since returned to background levels. Field surveys conducted in July 2022 indicated most of the vegetation ground cover within the Project area has since been re-established. Regardless, residual burnt soil and ash material may still be present within the Project area and will need to be considered when undertaking initial ground clearing activities.

4.7 Environmental receptors

Water is an essential component of the environment, supporting survival of terrestrial flora and fauna and providing habitat for aquatic species. Natural flows in rivers and creeks are managed to maintain a component of 'environmental water' reserved for the maintenance of aquatic values. A range of environmental receptors exist within and adjacent to the Project area including aquatic flora and fauna, groundwater dependent ecosystems (GDEs), and World Heritage listed rainforest.

The Macleay River and its tributaries are mapped as 'key fish habitat' upstream, adjacent to, and downstream of the Project area (DPI, Fisheries Spatial Data Portal, 2022) and are understood to support a wide range of aquatic species including Australian Bass, Long Fined Eel, Freshwater Mullet, and several species of gudgeon (Butler, et al., 2016). GDEs across the Project area include select riparian vegetation located on the Macleay River floodplain and the sedges and rushes associated with the fens on the Carrai plateau (refer to Section 4.3.3).

The Gondwana Rainforests of Australia (GRA) World Heritage Site is to the south and west of the Project area. The GRA is separated from the Project area by the Macleay River to the west and Peach Tree Creek to the south. The Macleay River is not included in the GRA World Heritage Site where it borders the Project area.

Further details on the aquatic species and GDEs found in vicinity of the Project area are provided in Appendix I of the EIS (Stantec, 2022) and Appendix M of the EIS (EMM, 2022a). The GRA World Heritage Site is described in Appendix U of the EIS (EMM, 2022f).

4.8 Water relevant cultural areas

Based on a search of the NSW state heritage inventory (DPE, 2022b), the 'Carrai Waterholes' were identified as a declared area of cultural significance, with a potential for groundwater interaction. The Carrai Waterholes are approximately 4.5 km south-east of the Project area and are shown in Figure 4.4.

4.9 Surface water-groundwater connectivity

Groundwater across the Project area generally flows from the higher elevations of the Carrai plateau to the lower elevations of the Macleay River. The Macleay River is understood to recharge the adjoining alluvial and fractured rock groundwater systems during periods of high streamflow. The groundwater system releases water back into the Macleay River as baseflow under typical and dry conditions. Many of the tributaries across the Project area also receive baseflow contributions from the shallow groundwater system.

The surface water and groundwater systems across the Project area are connected via the following key mechanisms:

- groundwater flows into the Macleay River as baseflow from the shallow fractured rock groundwater system when water levels in the river are low (i.e. during dry conditions)
- streamflow from the Macleay River flows into the adjoining alluvial and shallow fractured rock groundwater systems when water levels in the river are high (i.e. during wet conditions)
- groundwater flows into local watercourses via springs in the upper tributaries, eventually discharging to the Macleay River.

Localised groundwater systems in the upper reaches of the Project area flow into fens and eventually support the local stream system. This surface water-groundwater interaction occurs in small, isolated pockets across the Project area.

4.10 Flooding

Existing flood behaviour was investigated along the Macleay River and Fingerboard Crossing Creek to inform Project development and preliminary designs and to understand potential flood related risks and impacts arising from the Project. The following sections refer to results of hydrologic and hydraulic modelling undertaken for the Project for the following purposes:

- Oven Mountain Pumped Hydro Energy Storage Project: feasibility design (SMEC, 2022) – Hydrologic modelling of the Fingerboard Crossing Creek catchment was undertaken to determine peak flows for the upper and lower dam and reservoir spillways for inclusion in a preliminary dam break assessment. A hydraulic model of the Macleay River from Carrai Creek to Georges Junction was developed to assess flood levels for Project infrastructure along this alignment.

- Oven Mountain Access Road: Hydraulic Assessment (LEGS, 2022) – Hydraulic modelling of the Macleay River between Georges Junction and Stockyard Creek was undertaken to provide hydraulic design information for the proposed bridge crossing over the Macleay River. A hydrologic assessment, informing the hydraulic modelling, incorporated flood frequency analysis of the Macleay River at D/S Georges River Junction gauge.

- Flood Assessment: Fingerboard Crossing Creek (refer to Attachment E) – Hydraulic modelling of Fingerboard Crossing Creek between the upper and lower dams and reservoirs was undertaken to support the geomorphology assessment (refer to Attachment B). Hydrologic model results from the SMEC (2022) feasibility design report were applied to the hydraulic model.

4.10.1 Fingerboard Crossing Creek

Flooding within Fingerboard Crossing Creek has only been assessed in the lower and mid portions of the catchment between the upper and lower dams and reservoirs. Flow in the upstream sections of the creek occurs as dispersed flow across a broader poorly defined channel area while flooding in the lower sections is confined within more defined channel banks. The middle reaches of the watercourse consist of steep vertical drops over granite bedrock.

Flood depths along Fingerboard Crossing Creek are generally lower in the upper reaches of the watercourse where the average depth of the 1% and 0.2% annual exceedance probability (AEP) events is approximately 0.4 m and 1.0 m respectively. Flood depths in the lower reaches of Fingerboard Crossing Creek are generally higher where the average depth of the 1% and 0.2% AEP events is approximately 1.0 m and 1.6 m respectively.

Flood extents and depths of inundation for Fingerboards Crossing Creek are presented in Attachment E.

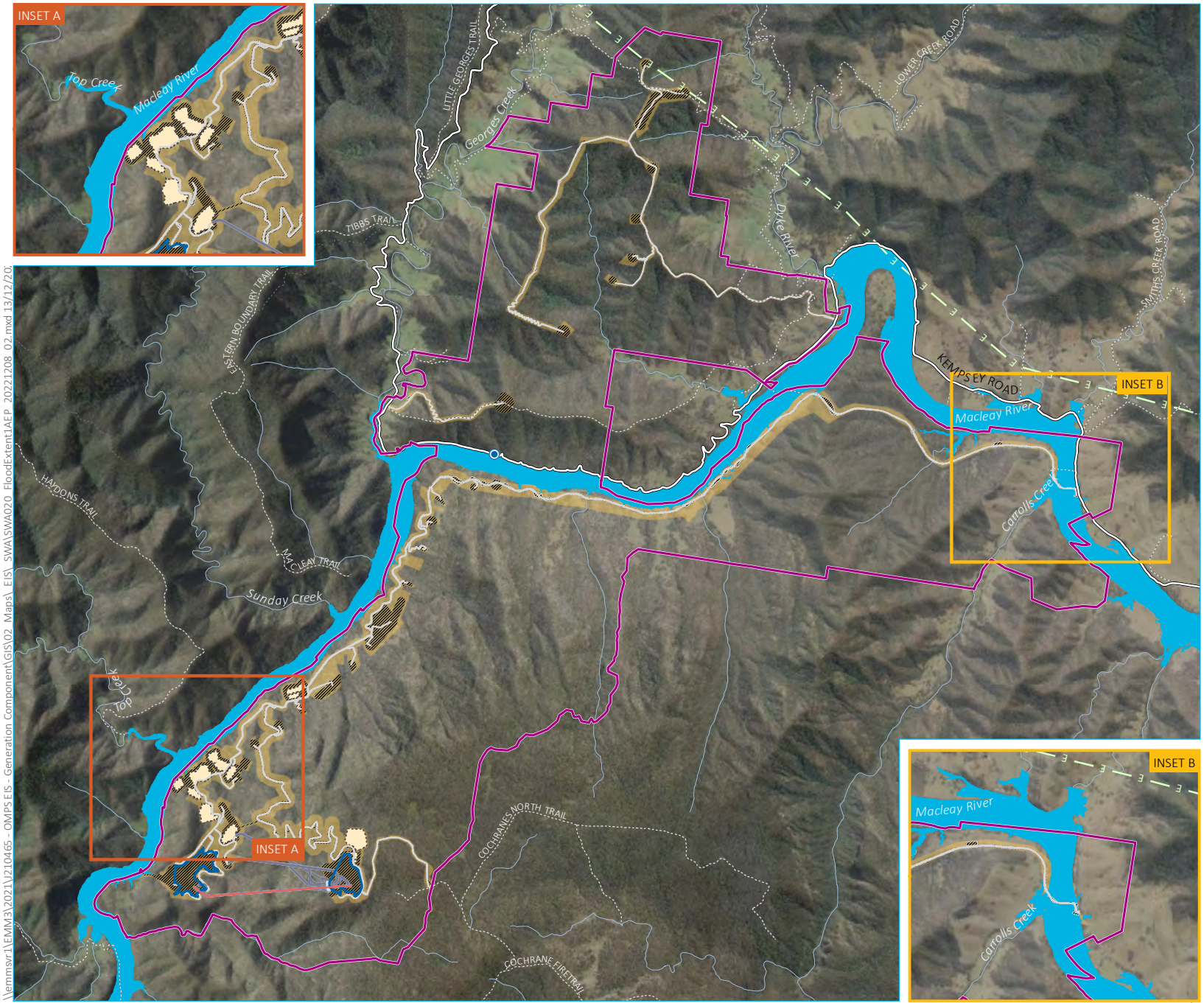
4.10.2 Macleay River

Flood flows within the Macleay River are predominantly one-dimensional in nature following the alignment of the river due to the steep longitudinal grade and confined valley setting of the river in the vicinity of the Project area. Several tributaries join the Macleay River near the Project area. However, due to the size of the Macleay River catchment and local topography, flows at each confluence are rapidly incorporated into mainstream flooding.

Under typical streamflow conditions, flows within the Macleay River are confined to the lower channel banks. During flood events, such as the 1% AEP event, flood levels within the Macleay River are approximately 15 m above typical flow conditions and extend up to 200 m each side of the river across the lower bank floodplain.

In larger (0.1% AEP) and extreme (0.01% AEP) events, flood levels increase above typical streamflow conditions by approximately 18 m and 23 m, respectively. Due to the steep banks either side of the floodplain, flood extents in the 0.1% and 0.01% AEP events are similar to the 1% AEP event and only increase flow widths by about 10 m and 30 m, respectively.

Flood extents and depths of inundation for the Macleay River for the 1% AEP event are presented in Figure 4.17.



KEY

- Project area
- Disturbance footprint
- Construction envelope
- 1% AEP flood extent
- Macleay River D/S Georges River Junction gauging station
- Waterway alignment
- Watercourse/drainage line
- Kempsey-Armidale Road
- Minor road
- Vehicular track
- Existing transmission line

Project operational elements

- Underground power station complex
- Tunnels, portals, intakes, shafts
- Permanent road
- Surface works
- Dams and reservoirs

Source: EMM (2022); DFSI (2020); GA (2011); SMEC (2022)

0 2.5 5 km

GDA 1994 MGA Zone 56

N

\\emmsvr1\EMM3\2021\210465 - OMPS EIS - Generation Component\GIS\02 Maps\ EIS\ SWA\SWA020 FloodExtent1AEP 20221208 02.mxd 13/12/20

Macleay River flood extent – 1% AEP (1 in 100 year)

Oven Mountain Pumped Hydro
Energy Storage Project
Surface water assessment
OMPS Pty Ltd
Figure 4.17

EMM
creating opportunities

5 Water management approach

5.1 Overview

This section describes the proposed water management approach to be applied during construction and operation of the Project. The management measures described in this section are based on the Project feasibility design prepared by SMEC (2022) and consider relevant industry standards and guidelines. Further refinement of the proposed water management approach will be undertaken in the future detailed design phase of the Project.

5.2 Erosion and sediment control

A key risk to surface water quality during construction is the management of soil erosion and transport of mobilised sediment into receiving watercourses. Small construction areas may adequately manage sediment using source controls such as sediment traps or filters, while, while larger construction areas will require more detailed plans for site water management, including water reuse where appropriate, to reduce the risk of discharging sediment affected water. Stormwater discharge risks from all construction areas will be managed via the implementation of ESCPs within a Project SWMP. The SWMP will be developed prior to the commencement of construction and will contain:

- drawings of construction area layouts
- details of how erosion control and soil and water management will be achieved
- description of treatment measures
- description of treatment maintenance measures
- a construction schedule, and description of how the plan will work through the various stages of construction
- design assumptions and calculations for the treatment measures, including hydrologic estimations of runoff volumes and rates, and swale and sediment basin capacities.

The Project will be constructed over a broad region and comprise of both small and large areas of disturbance. Erosion and sediment control at smaller disturbance areas may be suitably managed using standalone ESCPs while the larger construction areas (e.g. accommodation camp and construction pads) will likely require ESCPs as well as more detailed specific measures to be outlined in the SWMP.

The Project SWMP and ESCPs will be developed in accordance with the best practice erosion and sediment control guidelines identified in Section 3.3.6. Further detail on erosion risk and proposed management measures is provided in the land, soils and erosion assessment (EMM, 2022c).

5.3 Stormwater management

5.3.1 Stormwater management during construction

Stormwater discharges will occur from all areas disturbed by construction activities including access roads, the accommodation camp, construction pads and associated temporary stockpiles, dam and reservoir footprints, and laydown areas required to construct the transmission line.

The potential for receiving water impacts is considered greatest during site establishment (e.g. vegetation clearing and earthworks) when the disturbance area is largest. After which, a portion of the disturbed area will be rehabilitated while the remainder will be used to facilitate broader construction activities (i.e. tunnelling and dam construction) in a controlled manner.

The stormwater management approach for each construction area will be documented within the SWMP and relevant ESCPs and will consider the following management measures (or design principles) consistent with best practice including those guidelines identified in Section 3.3.6:

- Clean water will be diverted around or through construction areas where practical. Runoff from clean water areas that cannot be diverted will be accounted for in the design of water management systems. The design event will be established during detailed design based on disturbance duration and other relevant factors. Clean water diversions will seek to avoid increasing flow rates in adjoining watercourses and incorporate suitable bed and bank protection measures to minimise scour potential.

- Runoff from construction areas will be managed by a drainage system that directs flow from a sediment basin or source controls prior to discharge. The drainage system will be designed and constructed to have non-erosive hydraulic capacity. The capacity of the drainage system is to be determined during detailed design.

- Where practical, runoff from disturbance areas will be directed to sediment basins for capture and treatment. The sediment basins will:

  - enable harvesting and reuse of captured water to reduce discharge volumes and frequency; and

  - provide sedimentation treatment during discharge (via overflow).

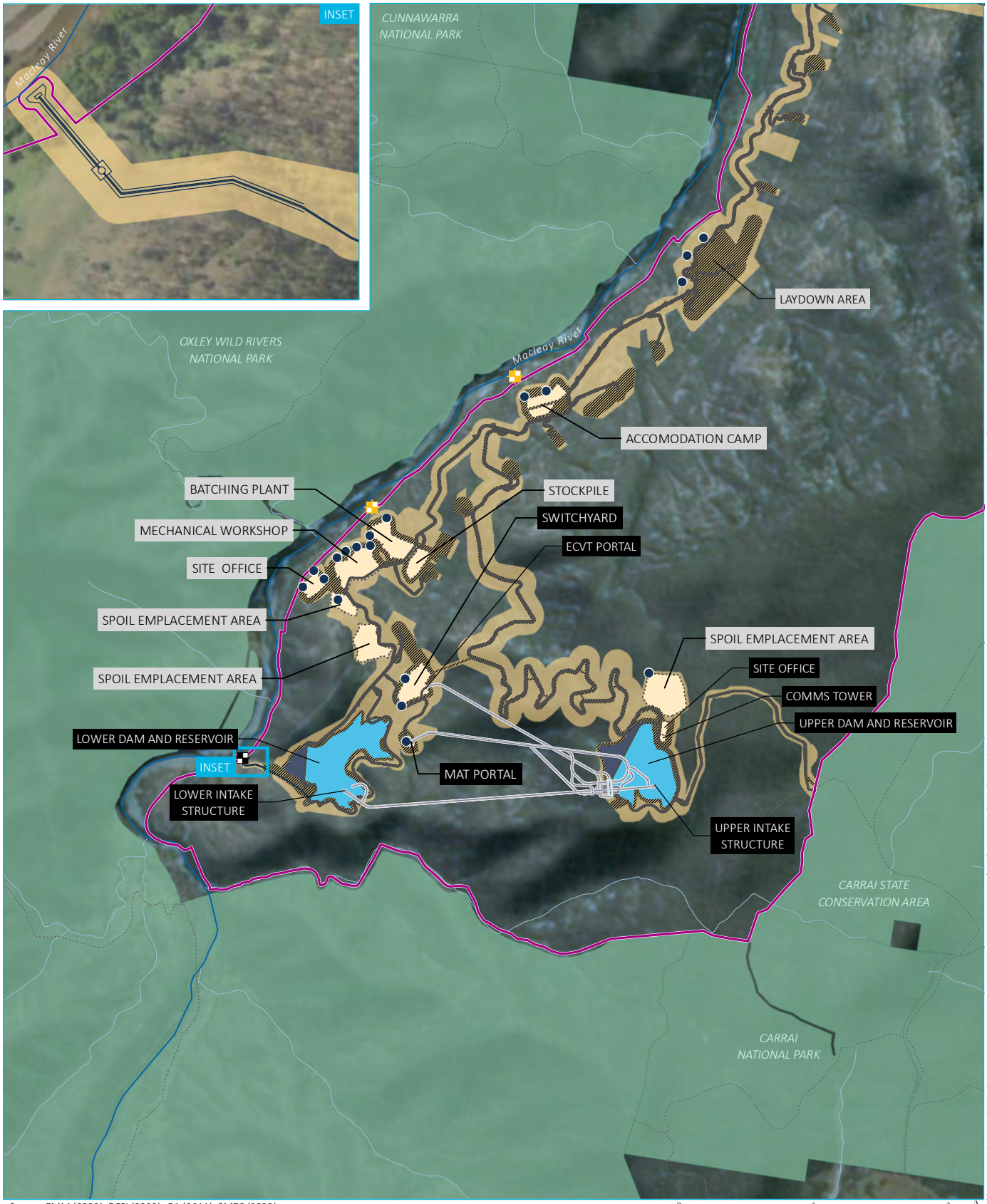
  The locations and capacity of sediment basins will be established at detailed design with consideration of topography, soil conditions, receiving environment and other relevant factors. Captured water will be harvested and used for dust suppression where possible. Indicative locations of sediment basins and potential discharge locations are shown in Figure 5.1.

- Where runoff from disturbed areas cannot be directed to sediment basins, source controls such as sediment traps or filters will be installed at discharge locations to reduce coarse sediment in runoff. Where practical, runoff from roads and other hardstand areas (i.e. accommodation camp and construction pads) will be treated in vegetated swales.

- Activities that have potential to contaminate stormwater runoff will be isolated from the stormwater system by covering (i.e. by a building or roof) and/or bunding, including concrete batching, wash bays, hazardous materials storage, fuels storage/refuelling areas, stockpile areas and aggregate storages.

- Cut and fill batters will be stabilised and rehabilitated as soon as practical following construction. Construction areas that are disturbed but are no longer used or required (e.g. temporary access roads) will be progressively rehabilitated as soon as practical to minimise the overall disturbance area.

Further details on specific management measures including sediment basins, management of areas with elevated water quality risks, and containment of leaks and spills are described in the sections below.



Source: EMM (2022); DFSI (2020); GA (2011); SMEC (2022)

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GDA 1994 MGA Zone 56

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KEY

- Project area
- Disturbance footprint
- Construction envelope
- Indicative sediment basin and discharge location
- General construction pump
- Initial storage fill pump
- Initial storage fill pump infrastructure

Project operational elements

- Underground power station complex
- Tunnels, portals, intakes, shafts
- Permanent road
- Surface works
- Reservoir
- Dam wall

Existing environment

- Macleay River
- Watercourse/drainage line
- Kempsey-Armidale Road
- Vehicular track
- Existing transmission line
- NPWS reserve

Label format

SURFACE PERMANENT INFRASTRUCTURE

TEMPORARY INFRASTRUCTURE

Key elements of the water managment approach

Oven Mountain Pumped Hydro Energy Storage Project
Surface water assessment
OMPS Pty Ltd
Figure 5.1

EMM creating opportunities

i Sediment basins

The design of construction sediment basins will consider terrain, local design rainfall rates, and local soil erosion hazard. The land, soils and erosion assessment (EMM, 2022c) contains a description of the soil properties and recommends sediment basins are constructed as high efficiency sediment (HES) basins due to the resulting efficiency of water treatment, sensitivity of the receiving environment, and personnel safety during wet conditions. It is recommended the HES basins are designed as Type D or Type F basins (as per IECA (2008) and Landcom (2004)) with a minimum 5-day, 85th percentile rainfall depth design capacity.

Coagulant and flocculant treatment within sediment basins can substantially enhance sediment removal compared to untreated basins. The need for, and specific coagulant and flocculant additives to be applied to sediment basins, will be determined prior to construction. The most appropriate coagulant/flocculant will be selected with consideration of potential downstream water quality risks resulting from the additives. Basin additives will be selected with the aim to minimise downstream water quality impacts.

ii Management of areas with elevated water quality risks

Several activities that will occur across the construction areas have the potential to contaminate stormwater and contain an increased risk of water quality impacts. These activities will be isolated from the stormwater management system by covering (i.e. building a roof) and/or bunding.

Activities that are considered to have an elevated water quality risk and therefore to be managed within covered and/or bunded areas are described in Table 5.1.

Table 5.1 Activities that will be undertaken in covered and bunded areas

Activity	Water quality risks	Proposed controls
Concrete batching	Runoff from cementitious areas can contain elevated pH, suspended sediments and metals.	• The proposed water management controls for concrete batching are described in Section 5.4.1.
Equipment wash bays	Construction equipment will be washed using designated wash bays. Wash down water is likely to contain elevated suspended solids and potential for oils and greases. The use of washing agents may also impact water quality.	• Equipment wash bays will be bunded to prevent stormwater ingress. • Runoff from the wash bays will be collected in sediment or water management basins and where practical, used for dust suppression and other non-consumptive water demands.
Hazardous materials storage	Hazardous material leaks or spills may impact quality of stormwater runoff.	• Hazardous materials will be covered and bunded to prevent stormwater ingress and capture any leaks or spills.
Fuel storage and refuelling area	Hydrocarbons in stormwater runoff and the risk of major leaks or spills of hydrocarbons.	• Fuel storage and refuelling areas will be covered and bunded to prevent stormwater ingress and capture any leaks or spills.
Stockpile areas and aggregate storages	Runoff from stockpile areas can contain elevated suspended sediments. Runoff from aggregate storage can contain fine sediments and metals.	• All stockpiles and aggregate storages will be bunded to prevent stormwater ingress and capture any runoff.

iii Containment of leaks or spills and fire water runoff

The containment of leaks and spills of hazardous materials will be managed within covered and bunded areas and in general accordance with the best practice bunding and spill management guidelines identified in Section 3.3.5. However, leaks and spills may also occur due to an accident or emergency where source controls may not be possible.

Sediment basins will provide some containment of leaks and spills or the runoff of firefighting water from the construction pads should containment at the source not be possible. Mobile spill kits will be maintained at key Project locations to facilitate containment of leaks or spills that occur outside of the construction pad footprint. Leaks and spills will be cleaned up and remediated as soon as it is practical and safe to do so.

5.3.2 Stormwater management during operation

Most of the surface infrastructure established to support construction activities will be decommissioned and rehabilitated in accordance with Appendix P of the EIS (EMM, 2022d). This will substantially reduce the disturbance area and associated stormwater management risks.

Permanent surface infrastructure will include reservoirs, access roads, tunnel portals, switch yard, overhead transmission lines, and small buildings and services. Stormwater management from operational areas will be documented within the SWMP and will consider the following management measures (or design principles):

- maintain sheet flow conditions across larger disturbance areas where possible
- implement drainage controls to manage stormwater runoff from infrastructure areas and upslope clean water areas where required
- use of sediment basins where practical and required
- activities that have potential to contaminate stormwater runoff will be isolated from the stormwater system by covering (i.e. by a building or roof) and/or bunding
- include measures to contain accidental leaks or spills.

Erosion risk and proposed erosion and sediment control measures during operation of the Project are provided in Appendix O of the EIS (EMM, 2022c).

5.4 Process water management

Process water includes the water supplied to, and the water produced by, construction activities. Key water uses (or system demands) include water used for underground construction (primarily as drilling fluid), concrete production, and dust suppression. Water supplied to the process water system and groundwater intercepted by underground workings will be the primary inflow to the process water management system.

Process water management will generally occur in isolation for each of the relevant Project construction areas. There are two primary activities that will generate process water that requires management:

- concrete batching
- tunnelling.

The following sections describe the water management approach for each of the process water producing activities. The water supply system is described in Section 5.5.

5.4.1 Concrete batching

Concrete will be required for a range of Project components including the power waterway tunnels, dam embankments, spillways, ancillary infrastructure, and transmission line substation and tower footings. CBPs will be established to produce concrete over the construction period. The locations for CBPs will be determined during future detailed design to best suit construction purposes, site logistics and access.

There are a range of environmental risks associated with concrete batching but with considered management and appropriate site design these risks can be eliminated or reduced to as low as reasonably practicable by a range of controls well understood and regularly applied within the construction industry.

The water management approach applicable to the CBPs will be documented within the SWMP and will consider the following management measures (or design principles):

- Isolating areas that may contaminate stormwater runoff (i.e. areas containing cement) from the stormwater system by covering (i.e. by a building or roof) and/or bunding.
- Installation of a first flush system for hardstand areas, which may receive dust drift or minor quantities of spilt material. The first flush system would typically capture the first 20 mm of rainfall runoff and direct it to a holding area. Subsequent rainfall runoff would then be deemed clean and could be incorporated into the stormwater management system.
- Installing a wastewater collection and recycling system to collect contaminated water from high-risk activities such as agitator washout, truck washing, concrete batching, and slump stand. Wastewater will be collected in dedicated settling ponds for reuse in concrete batching.
- Any excess wastewater from the concrete batching process will be treated prior to discharge. It is expected the treatment process may include screening, chemical dosing, sedimentation and/or filtration. The most suitable treatment processes and plant configuration will be established at detailed design.
- Installing a vehicle washdown facility for vehicles moving in and out of the batching area.

5.4.2 Management of tunnel affected water

Tunnel affected water refers to all water that will be dewatered from the underground works during construction of the Project. Tunnel affected water will originate from:

- groundwater inflows into the underground works
- a portion of the underground water demand is also expected to be captured in sump pits and dewatered back to the surface.

Tunnel affected water will be collected in sumps underground and treated for potential hydrocarbon contamination before being dewatered to the surface. Water that is dewatered from the underground works will be collected in a basin(s) before being treated and reused to supply the underground construction water demand. Tunnel affected water may also be used to meet other construction water demands (eg dust suppression) where practical. The location of the basin(s) will be determined during future detailed design to best suit construction purposes, site logistics and access.

If the volume of water pumped from the underground works exceeds the underground water demand, the excess water will be discharged into the local receiving environment and ultimately discharge to the Macleay River. The level of treatment applied prior to discharge will depend on the observed water quality of tunnel affected water contained in the sediment basin. The following approach will be applied:

1. If the water quality is suitable for discharge to the receiving environment, excess water will be allowed to overflow directly from the basin.
2. If the water quality is unsuitable for discharge to the receiving environment, additional treatment measures will be applied to improve water quality prior to overflow or controlled discharge.

The location and configuration of any overflow, as well as localised treatments for scour protection of receiving drainage lines, will be determined during future detailed design to best suit site layout needs and to minimise potential discharge related impacts.

5.5 Water supply system

5.5.1 Overview

A water supply system is proposed to supply water for potable water use, general construction water demand and for the initial fill of Project reservoirs. Elements of the water supply system will be retained during operation of the Project.

5.5.2 Construction phase water requirements

i Potable water supply

Potable water will be supplied to all accommodation camps and construction facilities that will have amenities. Water will be sourced from the Macleay River via pump and pipeline. Water will be treated to a potable water standard before use.

Potable water usage demand will vary over the construction phase of the project in line with the size of the construction workforce. Potable water demand has been calculated based on an assumed workforce of 1,000 people and a usage rate of 150 litres per person per day (L/person/day). It is estimated that 0.15 ML/day of potable water will be required.

ii Construction water supply

Construction water will be used for activities such as site establishment and access road construction, dust suppression, concrete batching, and firefighting. Process water will also be required to supply the underground works and construct the transmission line. Process water requirements are estimated as follows:

- general construction water (including concrete batching) – 0.45 ML/day
- underground works – 0.35 ML/day
- transmission line construction – 0.09 ML/day.

It is estimated a total of 0.89 ML/day will be required to meet construction water demands. Construction water will be sourced from the Macleay River via pump and pipeline. Groundwater extraction from water supply bores may also be used to supplement the water supply system where required. The use of groundwater to meet construction water demand is considered further in the groundwater impact assessment (EMM, 2022a). However, for the purposes of this surface water assessment, it is assumed that all construction water demand will be supplied from the Macleay River. Final decisions around water supply planning, within the bounds of impacts and licensing implications assessed as part of the EIS, will be made as part of future detailed design.

iii Initial storage fill

Once constructed, the Project reservoirs require an initial one-off fill of 6,500 ML to reach the target operational volume. The Project reservoirs are located off-river and are not anticipated to receive sufficient local catchment runoff to achieve the initial storage fill. Hence, it is proposed to extract the 6,500 ML initial fill volume from the Macleay River via pump and pipeline during certain licenced river conditions.

5.5.3 Proposed pump infrastructure

i Infrastructure for general construction water

It is proposed to install several smaller pumps and associated pipelines along the Macleay River to extract water for general construction purposes. These pumps will be sized to extract up to a combined 1 ML/day with the specific capacity, pump screening requirements and location of each pump to be determined during detailed design. The design and construction of pump screening will be undertaken with consideration of the following NSW DPI Fisheries recommended guidelines:

- *The practical guide to modern fish-protection screening in Australia* (Boys, Rayner, Kelly, Doyle, & Baumgartner, 2021)
- *Design specifications for fish protection screens in Australia* (Boys, Design specifications for fish-protection screens in Australia. Edition 1. NSW Department of Primary Industries., 2021).

Indicative pump locations for the accommodation camp and CBP pad are shown in Figure 5.1.

ii Infrastructure for the initial storage fill

It is proposed to locate the initial storage fill pumps and pipeline on the right (eastern) bank of the Macleay River near the lower dam and reservoir as shown in Figure 5.1. Key components of the initial storage fill pump infrastructure are as follows:

- An underwater stainless steel wedge wire intake screen to protect aquatic species and minimise the uptake of debris. The pump screens will be designed and constructed in general accordance with the following NSW DPI Fisheries recommended guidelines:
  - *The practical guide to modern fish-protection screening in Australia* (Boys, Rayner, Kelly, Doyle, & Baumgartner, 2021)
  - *Design specifications for fish protection screens in Australia* (Boys, Design specifications for fish-protection screens in Australia. Edition 1. NSW Department of Primary Industries., 2021).
- An inclined access arrangement to provide a lifting mechanism for the screen allowing for inspection and maintenance.
- An underground dry well with duty and backup pumps. The pumps will be designed to pump water at a rate of up to 1 cubic metre per second (m^3/s) (84.6 ML/day).
- The top of the well would sit flush with the ground elevation and nominally above the 1% AEP flood level (flood protection level to be confirmed at detailed design).
- Power would be provided to the pumps via a local distribution supply which could run in a conduit.
- The rising main to the lower dam and reservoir will be buried underground until it meets the bottom of the spillway. Here, the pipe will be installed into the spillway wall where it is protected. The outlet of the pipe will be located at the upper sill of the spillway.
- Water will discharge from the outlet into the lower reservoir via a natural channel adjacent to the spillway.

Following construction, it is proposed to retain the initial storage fill pumps and pipe infrastructure to facilitate periodic top-up of the reservoirs during the operational phase of the Project.

5.5.4 Proposed extraction regimes

i Construction water supply

Construction activities will require a steady source of water at relatively low rates. The proposed extraction rate of up to 1 ML/day (in the order of 10–20 L/s varying over the course of 24 hours) is expected to be of similar magnitude to extraction rates used for irrigation purposes in the downstream Macleay Valley Water Source and across the broader Macleay River catchment. Hence, it is proposed to apply the access rules outlined in the Macleay WSP for the relevant water sources to water extracted (at low pump rates) from the Macleay River for construction purposes. It is proposed to source construction water from several locations along the Macleay River adjacent to key construction areas (refer to Figure 5.1).

Access conditions are proposed to limit water take and protect existing downstream users and environmental receptors during dry periods. For example, water will cease to be extracted from the Macleay River for construction purposes when streamflow at the Macleay River at D/S Georges River Junction (206024) gauge is below the 'Very Low Flow Class' flow rate of 13 ML/day. This is described further in Section 4.4.2iv.

Construction water may also be sourced at higher extraction rates (i.e. above 1 ML/day) from the initial storage fill pumps and pipeline should a sufficiently large water storage (e.g. turkey nest dam) be established as part of the construction process or once the lower dam and reservoir is constructed. Any construction water sourced at such higher flow rates will be subject to the extraction conditions described in Section 5.5.4ii.

ii Initial storage fill

Greater extraction rates are required for the initial storage fill (6,500 ML) compared to the rates required for general construction activities (365 ML/year). To minimise potential impacts to downstream users and environmental receptors, extraction for initial fill purposes will only occur during periods of high flow.

The Macleay WSP does not define high-flow-only access conditions for the Macleay Gorges Water Source but does however define high-flow-only access conditions for the Macleay Valley and Apsley River water sources (refer to Attachment A), where high flow is defined as the 50th percentile streamflow (ie the flow that is exceeded on 50% of days). The principles used to define high flow conditions in these other two water sources are considered applicable to the Macleay Gorges Water Source. Hence, the 50th percentile streamflow (597 ML/day) at the Macleay River at D/S Georges River Junction (206024) stream gauge has been used to define the high flow conditions to be applied to the initial storage fill extraction.

It is proposed to maintain the 50th percentile streamflow by extracting only flows in the Macleay River in excess of 597 ML/day, up to a maximum extraction rate of 86.4 ML/day. The full 86.4 ML/day will not be taken until the flows in the river reach 683.4 ML/day. The proposed extraction rate represents the upper limit on pumping from the Macleay River, noting other extraction restrictions are also proposed. Lower extraction rates may be identified as preferable during future Project design.

iii Summary of extraction conditions

The proposed extraction conditions for water take from the Macleay River for construction and initial storage fill purposes are summarised in Table 5.2. The proposed extraction conditions have been used to assess potential impacts in Section 6.3.7.

Table 5.2 Proposed extraction conditions – Macleay River

Water take	Volume required	Estimated extraction period	Cease to pump trigger[1]	Pumping rate	Additional conditions
Construction water	365 ML/year	5 years	13 ML/day[2]	1 ML/day	N/A
Initial storage fill	6,500 ML	3–12 months	597 ML/day	86.4 ML/day (1 m^3/s)	The 50th percentile streamflow value is to be maintained. Pumping to cease if 30-day streamflow total[1] below 5-year ARI value of 1,936 ML. No extraction for first seven days following a flow event greater than 50th percentile streamflow[1] value following extended dry period or drought[3].

Notes: 1. Streamflow measured at Macleay River at D/S Georges River Junction (206024) stream gauge.
2. 'Very low flow' conditions for the Macleay Gorges Water Source as defined in the Macleay WSP.
3. Extended dry period or drought refers to the 30-day streamflow total below 5-year ARI (1,936 ML) as defined in Section 4.4.2iv.

5.5.5 Estimated time to achieve initial storage fill

The monthly extraction volumes based on the historical streamflow record were used to assess the length of time required to achieve the initial storage fill volume (6,500 ML) as a function of the month extraction commences. The number of months to extract the initial storage fill are presented in Figure 5.2.

The results presented in Figure 5.2 show the minimum time to achieve the initial storage fill is three months. A shorter initial storage fill period is expected if extraction commences from December to March compared to the rest of the year. The median fill time from December to March is four months while the median fill time for the remainder of the year ranges from 5–6 months.

The chance of extracting less than the full initial storage fill volume within a 12 month period occurs in 8–11 years over the entire streamflow record of 53 years depending on the month in which extraction commences. Extracting less than the full initial storage fill volume is generally associated with periods (years) of below average streamflow or droughts when the full volume could not be achieved regardless of which month extraction commenced.

Overall, the results indicate an 82% probability of achieving the initial fill volume within a 12-month period based on the historical streamflow record and the proposed extraction conditions. The initial storage fill volume can generally be achieved in a shorter period if extraction commences immediately prior to or during summer.

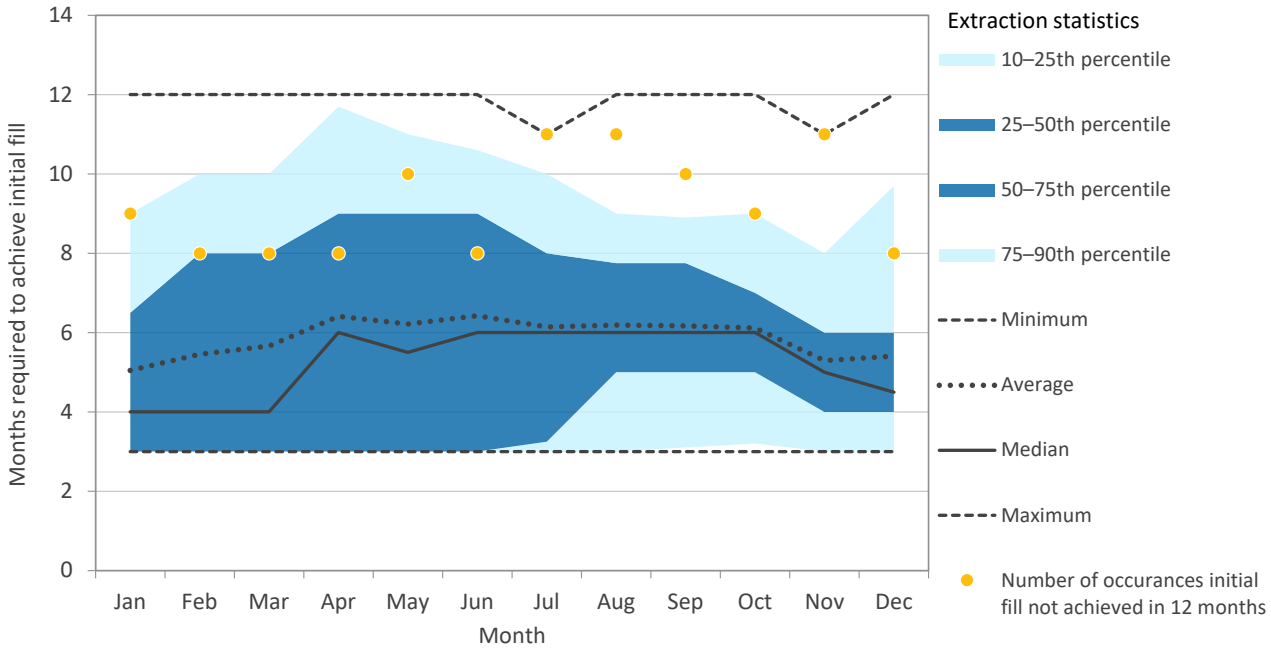


Figure 5.2 Number of months required to achieve the initial storage fill

5.5.6 Contingency measures for initial storage fill water requirements

It is proposed to extract the initial storage fill volume within a 12 month period. The average time to achieve the initial storage fill is estimated at six months. However, the time to achieve the fill is expected to be shorter (three months) during a wet period and longer (up to two years) during an extended dry period. The following contingency measures can be implemented if the initial storage fill takes longer than the proposed 12 months:

- extended the duration of the initial fill period (say up to two years)
- commission the Project at lower than 100% operational capacity and progressively top-up as water becomes available
- supplement the initial storage fill water demand with groundwater entitlements, which will be acquired to meet peak groundwater interception volumes.

As the specific streamflow conditions at the time of the initial storage fill are unknown and difficult to predict, the most appropriate contingency measure(s), if required, would be determined during Project construction.

5.5.7 Operational water supply

Raw water supply will be required for firefighting at the power station complex, access tunnels and portals, and treatment to potable standard. Raw water will be sourced via internal offtake pipelines that will be established during construction. Water will be sourced from the reservoirs for ongoing operational water supply which is anticipated to be relatively minor compared to the volume stored in the reservoirs.

Potable water supply will be required at the office building and accommodation camp for staff facilities. A water treatment plant will be used to treat raw water and supply potable water for use on site.

Water will also be required to top-up the Project reservoirs following extend dry periods. It is proposed to source this water using the initial storge fill pump infrastructure described in Section 5.5.3 and in accordance with the extraction conditions described in Section5.5.4. The frequency and volume of water required for operational top-up are described in the operational water balance described in Section 7.2.

5.6 Wastewater management

5.6.1 Construction wastewater management

Wastewater will be produced at the accommodation camp, construction areas, and facilities that have amenities. Wastewater loads have been estimated based on an assumed peak workforce of 1,000 people with an average load of 0.15 ML/day and a maximum treatment rate of 53 L/s.

All wastewaters will be treated in general accordance with the *National Water Quality Management Strategy: Australian Guidelines for Sewerage Systems* (ANZECC, 1997) prior to discharge with the location and number of treatment plants to be established at detailed design. Wastewater will be treated as follows:

- Sewage treatment plants (STPs) will be established to treat wastewater at the accommodation camp and other high occupancy areas. It is expected the STPs will include screening, chemical dosing, sedimentation, biological treatment, filtration, and disinfection. The most suitable treatment processes and plant configurations will be established at detailed design.
- Bio-septic tanks with absorption trenches (for permanent infrastructure) or temporary ablution facilities with a pump out arrangement are proposed for low occupancy areas.

Treated effluent from the STPs will be discharged to the Macleay River. Sludge and solid waste by-products will be periodically pumped into tanks and disposed of an appropriate offsite facility.

5.6.2 Operational wastewater management

Wastewater produced from permanent surface infrastructure will be serviced by septic tanks and infiltration fields. Small amounts of wastewater will also be produced by amenities at the power station. Wastewater produced at the power station will either be trucked to a licenced wastewater treatment plant or treated on site.

The application of wastewater to infiltration fields will be undertaken in general accordance with relevant effluent disposal guidelines with the aim to minimise risk to receiving water quality. If insufficient area is available for infiltration, treated wastewater may be discharged to the receiving environment and ultimately the Macleay River.

5.7 Management of groundwater inflows to excavations

The following Project activities require excavations and may intercept the shallow groundwater system and subsequently require management:

- quarrying within the upper and lower reservoir footprints to source rock for the dam embankments and increase reservoir capacity
- excavations to establish stable footings for the transmission towers and Macleay River bridge crossing
- bulk earthworks that will occur across the Project area including at construction pads, accommodation camp and tunnel portals to achieve construction design levels.

Intercepted groundwater will be pumped out and either used locally where practical (e.g. for dust suppression), discharged to a nearby drainage line, or collected in tankers and disposed of offsite depending on the observed water quality. The management approach for each intercepted groundwater stream will be developed as part of the SWMP.

5.8 Spoil emplacements

A large volume of rock and soil will be produced during construction of the Project. A portion of the material excavated by these actions will be used as aggregate for the construction of the reservoir dam walls, however the material which is not suitable for this purpose will be disposed in the following spoil emplacement areas (refer to Figure 2.2):

- spoil from works near the lower dam and reservoir will be placed into two separate emplacement areas in the upper reaches of Watercourse 1
- spoil from works near the upper dam and reservoir will be placed in one emplacement area in the upper reaches of Watercourse 2.

The emplacement will be constructed from the 'bottom up' using conventional earthmoving techniques. Prior to the emplacement of rock, vegetation will be removed, topsoil stripped (if accessible by machinery and assessed as suitable for rehabilitation re-use), and a level base platform established. Drainage diversions and infrastructure will also be installed at this stage.

The stormwater management approach applied to the construction of spoil emplacements will be documented within the SWMP and ESCPs and will be in general accordance with the management measures (or design principles) described in Section 5.3. Additional measures specific to spoil emplacements may include:

- compressing the rock at the top of emplacements to provide a surface for the reinstatement of soils or other growth media to facilitate revegetation
- revegetation (primarily grasses, groundcovers, and small vegetation species) of emplacements via direct seeding.

The emplacement outer batters will not be compressed or revegetated and will be retained as bare rock for general fauna habitat. The construction methodology and final landform of spoil emplacements will be developed in future detailed design phases of the Project. Further detail on the rehabilitation method for spoil emplacements is provided in Appendix P of the EIS (EMM, 2022d).

5.9 Instream works and disturbance of waterfront land

The WM Act defines waterfront land as the bed of any river, lake or estuary and any land within 40 m of a riverbank, lake shore or estuary mean high water mark. Instream works refer to modifications or enhancements to a watercourse. Several aspects of the Project will be constructed instream or within 40 m of the top bank of a watercourse.

The management approach for all instream works and works on waterfront land will be documented within the SWMP and ESCPs in accordance with Section 5.2. Proposed works on waterfront land and the corresponding water management approach are identified in Table 5.3. Works will be undertaken in accordance with relevant guidelines for controlled activities described in Section 3.3.2, where practical.

Table 5.3 Works on waterfront land

Type	Description	Water management approach
Instream works		
Watercourse diversions	Any watercourse that traverses the Project disturbance area may be temporarily or permanently diverted.	The stormwater management approach described in Section 5.3 will be applied to watercourse diversions.
Waterway crossings	Culvert and bridge crossings of watercourses are proposed at numerous locations within the Project disturbance area including across the Macleay River.	All waterway crossings will be designed by a suitably qualified professional in accordance with the relevant Austroads Guidelines. For watercourse crossing locations where fish passage is likely to occur, waterway crossings will be designed and constructed in general accordance with: • *Why Do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings* (Fairfull & Witheridge, 2003) • *Policy & Guidelines for Fish Habitat Conservation & Management* (DPI, 2013).
Dam and reservoir construction	The upper and lower dams and reservoirs will be constructed on Fingerboard Crossing Creek.	The stormwater management approach described in Section 5.3 will be applied to construction of the dams and reservoirs. A cofferdam and diversion tunnel will be installed upstream of dam and reservoir construction areas to mitigate impacts to watercourses during construction and reduce flood risk. The cofferdam will be designed to bypass flows and provide flood immunity up to the 1% AEP design flood event.
Pump infrastructure	Pump infrastructure is proposed at several locations in the Macleay River including permanent infrastructure to facilitate the initial storage fill and operational top-up.	Proposed pump infrastructure and extraction regimes are described in Section 5.5.3 and Section 5.5.4 respectively.
Spoil emplacements	It is proposed to place excavated rock and spoil within emplacements located in watercourses and drainage lines.	The management approach for excavated rock and spoil emplacements is described in Section 5.8.
Service crossings	Service crossings of watercourses are likely to occur at numerous locations within the Project disturbance area.	All service crossings will be designed by a suitably qualified professional in accordance with best practice methods.
Other works		
Works within 40 m of the top of bank of a watercourse	Disturbance may occur on any land within the Project disturbance area that is within 40 m of a watercourse.	The stormwater management approach described in Section 5.3 will be applied to works within 40 m of a watercourse.

5.10 Flood risk management

Most of the infrastructure required to support construction activities will be located above the 0.01% AEP (1 in 10,000 year) flood level and therefore will have a low risk of being affected by flooding.

It is proposed to construct a low-level bridge across the Macleay River to provide access to the site during construction and operation. The low-level bridge is predicted to be inundated by floodwater approximately once per year for approximately 20 hours duration on average (LEGS, 2022). Access to and from the site will be restricted when the Macleay River bridge is inundated.

Flood risk management procedures during construction and operation, including those to respond to restricted site access, will be documented within a Project specific Flood Management Plan (FMP) to be developed prior to the commencement of construction.

5.11 Decommissioning of the Project

Most of the ancillary infrastructure (construction pads, accommodation camp, access roads, etc) established to support construction activities will be decommissioned and rehabilitated during or shortly after construction. Infrastructure that is required to support operations such as utilities, the PHGW, and transmission lines will be maintained throughout the operational life of the Project.

It is proposed to decommission most of the operational infrastructure at the end of the Project lifespan except for the following:

- the upper and lower dams and reservoirs may be retained and managed so that inflows in excess of the storage capacity will overflow downstream via the spillways
- certain infrastructure with an ongoing asset value, such as overhead transmission and communications infrastructure, may be retained and transferred to third parties.

Further detail on Project decommissioning and rehabilitation is provided in Appendix P of the EIS (EMM, 2022d).

6 Construction impact assessment

6.1 Overview

This chapter provides an assessment of impacts during construction of the Project. Impacts to streamflow, water quality, existing water users, and the receiving environment are addressed with consideration of the water management approach described in Chapter 5.

6.2 Construction water balance

6.2.1 Overview

A conceptual water balance was developed for the construction phase of the Project. The purpose of the water balance is to:

- assess the potential for inflows to the process water system to offset reliance on the water supply system
- quantify the volume of construction water that requires discharge to the receiving environment.

Water that is extracted from the Macleay River for the initial storage fill is assessed separately in Section 6.3.7.

6.2.2 Methodology

A simple water balance methodology was applied whereby inflows to the process water system were subtracted from water demand to determine water deficit and discharge volumes. The following sections describe system inflows and demands.

i System inflows

Groundwater intercepted by the underground works is expected to be the primary inflow to the process water system. Groundwater inflow estimates over the construction phase are established in Appendix M of the EIS (EMM, 2022a).

The base case groundwater inflow estimates have been applied to inform the construction phase water balance. The ground impact assessment (EMM, 2022a) in Appendix M of the EIS notes the groundwater model predictions are based on several conservative assumptions including:

- The modelling does not consider actual design, management or mitigating activities (i.e. grouting, concrete lining and steel lining) which may reduce the overall volume of groundwater intercepted by the underground infrastructure.
- The hydraulic parameters applied to the Macleay River floodplain alluvium are conservative and assume significant permeability and flow. However, the entire unit may not behave like this, with some parts expected to be much less permeable with storage also expected to be constrained by thickness.

For the purpose of the water balance, the predicted annual groundwater inflow estimates were converted to a daily rate to allow comparison to daily construction water demands. It should be noted however that the groundwater inflow volumes are expected to be highly variable over the construction phase with greater inflows occurring when tunnelling through high permeability rock and lower inflows occurring when tunnelling through low permeability rock.

The adopted base case groundwater inflow estimates during construction are shown in Figure 6.1.

ii System demands

Construction water demand is required for potable water supply, general construction activities (concrete batching, dust suppression, etc), underground works, and construction of the transmission line. It is estimated up to 1 ML/day will be required for general construction activities. It is noted that water demand will likely vary over the construction period and demand may at times be more than, or less than, the assumed 1 ML/day.

Groundwater inflows will be treated and reused to offset water demand to the underground works. The underground works are estimated to required 0.35 ML/day. It is assumed that groundwater inflows in excess of the underground works water demand will discharge to the receiving environment as described in Section 5.4.2.

6.2.3 Water balance results

Construction water demand, groundwater inflows, and discharges from the process water system over the construction period are shown in Figure 6.1.

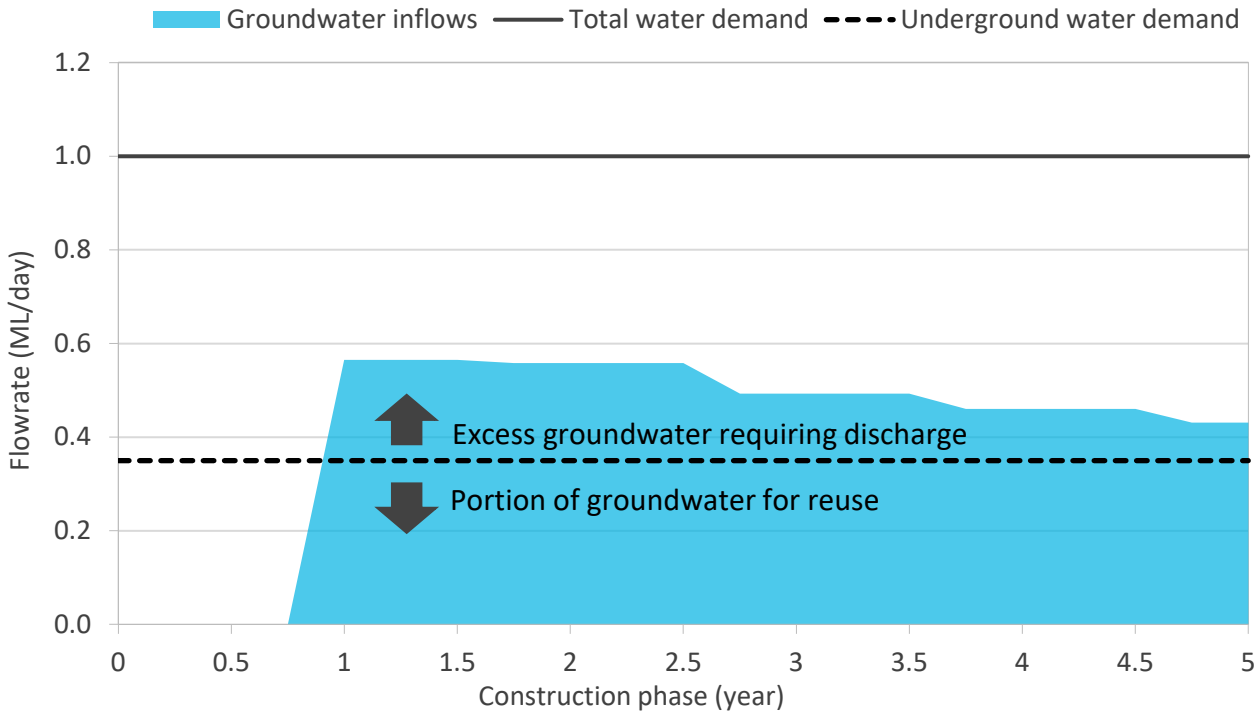


Figure 6.1 Construction water balance

The water balance results in Figure 6.1 indicate:

- The full 1 ML/day general construction water demand will need to be sourced from the water supply system in the first year of construction.
- The demand on the water supply system is expected to decrease to 0.65 ML/day following the first year of construction as groundwater inflows are used to offset the 0.35 ML/day underground water demand.
- Groundwater inflows are predicted to exceed the underground water demand from the first year of construction onwards.

On average, approximately 0.2 ML/day of groundwater will need to be discharged to the receiving environment in the early years of construction. Groundwater discharges are predicted to decrease to less than 0.1 ML/day by the end of the construction program.

The groundwater inflows presented in Figure 6.1 are based on the base case groundwater model. The discharge volumes described above may increase (or decrease) should groundwater inflows during construction be greater (or less) than those predicted for the base case scenario. Mitigation measures such as grouting, and tunnel lining may also result in a reduction to the intercepted groundwater volumes, and hence a reduction in discharge volume.

6.3 Impacts to streamflow regime

6.3.1 Overview

Construction of the Project has the potential to result in the following impacts to streamflow:

- increased streamflow resulting from changes in land use and discharges from the stormwater management system
- decreased streamflow due to the capture of stormwater runoff in sediment basins
- increased streamflow resulting from controlled discharges from the process water and wastewater management system
- reduced or altered streamflow due to watercourse diversions or the construction of instream structures
- reduced streamflow resulting from water extraction to supply construction activities (e.g. initial storage fill).

This section assesses impacts to the streamflow regime of minor watercourses and the Macleay River during construction of the Project.

Impacts to streamflow and baseflow in the Macleay River and minor watercourses resulting from groundwater drawdown are described in Section 6.7.

6.3.2 Stormwater discharges

The removal of vegetation, compaction of soil and establishment of hardstand or stabilised surfaces for access roads and construction areas will increase the portion of rainfall that is converted to runoff and subsequently ends up as streamflow. In general, access roads and construction areas make up a small portion of the overall contributing catchment to minor watercourses across the Project area. Larger construction areas such as the accommodation camp and construction pads may form a greater portion of the contributing catchment to receiving watercourses. Sediment basins are proposed to detain a portion of the additional runoff from construction areas in larger rainfall events, and all runoff in smaller rainfall events (i.e. those below the design capacity). Water captured in sediment basins will be reused where practical for construction purposes to minimise demand from other water sources, which will assist in minimising discharges to receiving watercourses.

No material impacts to minor watercourse streamflow regimes are expected to occur as a result of altered runoff from disturbance area due to:

- the proposed measures to manage runoff and stormwater discharges from construction areas (refer to Section 5.3)
- the relatively small disturbance area that will occur in most watercourse catchments.

Any residual impacts to minor watercourses are anticipated be localised, minor in nature, and only occur for short periods of time.

No material impacts to streamflow in the Macleay River are anticipated given the volumes of water discharged from construction areas or captured in sediment basins will be insignificant compared to the existing flows in the river.

6.3.3 Process water discharges

Discharges from the process water system will occur when the volume of inflows (due to groundwater interception) exceed the volume of water required for general construction purposes (specifically the underground works). Process water will be discharged to the nearest drainage line and ultimately the Macleay River.

Process water discharge rates are expected to be highly variable over the construction phase. Process water discharges will temporarily increase streamflow within the receiving watercourse. The water balance results presented in Section 6.2.3 indicate up to 0.2 ML/day of groundwater (or tunnel affected water) may be discharged to the receiving watercourse (or drainage line).

Process water discharge rates are expected to be of similar magnitude to streamflow rates that occur naturally within minor watercourses across the Project area. Any residual risk to watercourse geomorphology resulting from an increase in streamflow will be mitigated through engineering design of suitable outlet protection measures to minimise localised scour potential.

Negligible impacts to the Macleay River are anticipated given typical streamflow values are three to four orders of magnitude greater than the proposed process water discharge rate.

6.3.4 Wastewater discharges

Treated wastewater will be discharged to the nearest drainage line and ultimately the Macleay River. It is estimated that treated wastewater will be discharged at a rate of 0.15 ML/day with a maximum flow rate of 53 L/s (refer to Section 5.6.1).

The treated wastewater discharge rate is expected to remain relatively consistent over the construction period resulting in a temporary change to the receiving watercourse (or drainage line) flow regime from occasional flow following rainfall (ephemeral), to flowing most of the time.

The peaking flow rate of 53 L/s is anticipated to be substantially less than the flow rate experienced naturally in most watercourses across the Project area following rainfall. Hence, it is expected the receiving watercourse will have sufficient capacity to convey the additional flow. Any residual risk to watercourse geomorphology resulting from an increase in streamflow will be mitigated through engineering design of suitable outlet protection measures to minimise scour potential.

Negligible impacts to the Macleay River are anticipated given typical streamflow values are three to four orders of magnitude greater than the proposed wastewater discharge rate.

6.3.5 Watercourse diversions

Impacts to the flow regime of minor watercourses will be unavoidable where it is necessary to divert a watercourse into an adjoining watercourse. These impacts are expected to be localised and relatively minor in nature. Appropriate engineering design and construction methodology are expected to mitigate risks to water quality and infrastructure resulting from scouring and erosion.

No watercourse diversions are proposed for the Macleay River.

6.3.6 Instream structures

Impacts to streamflow regime resulting from instream works such as culverts and bridges will be mitigated through appropriate design and construction methodologies (refer to Section 5.9). In most instances, streamflow will pass though or around infrastructure (e.g. roads) with negligible changes to peak flow rate and streamflow volumes.

Cofferdams and bypass tunnels will be installed during construction of the dam embankments to pass streamflow from upstream to downstream of the works (refer to Section 5.9). The bypass arrangement is anticipated to have minimal impact on Fingerboard Crossing Creek as all typical streamflow and flood flows (up to the 1% AEP) will be allowed to pass downstream in a similar manner to existing conditions.

Once construction of the dams is complete, the bypass tunnels will be sealed off and all upstream inflows will be captured within the Project reservoirs. The lower reservoir will capture all runoff from the Fingerboard Crossing Creek catchment until the initial storage fill is complete. After which, streamflow that enters the lower reservoir may discharge downstream via the spillway. Impacts to the streamflow regime of Fingerboard Crossing Creek during Project operation are assessed in Section 7.3.

Flood risks associated with the cofferdam and bypass tunnel arrangement during construction will be managed through the development and implementation of the Project FMP, which will include consideration of flood-related impacts and risks across the Project.

Constructing a bridge across the Macleay River is not anticipated to impact streamflow regimes as water will be able to pass beneath and above the structure depending on flow conditions. Constructing a bridge across the Macleay River has the potential to impact flood regimes which is discussed separately in Section 7.8.

6.3.7 Water extraction

Extracting water from the Macleay River has the potential to directly impact the streamflow regime, resulting in indirect impacts to downstream water users and the environment. This section describes impacts to the Macleay River streamflow regime as a result of extracting water for construction and initial storage fill.

Streamflow impacts have been assessed by comparing the historical streamflow record for the Macleay River at D/S Georges River Junction gauge against the historical gauge record less the volume of water extracted to meet construction and initial storage fill requirements.

The impacts presented in this section are used to describe indirect impacts to downstream environmental receptors and water users in Section 6.5 and Section 6.6 respectively.

i Percentage of annual streamflow extracted

The maximum annual volume extracted from the Macleay River is estimated at 6,865 ML and is comprised of 6,500 ML initial storage fill and 365 ML general construction water. The annual streamflow volume at the Macleay River at D/S Georges River Junction gauge, maximum proposed annual extraction volume (6,865 ML) as a percentage of annual streamflow, and the potential extraction volume when implementing the proposed cease to pump (CTP) conditions (refer to Section 5.5.4) as a percentage of annual streamflow are presented in Figure 6.2.

The maximum required annual extraction volume represents a small percentage of the overall flow observed at the gauge with the required volume representing less than 1% of streamflow in wetter years to about 7% of streamflow in drier years. The streamflow volume that could be taken when applying the proposed extraction rules described in Section 5.5.4 ranges from less than 1% to about 3% of streamflow. This is due to the proposed CTP rules limiting the volume of water that can be extracted during low flow conditions.

The impact on annual streamflow volume is expected to decrease with distance downstream as runoff from the downstream catchment progressively forms a larger portion of observed streamflow.

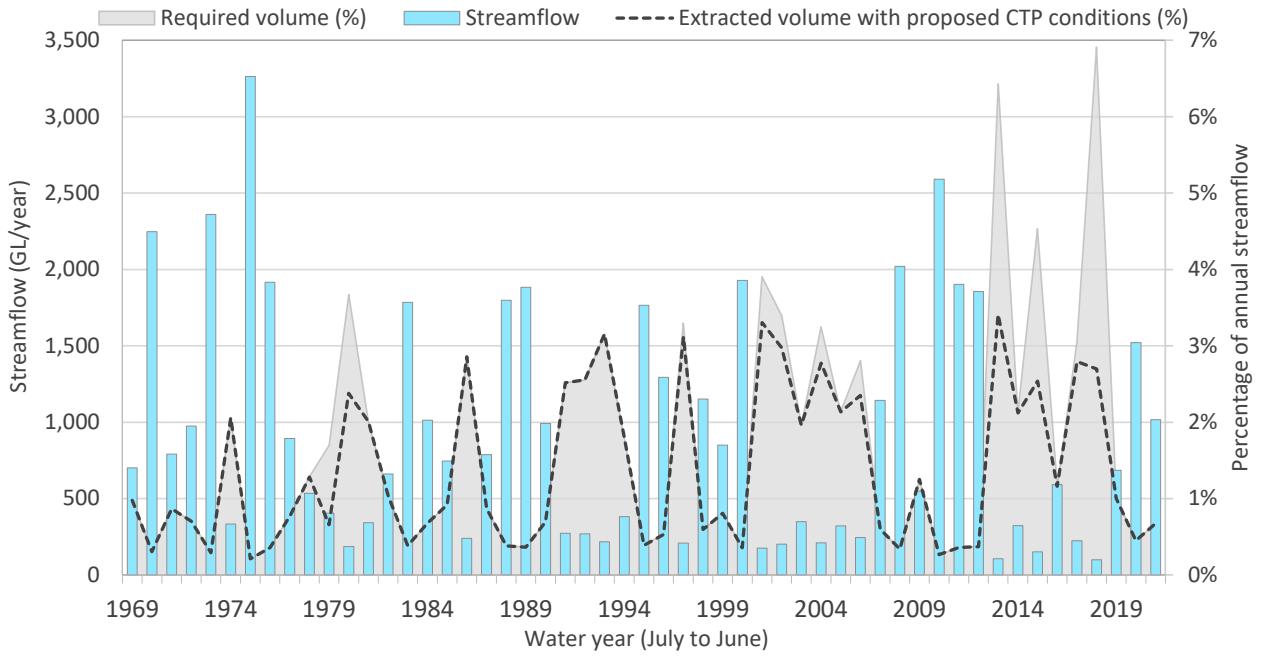


Figure 6.2 Extraction volume as a percentage of annual streamflow

ii Impacts to flow duration curve

This section describes potential impacts of the construction and initial storage fill extraction on daily flows. It compares the frequency of historical daily flow rates recorded at the Macleay River at D/S Georges River Junction gauge (refer to Section 4.4.2ii) with the frequency of historical flow rates less the extracted volume. The result is a revised flow duration curve which represents the impacted daily streamflow regime. Impacts to the streamflow regime are shown in the following:

- Figure 6.3 presents the reduction in streamflow as a percentage of total streamflow throughout the flow duration curve.
- Figure 6.4 presents the percentage reduction in streamflow frequency throughout the flow duration curve.

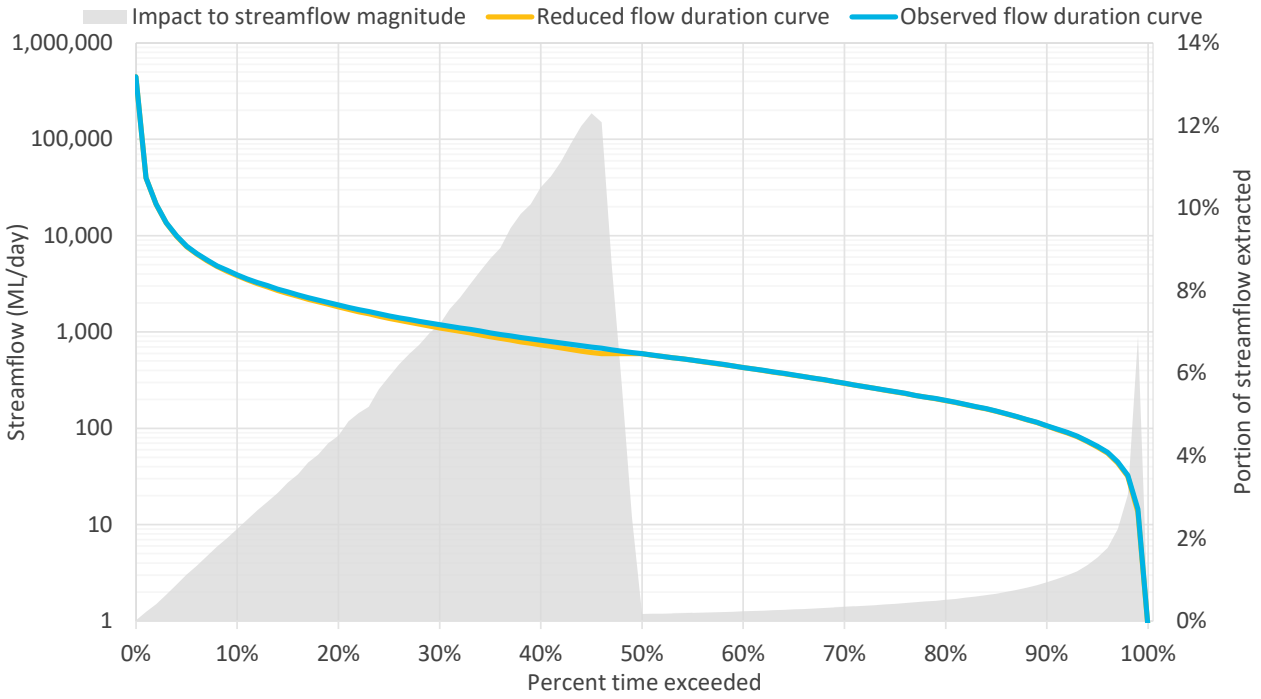


Figure 6.3 **Impact to flow duration curve – proportion of streamflow extracted**

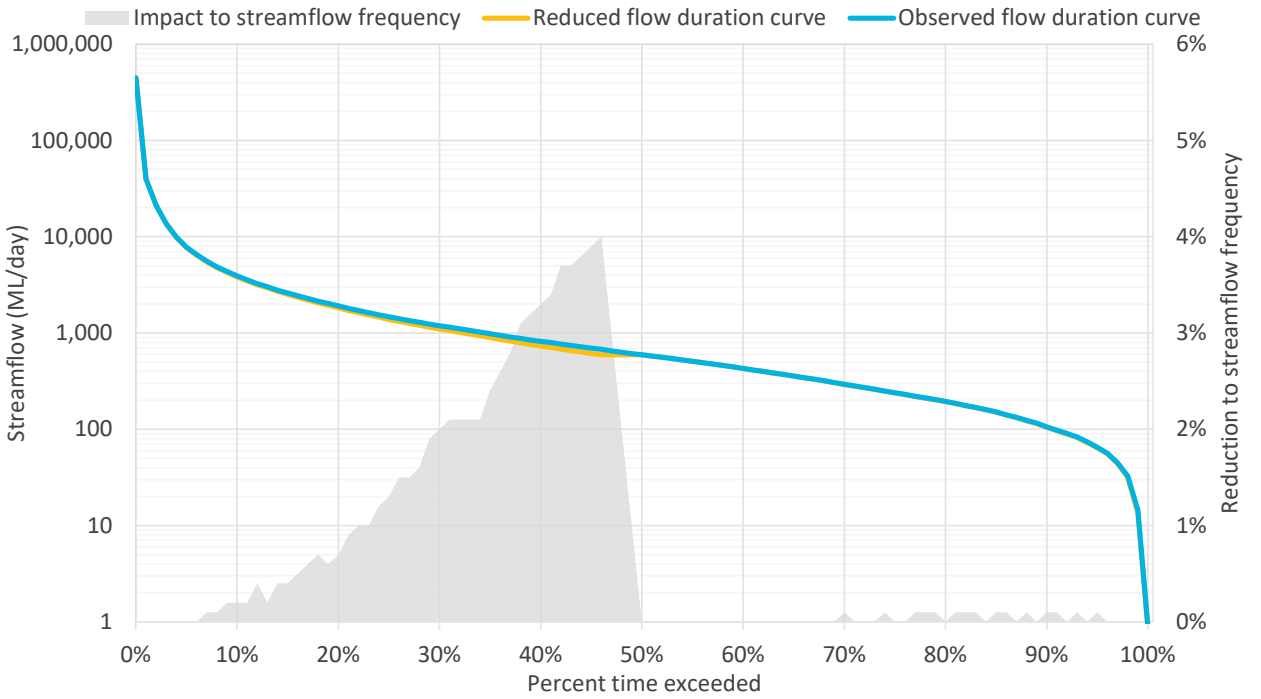


Figure 6.4 **Impact to flow duration curve – reduction to streamflow frequency**

The flow duration curve data shown in Figure 6.3 and Figure 6.4 indicates:

- There is generally little difference between the shape and magnitude of the observed (blue line) and reduced (yellow line) flow duration curves. This indicates minimal impacts to the percentage of time a particular streamflow is exceeded.

- Extracting water for general construction purposes may result in a maximum 6.9% reduction in the streamflow volume that is exceeded 99% of the time (14 ML/day). This impact would only occur if very low flow conditions were experienced during the construction period.

- Extracting water for general construction purposes is predicted to have less than a 1% impact on the streamflow magnitude for 90% of Macleay River flow conditions. Extracting water for construction purposes has negligible impact on the frequency at which a particular flow rate occurs.

- The maximum potential streamflow reduction of 12.6% occurs at a streamflow of 683.4 ML/day, when the full 86.4 ML/day extraction rate can be achieved while maintaining the 50th percentile streamflow of 597 ML/day. The impact of the proposed extraction on streamflow magnitude decreases as the observed streamflow increases so that on average an extraction rate of 86.4 ML/day results in a 6.1% reduction to streamflow based on the historical streamflow record

- The maximum reduction in streamflow frequency of 4.0% also occurs at a streamflow of 683.4 ML/day. The impact on streamflow frequency decreases as the observed streamflow increases.

It should be noted the impacts presented in this section have been determined by applying the proposed extraction rules to the entire length of the historical streamflow record, representing potential impacts should the proposed extraction regime be continued in perpetuity. The largest impacts are associated with the initial storage fill component which is a one-off take and is likely to be fulfilled within a 12 month period. In a high flow year, the initial storage fill volume may be achieved within a three-month period, after which the extraction of water would be limited to that required for general construction purposes only (1 ML/day).

iii Impacts on a typical streamflow event

The impacts to the streamflow duration curve described in Section 6.3.7ii represent changes to the Macleay River streamflow regime if the proposed extraction regime was continued in perpetuity. As the initial storage fill is a one-off take occurring over a relatively short period of time (3–12 months), potential impacts to individual streamflow events are considered to be more representative of actual impacts. The impact of the proposed extraction regime on a typical streamflow event is shown in the following:

- Figure 6.5 presents the reduction in streamflow as a percentage of total streamflow over the length of the streamflow event

- Figure 6.6 compares the cumulative extraction volume and the cumulative streamflow volume over the length of the streamflow event.

The typical streamflow event analysed in Figure 6.5 and Figure 6.6 occurred from June to August 2017 and has a peak mean daily streamflow of 10,750 ML/day. Streamflow events of this magnitude occur approximately 2–3 times per year. It is expected that most of the initial storage fill volume will be extracted during similar streamflow events.

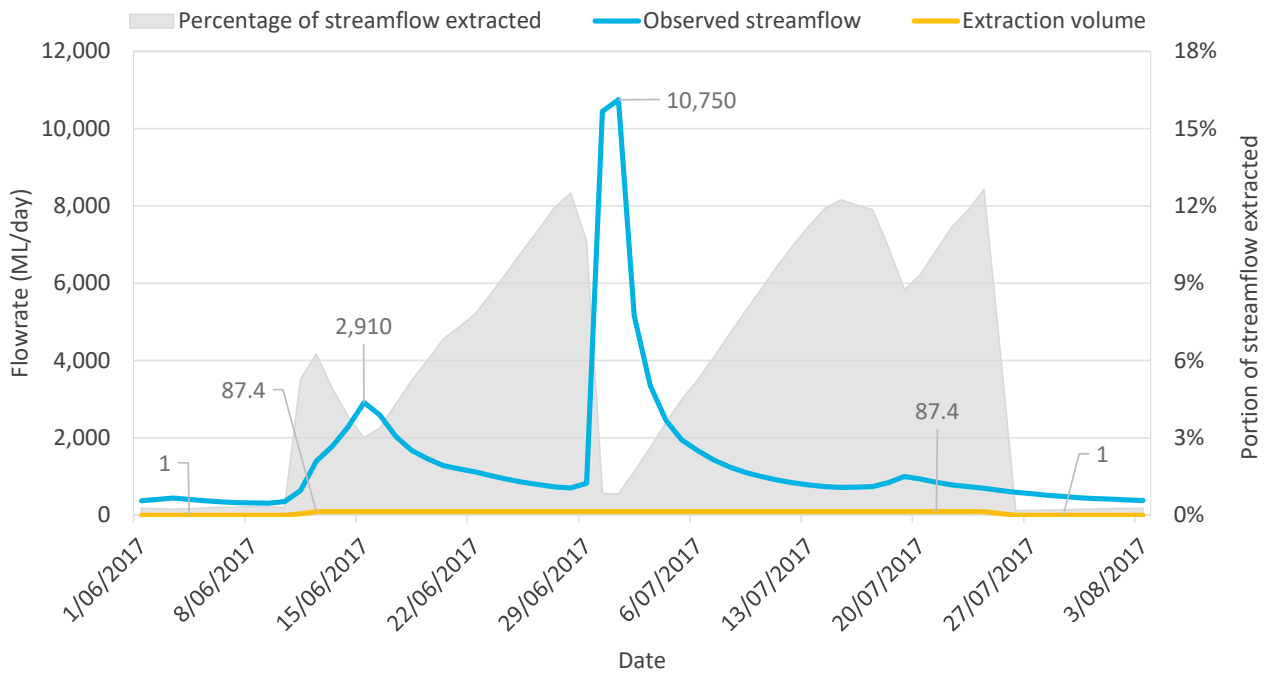


Figure 6.5 **Impact on typical streamflow event – portion of streamflow extracted**

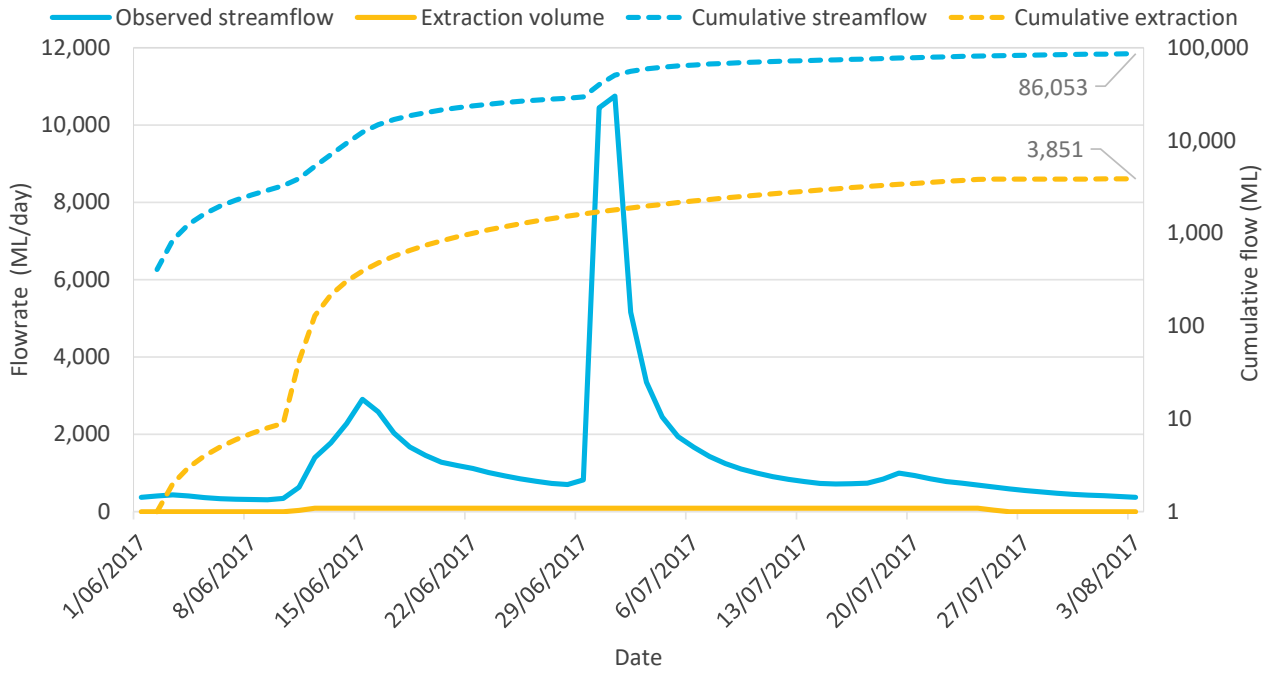


Figure 6.6 **Impact on typical streamflow event – cumulative extraction volume**

The impacts to a typical streamflow event shown in Figure 6.5 and Figure 6.6 indicate:

- The maximum streamflow reduction of 12.6% (refer to Section 6.3.7ii) only occurs for a short period (hours) of time when extraction first commences or just before CTP conditions occur. Streamflow impacts decrease as the observed streamflow rate increases.
- The maximum extraction volume of 87.4 ML/day (construction and initial storage fill requirement) results in less than a 1% reduction to the streamflow event peak flow rate of 10,750 ML/day.
- Based on the entire streamflow record, the maximum extraction volume (87.4 ML/day) results in a 6.1% reduction to streamflow on average when the initial storage fill extraction is occurring. Streamflow impacts associated with the 1 ML/day construction water take are negligible.
- The total extraction volume (3,851 ML) represents 4.5% of the total streamflow volume (86,053 ML) over a the two-month period shown in the figures.

It is noted the above impacts are only representative of one particular streamflow event. Actual impacts would vary depending on the streamflow characteristics at the time initial storage fill extraction occurs, but are expected to be broadly consistent in order of magnitude terms.

iv Impacts during and following low flow conditions

No streamflow impacts are anticipated during very low flow (less than 13 ML/day) or extended dry/drought conditions as extraction will cease under such conditions. Indirect impacts following an extended dry period will be mitigated by waiting seven days before extracting from the first high flow event (greater than 50th percentile) following an extended dry period.

Impacts to the Macleay River when streamflow is less than the 50th percentile (597 ML/day) value are limited to the extraction of water at low rates (up to 1 ML/day) for construction purposes. The streamflow impacts described in Section 6.3.7ii indicate the change in streamflow regime below the 50th percentile value is generally less than 1%.

Extracting water at higher pump rates for initial storage fill (up to 86.4 ML/day) will not occur during low flow conditions.

v Impacts on streamflow depth

This section describes the predicted impact to streamflow depth due to the proposed extraction regime. Impacts are described in relation to the streamflow depth at the Macleay River at D/S Georges River Junction gauge using available rating curve data (WaterNSW, 2021b). The impacts to streamflow depth at the Macleay River at D/S Georges River Junction gauge location are shown in Figure 6.7. The following impacts are predicted:

- A maximum reduction in depth of 0.05 m, which represents a 5% change in depth from a streamflow rate of 683.4 ML/day (0.95 m depth) to a streamflow rate of 597 ML/day (0.90 m depth).
- No material impacts on streamflow depth are anticipated when extracting 1 ML/day for construction purposes.

While the impacts described above only represent one cross-section of the river, streamflow depth impacts along other sections of the river are expected to be of a similar magnitude (i.e. centimetres). The potential impact on streamflow depth is greatest in the section of river immediately downstream of the initial storage fill extraction location and is expected to decrease with distance from the extraction location as downstream tributaries contribute additional streamflow to the Macleay River.

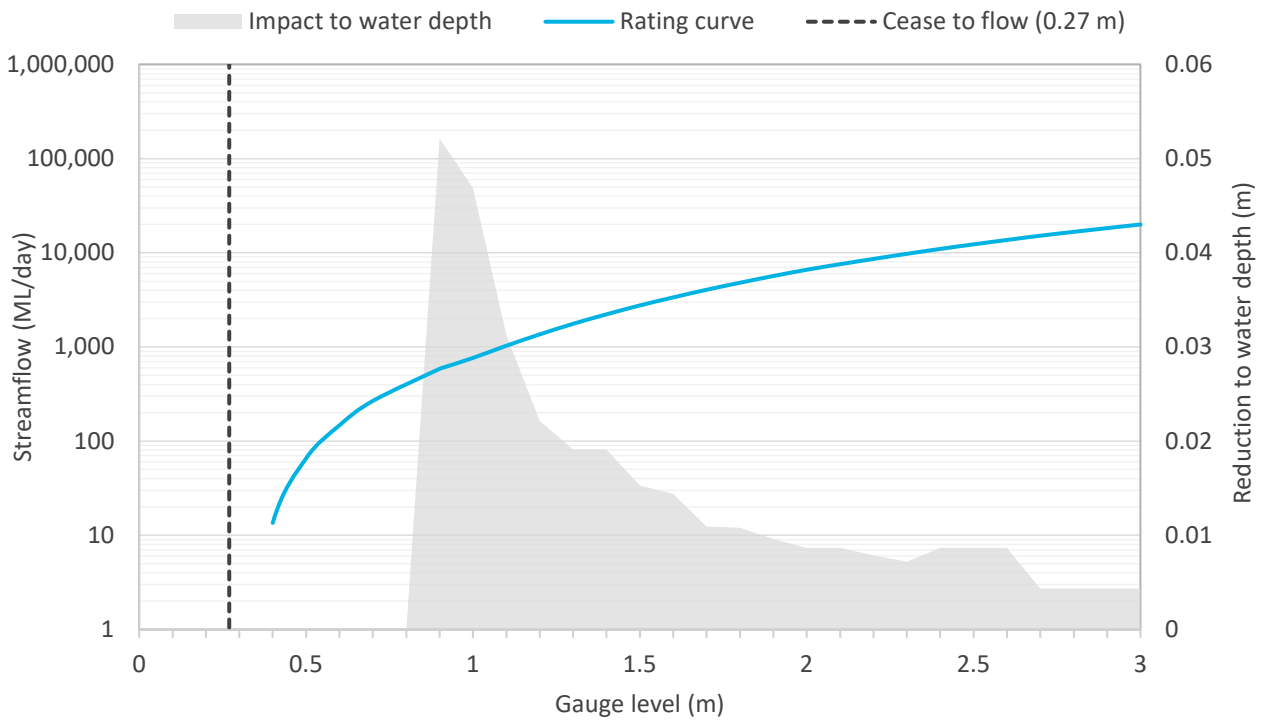


Figure 6.7 Impact on streamflow depth at gauge location

vi Impacts to geomorphology

Extraction for the initial storage fill is predicted to result in a maximum reduction in flow depth of 0.05 m (refer to Section 6.3.7v), which represents a 5% change in depth from a streamflow rate of 683.4 ML/day (0.95 m depth) to a streamflow rate of 597 ML/day (0.90 m depth). The reduction in water depth due to extraction is expected be associated with a similar, relatively small, reduction in bed shear stress. This implies a reduction in the likelihood, spatial extent, or particle size range of bed sediment mobilisation at times of water extraction from the river.

The overall impact of water extraction on sediment transport processes in the Macleay River will be to create conditions that emulated a slightly drier period with lower flood peaks. This would have a minor short-term impact, and a negligible long-term impact, on sediment transport processes within the river.

vii Influence of downstream catchment on gauged flows

The proposed initial storage fill extraction location (refer to Figure 5.1) is located several kilometres upstream of the Macleay River at D/S Georges River Junction gauge. Several tributaries, including Georges Creek flow into the Macleay River between the extraction location and the streamflow gauge. The catchment area downstream of the proposed initial storage fill location is approximately 334 km^2, or 4% of the total Macleay River catchment area (7,930 km^2) reporting to the gauge location.

Localised rainfall may result in an increase to streamflow in these tributaries and the flow recorded at the Macleay River at D/S Georges River Junction gauge without a similar rise occurring from the broader upstream Macleay River catchment. In such circumstances, streamflow conditions recorded at the gauge may not be representative of conditions at the proposed extraction location.

The influence of the downstream catchment at the Macleay River at D/S Georges River Junction gauge is expected to have negligible impact the outcomes of this assessment as:

- The relatively small downstream contributing catchment (4%) is unlikely to result in a material portion of streamflow at the gauge during regional rainfall events.
- Localised rainfall that results in a streamflow response from the downstream catchment alone are expected to occur infrequently compared to localised rainfall events that occur over the remaining 96% of the catchment.

The residual risk associated with localised rainfall events causing a rise in streamflow at the gauge while low flow conditions are observed at the point of extraction is expected to be mostly mitigated through the following visible flow condition applied to all access licences:

> Water must only be taken when there is a visible flow in the water source at the location where water is to be taken.

Some residual risk remains where the visible flow condition would allow extraction to commence when streamflow at the Macleay River at D/S Georges River Junction gauge satisfies the CTP conditions proposed in Section 5.5.4 but streamflow at the pump site does not. It is anticipated that this scenario would have a low chance of occurring during the initial storage fill period.

6.4 Impacts to surface water quality

6.4.1 Overview

Construction of the Project has the potential to result in the following impacts to water quality:

- increased sedimentation in receiving waters due to stormwater discharges and runoff from disturbance and construction areas and the direct disturbance of watercourses via instream works
- contamination of receiving waters due to uncontrolled spills or leaks of hazardous materials from disturbance, storage, and construction areas
- increased nutrients, hydrocarbons and metals in receiving waters resulting from controlled discharges
- changes to the ambient water quality of the Macleay River due to indirect effects of reduced streamflow due to water extraction
- increased concentrations of sediment and dissolved metals in receiving waters due to stormwater discharges and seepage from spoil emplacement areas.

This section assesses impacts to the water quality of minor watercourses and the Macleay River during construction of the Project.

6.4.2 Stormwater discharges

Construction of the Project will unavoidably require the removal of vegetation and disturbance of soils. Access roads and construction areas will also require the establishment of unsealed hardstand areas. Erosion and sediment controls (to be outlined in ESCPs) are proposed to manage sediment laden runoff from disturbance areas.

Erosion and sediment controls are expected to effectively remove coarse sediment in runoff from disturbance areas. Where practical, sediment basins are proposed to capture and treat runoff from disturbance areas. The basins are expected to:

- prevent discharge of sediment laden water for rainfall events up to the design capacity; and
- during overflow conditions, provide sediment treatment, reducing the concentration of sediment entering receiving waters.

It is expected the proposed controls will mitigate most potential water management impacts. Some residual water quality impacts may be experienced as a result of sediment basin overflows which will occur approximately 4–6 times per year[1] during and following intense or prolonged periods of wet weather. Any residual impact is expected to be short-term (i.e. when the basin is overflowing) and nearfield as substantial dilution would occur downstream of the sediment basin under wet weather conditions.

For Project areas where the construction of sediment basins is not feasible due to terrain or other constraints, erosion and sediment controls may not effectively remove fine dispersive sediments from disturbed area runoff. Stormwater discharges from construction areas entrained with fine and potentially dispersive sediments are expected to enter receiving waters during and shortly after rainfall. It is expected that any sediment laden water that enters the Macleay River will be significantly diluted by river flows and will rapidly dissipate.

It should be noted the residual risk will only occur during the construction phase (approximately 5 year period) of the Project with the greatest risk occurring during site establishment (1–2 year period) when the disturbance area is greatest.

Risks associated with potential spills or leaks of hazardous materials will be readily managed by controls that will be documented in the SWMP and ESCPs, as described in Section 5.3.

6.4.3 Instream works

The proposed management measures described in Section 5.9 are expected to mitigate water quality risks associated with the direct disturbance of watercourses via instream works. Hence, no material water quality impacts resulting from instream works are anticipated to occur during construction.

6.4.4 Controlled discharges

i Treated wastewater

Treated wastewater will be discharged to the nearest drainage line and ultimately the Macleay River. It is estimated that treated wastewater will be discharged at a rate of 0.15 ML/day. The STP(s) will be designed in general accordance with the *National Water Quality Management Strategy: Australian Guidelines for Sewerage Systems* (ANZECC, 1997) with the aim to minimise risk to receiving water quality. However, some residual risk remains where concentrations of contaminants in treated water (e.g. nitrogen and phosphorus) are above the WQOs and ambient receiving water values.

ii Concrete batching plant(s)

Water management risks and potential impacts associated with concrete production can be eliminated or reduced to as low as reasonably practicable by appropriate site design and controls well understood and regularly applied within the construction industry.

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

The CBP(s) will be designed to minimise risk to receiving water quality. However, some residual risk remains where concentrations of contaminants in treated water (e.g. nutrients and metals) are above the WQOs and ambient receiving water values.

iii Tunnel affected water

Tunnel affected water dewatered from the underground works will be stored in a sediment basin(s) prior to treatment and reuse back underground. Inflows to the sediment basin(s) will be comprised of intercepted groundwater along with a portion of the underground works process water supply. The quality of tunnel affected water will be a function of:

- the groundwater inflow quality
- any degradation caused by construction activities such as drilling.

a Groundwater inflow quality

The majority of tunnel affected water will occur from groundwater inflows. Groundwater quality across the Project area is characterised as (EMM, 2022a):

- slightly acidic with pH values typically ranging from 5.1 to 6.7
- low to moderate salinity with electrical conductivity typically ranging from 124 µS/cm to 995 µS/cm
- typical (as indicated by median values) nutrient concentrations are three to four times greater than the WQO values and ambient receiving water quality
- typical (as indicated by median values) metals concentrations are similar to the WQO values and ambient receiving water quality except for iron which is approximately five times greater than the WQO value and eight times greater than the ambient receiving water quality.

b Underground construction activities

A summary of construction activities that will occur underground and the associated water quality risks is provided in Table 6.1.

Table 6.1 Tunnel affected water quality – construction activity risks

Construction activity	Associated water quality risks
Use of explosives	Nitrates
Drilling and spoil generation	Suspended solids
Concreting and grouting	Alkaline water (i.e. high pH), nitrates, metals
Plant and equipment washdown	Hydrocarbons, nutrients, metals, surfactants (associated with detergents)
Leaks and spills	Hydrocarbons, metals

c Expected water quality of discharges

It is expected that the quality of water dewatered from the underground works will be highly variable. Generally, the water quality is expected to reflect the quality of groundwater inflows with varying degrees of degradation from construction activities. The expected water quality characteristics of tunnel affected water are described in Table 6.2.

Table 6.2 Expected water quality – tunnel affected water

Underground works	Expected water quality characteristics
Construction is complete	• The water quality of completed tunnel sections is expected to be similar to the quality of groundwater inflows. • There is some risk of degradation due to broader construction activities such as vehicle movements and spoil removal. However, the relative impacts on water quality characteristics are anticipated to be minor.
Construction is occurring	• Salinity levels are expected to be similar to levels in groundwater inflows. • Construction activities may result in changes to pH and increases to suspended sediment, hydrocarbons, nutrients, and metal concentrations. The magnitude of degradation is expected to be highly variable.

d Impacts to receiving watercourses

Excess tunnel affected water will be discharged to the local receiving environment and ultimately the Macleay River. Tunnel affected water will be treated prior to discharge with the level of treatment depending on the observed water quality. The following treatment approach is proposed:

1. If the water quality is suitable for discharge to the receiving environment, excess water will be allowed to overflow directly from the basin without any further treatment.

2. If the water quality is unsuitable for discharge to the receiving environment, additional treatment measures will be applied to improve water quality prior to overflow or controlled discharge.

The above treatment approach is expected to minimise water quality risks to the immediate receiving watercourse and the Macleay River. Some residual risk may remain to the immediate receiving watercourse where concentrations of contaminants in treated water are above the WQOs and ambient receiving water values.

Residual water quality impacts to the Macleay River are anticipated to be minor and localised given typical streamflow values in the river are three to four orders of magnitude greater than the estimated process water discharge rate (0.2 ML/day) and substantial mixing and dilution will occur.

6.4.5 Indirect effects of reduced streamflow

Extracting water from the Macleay River for construction and initial storage fill has the potential to impact river water quality via two primary mechanisms:

- Direct impacts associated with the disturbance of the river and banks during the installation of pump and pipe infrastructure resulting in increased turbidity and suspended sediment.

- Indirect impacts associated with reduced streamflow resulting in increased turbidity and temperature and decreased dissolved oxygen concentrations and mixing of nutrients. Several follow-on effects may also result from changes to water quality including eutrophication and potential formation of algal blooms.

Potential water quality impacts resulting from the installation of pumps and pipeline infrastructure will be mitigated through use of appropriate construction methodologies and management procedures. The construction approach for working near and within watercourses will be documented within the Project SWMP.

Water quality impacts resulting from reduced streamflow are more likely to occur under low flow conditions when flows are shallower and there is less turnover of water in pool sections. Extracting the initial storage fill volume under high flow (above 50th percentile) only conditions is expected to maintain sufficient throughflow to minimise any water quality impacts resulting from stagnant or low flowing water.

A reduction in streamflow depth can result in increased water temperatures due to increased solar heating. The initial storage fill extraction is estimated to result in a maximum 0.05 m (or 5%) reduction in streamflow depth. Given the relatively minor decrease in water depth, it is not anticipated any material changes to water temperature would occur as a result. Furthermore, the impact to both streamflow and resulting water quality such as temperature will decrease moving downstream from the extraction location as additional catchment areas contribute flows to the Macleay River.

Water quality monitoring is proposed (refer to Chapter 9) downstream of the initial storage fill extraction location to identify and respond to any residual water quality impacts that may occur during the initial storage fill period. The response to identified water quality impacts will be developed and documented via a suitable trigger action response plan (TARP) within the SWMP, with the water quality monitoring results used as a trigger.

6.4.6 Risks associated with spoil emplacements

Waste rock generated from drill and blast activities will primarily comprise of large rocks. The waste rock will be land formed into engineered spoil emplacement areas near the upper and lower dams and reservoirs. In addition to typical water quality risks associated with construction activities (ie increased sediment), water that passes through the spoil emplacements has the potential to leach metals and other constituents from the rock. This section describes the mechanisms by which discharge from the spoil emplacements may occur and assesses the potential water quality risks.

i Discharge regimes

Discharge from the spoil emplacements is predicted to primarily occur as a result of direct rainfall onto the emplacement which percolates through the rock matrix and discharges at the toe of each landform as seepage. Surface water runoff from the spoil emplacements is not expected due to the predicted high permeability of the rock landform.

There is potential for water that collects at the base of the rock landform to infiltrate into underlying shallow groundwater systems. However, infiltration rates into the shallow groundwater system are anticipated to be relatively minor.

All seepage and stormwater runoff from emplacement areas will be captured in sediment basins. The sediment basins will discharge to the receiving environment following intense or prolonged rainfall.

ii Seepage water quality

A geochemistry assessment was completed to characterise the waste rock in terms of mineralogy, acid forming potential and leachate quality. The geochemistry assessment is provided as Appendix N of the EIS (EMM, 2022e). Potentially acid forming material was not identified in the waste rock. The waste rock was classified as virgin excavated natural material as chemistry results indicated the material does not leach metals or metalloids in excess of the adopted criteria for general solid waste.

The leachate results indicate dissolved metals concentrations are generally below or similar to the laboratory detection limits except for:

- aluminium which ranged between 2.4 mg/L and 4.2 mg/L
- iron which ranged between 1.0 mg/L and 5.9 mg/L.

It should be noted that actual concentrations within seepage from the emplacements may vary from the values observed in the leachate testing. Hence, the leachate testing results have been used to identify water quality risks associated with the spoil emplacements rather than as a predictor of expected water quality in the section below.

iii Receiving water impacts

The proposed sediment basins to be established downstream of emplacement areas during construction are expected to effectively manage coarse sediment. However, overflows from the basins may have elevated turbidity if fines are mobilised in stormwater runoff from the construction area. Leachate results indicate seepage from the emplacements may have elevated aluminium and iron concentrations.

The sediment basins are expected to:

- prevent discharge of sediment laden water and water containing elevated aluminium and iron concentrations for rainfall events up to the design capacity
- during overflow conditions, provide sediment treatment, reducing the concentration of sediment entering receiving waters.

The sediment basins are not predicted to reduce aluminium and iron concentrations during overflow conditions. However, overflows from sediment basins will only occur during and shortly after significant wet weather events when elevated streamflow in receiving waters is likely to occur. Substantial dilution is anticipated to occur within watercourses immediately downstream of the emplacement areas. Any residual sediment or metals that enter the Macleay River will be further diluted by river flows and will rapidly dissipate.

It should be noted the ambient water quality of minor watercourses (refer to Section 4.6.3) frequently exceed the WQO values for aluminium and iron. Ambient water quality concentrations are generally less than the predicted leachate water quality results, however, concentrations similar to the leachate results were observed in isolated instances.

6.5 Impacts to environmental receptors

6.5.1 Water availability

Streamflow extraction can increase the frequency and duration of low flow conditions leading to a disruption to flow cues, impeded fish passage and reduced habitat availability. Impacts to environmental water availability in the Macleay River are summarised as follows:

- The maximum estimated water level reduction of 0.05 m (or 5% of streamflow depth) in the Macleay River is anticipated to have minimal impacts on local habitat availability. Water level impacts are predicted to decrease as the observed streamflow increases. Predicted impacts to depth and habitat availability will also rapidly reduce moving downstream as additional catchment area contributes to streamflow in the river.
- No material impacts to fish passage are predicted as it is proposed to extract the initial storage fill under high flow conditions (50th percentile) when it is expected that sufficient flow will be available to allow fish movement over riffle sections and other potential barriers.

- Numerous species in the Macleay River rely on flow cues. It is likely that each species will rely on specific flow cues that occur at separate or overlapping times of the year, so that as a whole, flow cues may be relied on year-round and so seasonal extraction conditions may not adequately protect all species present. Maintaining the 50th percentile streamflow value (597 ML/day) is expected to minimise disruption of flow cues by allowing low and moderate streamflow events (i.e. less than 597 ML/day) to pass downstream unimpacted by the Project.

- For species that rely on higher streamflow cues (i.e. greater than 50th percentile), the maximum streamflow reduction is 12.6% which generally only occurs when extraction first commences or immediately prior to CTP conditions being triggered. Streamflow events that have low peak flow rates experience the largest impacts as the maximum extraction volume (87.4 ML/day) represents a greater portion of streamflow. Typically, the observed streamflow peak is substantially larger than the maximum extraction volume which may be as little as 1% of the observed streamflow peak.

The largest potential impacts occur during the initial storage fill period which is estimated to take 3–12 months. Hence, any minor residual impacts on environmental water availability will be short term.

6.5.2 Pumping infrastructure and fish screening

The installation and operation of pump infrastructure within a watercourse can inadvertently result in the uptake of aquatic species and debris. To minimise potential impacts associated with extracting water from the Macleay River, fish screening is to be installed on pump infrastructure in general accordance with:

- *The practical guide to modern fish-protection screening in Australia* (Boys, Rayner, Kelly, Doyle, & Baumgartner, 2021)

- *Design specifications for fish protection screens in Australia* (Boys, Design specifications for fish-protection screens in Australia. Edition 1. NSW Department of Primary Industries., 2021).

As several factors require consideration when designing an effective fish-protection screen, OMPS will continue to consult with NSW DPE Water and NSW DPI Fisheries over the fish screen design moving forward and into detail design. The implementation of appropriate fish screens is expected to mitigate the potential risks associated with pump operation.

6.5.3 Blockage of fish passage

The majority of waterway crossings are not expected to be constructed within key fish passage habitat and hence no impacts are anticipated. Applying the relevant fish passage guidelines is expected to mitigate most of the residual impacts associated with constructing waterway crossings within potential fish passage corridors.

The construction of the upper and lower dams and reservoirs and dams will unavoidably block fish passage along Fingerboard Crossing Creek. The blockage of fish passage is assessed in more detail in Appendix I of the EIS (Stantec, 2022).

The construction of the Macleay River bridge crossing will provide sufficient waterway area and flow conditions to maintain fish passage during construction and operation.

6.6 Impacts to existing water users

6.6.1 Water availability

The largest water user in proximity to the Project area is a 243 ML water entitlement for irrigation purposes and is approximately 24 km downstream of the proposed initial storage fill extraction location (refer to Figure 4.14). The largest downstream water user is KSC which holds approximately 73% (10,141 ML) of the downstream water entitlements.

Extracting water for construction and initial storage fill is not expected to impact the security of water supply to downstream users as:

- The maximum extraction volume in a given year (6,865 ML) represents on average 1% of the annual streamflow volume adjacent to the Project area and hence water available to downstream users.
- Extracting water for construction at a rate of 1 ML/day is expected to be in line with extraction rates experienced across the broader Macleay River catchment and is predicted to have less than a 1% impact on the streamflow regime for 90% of Macleay River flow conditions adjacent to the Project area.
- It is proposed to maintain the 50th percentile streamflow when extracting water at higher rates (up to 86.4 ML/day), thus no impacts to downstream water security are expected during periods of low flow.
- High-flow-only access means there will still be a minimum of 597 ML/day available for downstream users when water for initial storage fill is being extracted.
- Only general construction water will be extracted (at rates of up to 1 ML/day) when streamflow is below the 235 ML/day used to define KSC town water supply restrictions (refer to Attachment A). Hence, an increase in the time and frequency water restrictions occur is not expected as a result of the Project.
- The maximum reduction in streamflow is approximately 12.6% when the full 86.4 ML/day initial storage fill extraction is realised. The proportion of streamflow extracted, and associated impacts decrease with distance downstream of the extraction site as the contributing catchment increases. In the context of the downstream users identified above:
    - An additional 665 km^2 (9%) catchment area contributes streamflow to the Macleay River at the 243 ML entitlement irrigation property 24 km downstream of the Project area.
    - An additional 2,604 km^2 (34%) catchment area contributes streamflow to the Macleay River at KSC's offtake location approximately 140 km downstream of the Project area.
- Most of the water take will occur during the initial storage fill period which is a one-off take and will occur for a relatively short period of time (i.e. 3–12 months). Hence, any residual impacts would be short-term.

6.6.2 Water quality

Water that is discharged from the Project during construction may have elevated concentrations of sediment, nutrients and some metals (refer to Section 6.4). Project discharges that exceed the ambient water quality of the Macleay River have the potential to impact the quality of water extracted by downstream users.

The nearest downstream water user for irrigation purposes is a 12 ML water entitlement approximately 16 km downstream of the PHGW and ancillary infrastructure (i.e. where most of the Project discharges are expected to occur). The nearest downstream water user for town water supply relates to the township of Bellbrook approximately 60 km downstream of the PHGW and ancillary infrastructure.

Project discharges during construction are not expected to result in material impacts to the quality of water extracted by downstream users as:

- Substantial dilution is anticipated to occur in the Macleay River at, and immediately downstream of, the point of discharge.
- Further dilution is expected to occur moving downstream as the contributing catchment to the river increases. In the context of the downstream users identified above:
  - An additional 570 km^2 (8%) catchment area contributes streamflow to the Macleay River at the nearest water user property 16 km downstream of the PHGW and ancillary infrastructure.
  - An additional 1,443 km^2 (19%) catchment area contributes streamflow to the Macleay River at the Bellbrook offtake location approximately 60 km downstream of the PHGW and ancillary infrastructure.

Management measures to mitigate water quality risks associated with Project discharges will be documented in the SWMP and ESCPs described in Section 5.3.

6.7 Impacts to groundwater and connected surface water systems

Groundwater modelling (EMM, 2022a) indicates groundwater drawdown, resulting in streamflow and baseflow losses to several minor watercourses and the Macleay River, is predicted to occur during construction of the Project. The maximum streamflow and baseflow loss of 194 ML/year occurs in the fourth year of construction and represents an approximate 1% reduction in flow from the Project area compared to existing conditions.

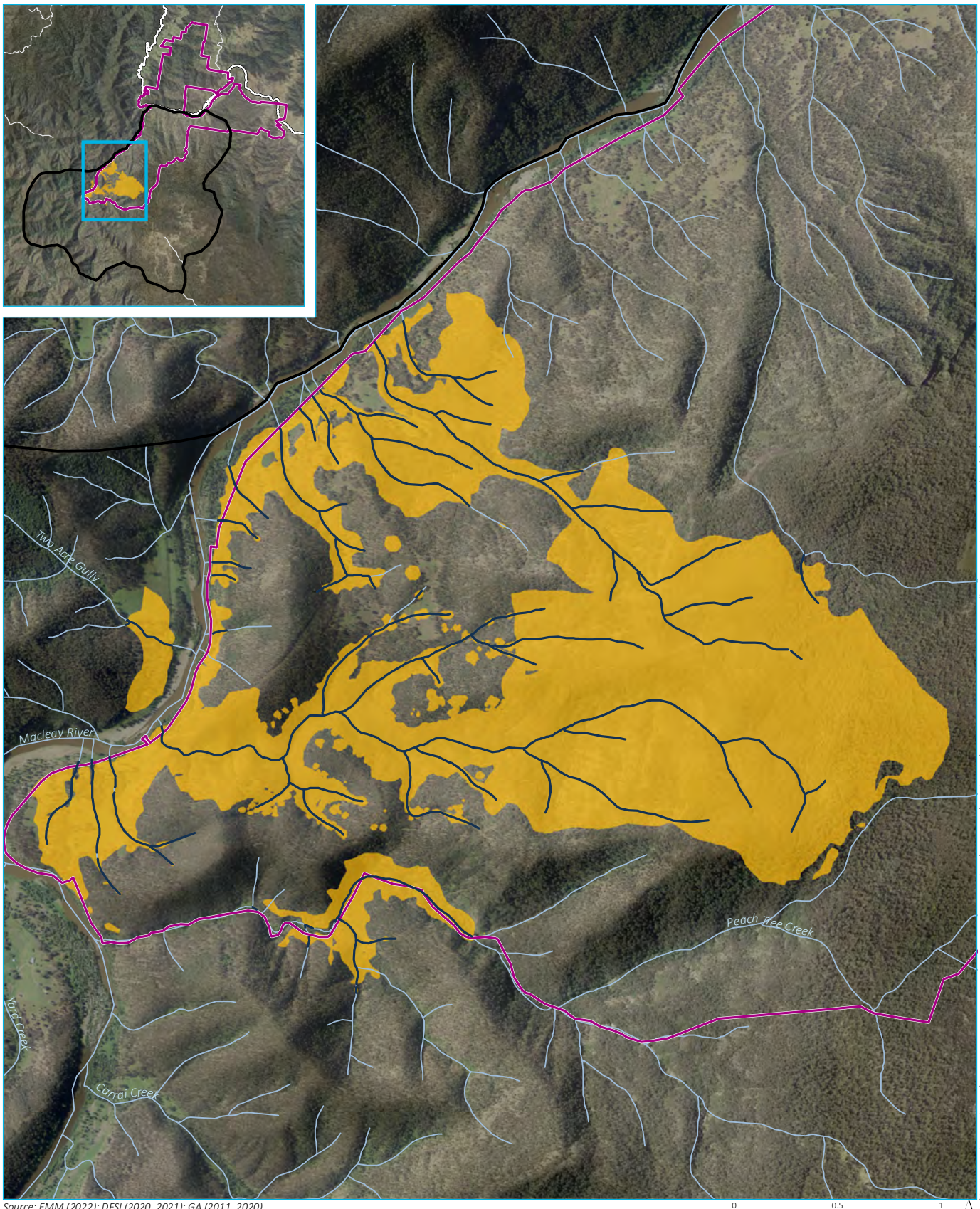
The predicted streamflow and baseflow losses during construction are summarised in Table 6.3.

Table 6.3 Streamflow and baseflow losses during construction

Construction year	Streamflow losses (ML/year)		Baseflow losses (ML/year)		Total losses (ML/year)
	Macleay River	Minor watercourses	Macleay River	Minor watercourses	All watercourses
1	11	0	37	25	73
2	28	0	90	42	160
3	31	0	105	46	182
4	33	0	113	48	194
5	33	0	117	43	193

Greater losses are experienced in the Macleay River compared to the minor watercourses due to a greater connectivity to the regional groundwater system via the adjacent alluvium. It is noted the predicted total losses represent a relatively small component of flows in the surface water system. For example, the maximum total loss of 194 ML/year in the fourth year of construction represents approximately 0.02% of the average annual streamflow in the Macleay River.

Baseflow losses to minor watercourses are anticipated to be greatest for watercourses closest to the underground works. The magnitude of baseflow losses decreases radially from the tunnel alignment. Regardless, the maximum baseflow loss to minor watercourses of 48 ML/year in the fourth year of construction represents less than 1% change in baseflow to minor watercourses across the Project area. No streamflow losses are predicted for minor watercourses. Watercourses that are predicted to experience groundwater drawdown and hence baseflow losses during the construction phase are identified in Figure 6.8. All baseflow losses occur within the Macleay Gorges Water Source.



Source: EMM (2022); DFSI (2020, 2021); GA (2011, 2020)

0 0.5 1 km

GDA 1994 MGA Zone 56

N

KEY

- Project area
- Area potentially affected by groundwater drawdown
- Watercourse potentially impacted by drawdown
- Groundwater model domain
- Watercourse/drainage line
- Kempsey-Armidale Road (refer to inset)

Watercourses impacted by groundwater drawdown during construction

Oven Mountain Pumped Hydro Energy Storage Project
Surface water assessment
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Figure 6.8

EMM creating opportunities

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6.8 Flooding regime

6.8.1 Fingerboard Crossing Creek

Impacts to the Fingerboard Crossing Creek flooding regime will occur once construction of the lower and upper dams and reservoirs commences and will vary over the construction period. Impacts are anticipated to be minor during the initial stages of construction when cofferdams and bypass tunnels will be established (refer to Table 5.3) to divert flows around construction areas.

The cofferdams will be designed to bypass flows and provide flood immunity up to the 1% AEP design flood event. A minor reduction in peak flows may occur while the cofferdams are in place. However, the overall volume of flood waters is not anticipated to be impacted. Flood events that exceed the 1% AEP design flood criteria may result in floodwaters entering the dam and reservoir construction areas.

Once the lower and upper dams and reservoirs are constructed, flood flows within Fingerboard Crossing Creek will be entirely captured within the dams and reservoirs until the operational capacity is reached. After which impacts to the Fingerboard Crossing Creek flooding regime will be the same as those described for the operational phase in Section 7.8.1.

6.8.2 Macleay River

Hydraulic modelling results from the Project feasibility design (SMEC, 2022) and the Eastern Access Road hydraulic assessment were used to inform the description of construction phase flooding impacts and risks. Project infrastructure that are within the Macleay River limit of flooding and the associated impacts are described in Table 6.4.

Table 6.4 Macleay River flooding impacts

Project infrastructure	Likely impact on flooding
Macleay River pump facility	The Macleay River pump facility will be located partially within the Macleay River (the pump intake screens) and partially above the 1% AEP flood level (the remainder of the pump facility infrastructure). The pump intakes will generally be circular, providing high hydraulic efficiency for river flows and minimising flood impacts. Negligible localised increases in flood levels are expected immediately upstream of the pump intake. The pump intake will be predominantly below low flow water levels, and as such flood impacts are expected to reduce in scale with an increase in flood magnitude.
Infrastructure adjacent to the Macleay River	The accommodation camp, mechanical workshop, site office, CBP, laydown area, lower dam and reservoir are located adjacent to the Macleay River. All Project infrastructure is situated above the existing 0.01% AEP flood level. Minimal localised impacts to flooding are possible during very rare flood events (e.g. the PMF).
Access roads	The access road from the lower dam and reservoir to Georges Junction is situated above the existing 0.01% AEP flood level, representing a low flood impact risk. Minimal localised impacts to flooding along this section of road are possible during very rare flood events (e.g. the PMF). Between Georges Junction and the Macleay River bridge crossing, the access road (Eastern Access Road) is predominantly located above the 1% AEP flood level. Several tributaries of the Macleay in this area experience back water flooding during a 1% AEP flood event, which extends to the location of the Eastern Access Road. However, the Eastern Access Road infrastructure is not expected to control flood levels in the Macleay River via this flood mechanism. During rare flood events (ie greater than 1% AEP), the Macleay River is predicted to inundate the Eastern Access Road for a 1 km section opposite Middle Creek and immediately adjacent to the western approach to the Macleay River bridge crossing. Flood impacts under these conditions are expected to be localised and immaterial relative to the scale of the flood event.

Table 6.4 Macleay River flooding impacts

Project infrastructure	Likely impact on flooding
Macleay River bridge crossing	The proposed Macleay River bridge crossing will extend approximately 100 m across Carrolls Creek and the Macleay River at a level of 113 m AHD. This low-level crossing is expected to be inundated once a year on average for approximately 20 hours duration. The bridge crossing will consist of piers, likely circular, that will be aligned to optimise the passage of flow and minimise flood impacts in low flow events. During higher flow events, the bridge deck and low-level guard rails will be inundated allowing flood flows to pass the crossing relatively unimpeded. Localised increases to flood level are expected immediately upstream of the bridge crossing with localised decreases likely to occur immediately downstream. Flood level increases are expected to be minor and are not anticipated to result in a material increase in flood inundation on adjoining properties or Kempsey-Armidale Road. The impacts of the bridge on flood characteristics are expected to reduce in scale with an increase in flood magnitude. Flood risk management procedures during construction, including those to respond to restricted site access, will be documented within a Project specific FMP to be developed prior to the commencement of construction.

6.8.3 Minor watercourses

No known flooding information exists for the minor watercourses across the Project area. Several minor watercourse crossings will be constructed as part of the network of site access roads which may result in minor localised flood impacts immediately upstream of each crossing.

6.9 Summary of residual impacts

Residual impacts resulting from construction of the Project are summarised in Table 6.5.

Table 6.5 Summary of residual impacts – construction phase

Impact category	Impact mechanism	Potential impact	Proposed mitigation measures	Residual impact
Streamflow regime	Water extraction from the Macleay River	Reduced streamflow in the Macleay River due to water take for general construction.	• Construction water requirements to be sourced at relatively low pump rates (1 ML/day). • Construction water CTP rules in accordance with those specified in the relevant WSP.	• Construction water take generally results in less than 1% streamflow reduction. • No material residual impact on frequency and duration of low flows due to construction water take.
		Reduced streamflow in the Macleay River due to water take for initial storage fill.	• High-flow-only access approach to be applied to initial storage fill water take whereby the 50th percentile streamflow value of 597 ML/day will be maintained. • Pumping to cease if 30-day streamflow total below 5-year ARI value of 1,936 ML. • No extraction during first 7 days of first flow event greater than 50th percentile streamflow value following extended dry period or drought.	• Water take for initial storage fill represents 1% of annual streamflow volume on average. • Initial storage fill water take results in maximum 12.6% streamflow reduction for short periods of time. • The magnitude of residual impacts decreases downstream as inflows from additional catchment areas contribute a larger portion of streamflow. • Any residual impacts are expected to be short-term (3–12 months). • The above streamflow impacts are not expected to impact water availability for downstream water users.
	Groundwater interception	Reduction in baseflow/streamflow due to groundwater drawdown.	• Tunnel grouting and lining proposed to reduce groundwater interception and subsequent drawdown impacts.	• A maximum baseflow/streamflow reduction of 194 ML/year which equates to about 0.02% of the average annual Macleay River streamflow. • Minor baseflow reductions are predicted to occur in several minor watercourses.

Table 6.5 Summary of residual impacts – construction phase

Impact category	Impact mechanism	Potential impact	Proposed mitigation measures	Residual impact
Water quality	Stormwater discharges	Stormwater discharges from areas disturbed by construction activities result in impacts to receiving water quality.	• SWMPs and ESCPs will be developed for all construction areas. • Stormwater system to be designed and constructed using industry standard practices. • Sediment basins will be constructed where practical to capture and treat stormwater runoff. • Areas with elevated risk of contamination will be separated from stormwater network.	• Some residual water quality impacts may be experienced when sediment basins overflow during and following intense or prolonged periods of wet weather. • Water quality impacts are anticipated to be short-term (ie when basin is overflowing) and nearfield as substantial dilution would occur downstream of sediment basins during wet weather.
	Controlled discharges	Discharge of treated process water results in impacts to receiving water quality.	• Source controls to be implemented to manage the volume and quality of process water produced. • Process water will be treated for re-use to minimise risk of discharges. • Surplus process water will be treated prior to discharge.	• Some residual risk remains where concentrations of contaminants in treated water are above the ambient receiving water values. • Substantial dilution is anticipated to occur in the Macleay River resulting in minor localised water quality impacts.
		Discharge of treated wastewater results in impacts to receiving water quality.	• STP(s) will be established to treat wastewater prior to discharge. • Temporary ablution facilities with a pump out arrangement are proposed for low occupancy areas.	• Some residual risk remains where concentrations of contaminants in treated water are above the ambient receiving water values.
	Spoil emplacements	Runoff and seepage from spoil emplacements impacts receiving water quality.	• Sediment basins will be constructed downstream of spoil emplacement areas to capture and treat runoff and seepage from emplacement areas.	• Potential minor increases to aluminium and iron concentrations in watercourses immediately downstream of sediment basins during overflow conditions. • Substantial dilution is anticipated to occur with any residual impact being localised and short-term (i.e. during and shortly after significant wet weather events).

Table 6.5 Summary of residual impacts – construction phase

Impact category	Impact mechanism	Potential impact	Proposed mitigation measures	Residual impact
Environmental receptors	Water extraction from the Macleay River	Reduced water availability to downstream environment.	• Water take will be subject to a range of CTP rules aimed at protecting environmental receptors. • Water quality monitoring is proposed to identify and respond to potential indirect water quality impacts which may impact environmental receptors.	• High-flow-only access for initial storage fill is expected to minimise disruption to flow cues by allowing low and moderate streamflow events to pass downstream untouched. Only a small portion (up to 12.6%) of higher streamflow events will be extracted. • The maximum estimated water level reduction of 0.05 m (or 5% of streamflow depth) is not anticipated to have a material impact on habitat availability, fish passage or water quality (e.g. temperature).
	Instream structures	Instream works result in a blockage of fish passage.	• For instream structures where fish passage is likely to occur, waterway crossings will be designed and constructed in general accordance with the relevant guidelines.	• Construction of the lower dam and reservoir will unavoidably block fish passage along Fingerboard Crossing Creek.
Flooding	Macleay River bridge	Impacts to flood level and extent	• Bridge design to provide adequate waterway area to pass flood flows and minimise flood impacts.	• Flood level increases are expected to be minor and are not anticipated to result in a material increase in flood inundation on adjoining properties or Kempsey-Armidale Road. • Impacts of the crossing are expected to reduce in scale with the increase in flood magnitude.

7 Operation impact assessment

7.1 Overview

This chapter provides an assessment of impacts during operation of the Project. Impacts to streamflow, water quality, downstream water users, flood regime and geomorphology are assessed with consideration of the water management approach described in Chapter 5.

7.2 Operational water balance

7.2.1 Overview

A conceptual water balance model was developed for the operational phase of the Project. The purpose of the water balance model is to:

- quantify impacts to the streamflow regime of Fingerboard Crossing Creek and the Macleay River as a result of Project operations
- estimate operational water take and hence establish water licensing requirements for the operational phase of the Project.

The following sections provide a summary of the modelling approach and key assumptions. Further details on the water balance model setup and assumptions are provided in Attachment D.

7.2.2 Modelling approach and assumptions

A water balance model for the operational phase of the Project was developed in GoldSim (version 14). A summary of the modelling methodology and data is presented in this section, with further details of the assumed model parameters provided in Attachment D. The model applied a continuous simulation methodology that assessed the performance of the water cycle under a range of climatic sequences. The model was created by representing the water cycle as a series of elements, each containing pre-set rules and data, that were linked together to simulate the interaction of these elements.

i Model description

The water balance model simulated the volume of water within the upper and lower dams and reservoirs based on the following equation:

Change in volume over time = inflows – outflows

Where:

- modelled inflows consisted of direct rainfall onto the water surface area of each reservoir, catchment runoff, groundwater inflows, transfers of water between reservoirs and top-up inflows from the Macleay River
- modelled outflows consisted of evaporation from the water surface area of each reservoir, groundwater outflows, transfers of water between reservoirs, and discharges from the lower dam and reservoir via the spillway.

ii Probabilistic modelling

The model simulated the water balance of the Project using hourly time steps. To assess the influence of climate variability on the water balance, the modelling was completed by applying 52 different patterns over the simulation timeline, based on the historical climate record and Macleay River streamflow record between 1970 and 2021. To complete this, the simulation timeline was modelled for 52 'realisations', where each realisation represented a single model run. Each realisation began with a different year of the historical climate record and Macleay River streamflow record, proceeding consecutively through the historical record (and looped to the start of the record where required). The results from all realisations were used to generate relevant statistical outputs. This method effectively includes all recorded historical climatic events in the water balance model, including high, average, and low rainfall periods.

iii Rainfall runoff response

Surface runoff from rainfall was estimated using the Australian Water Balance Model (AWBM). The AWBM was developed by Boughton (Boughton, 2004) and is widely used across Australia to estimate runoff. The hydrological model calculates runoff and baseflow components from rainfall after allowing for relevant losses and storage. The AWBM was incorporated into the GoldSim water balance model for the Project.

iv Groundwater inflows and outflow

The Project reservoirs and dams and underground infrastructure are predicted to receive inflows from the local groundwater system as well as leak water into the local groundwater system during operations. Groundwater inflow and outflow (ie leakage) estimates over the operational phase of the Project are established in Appendix M of the EIS (EMM, 2022a).

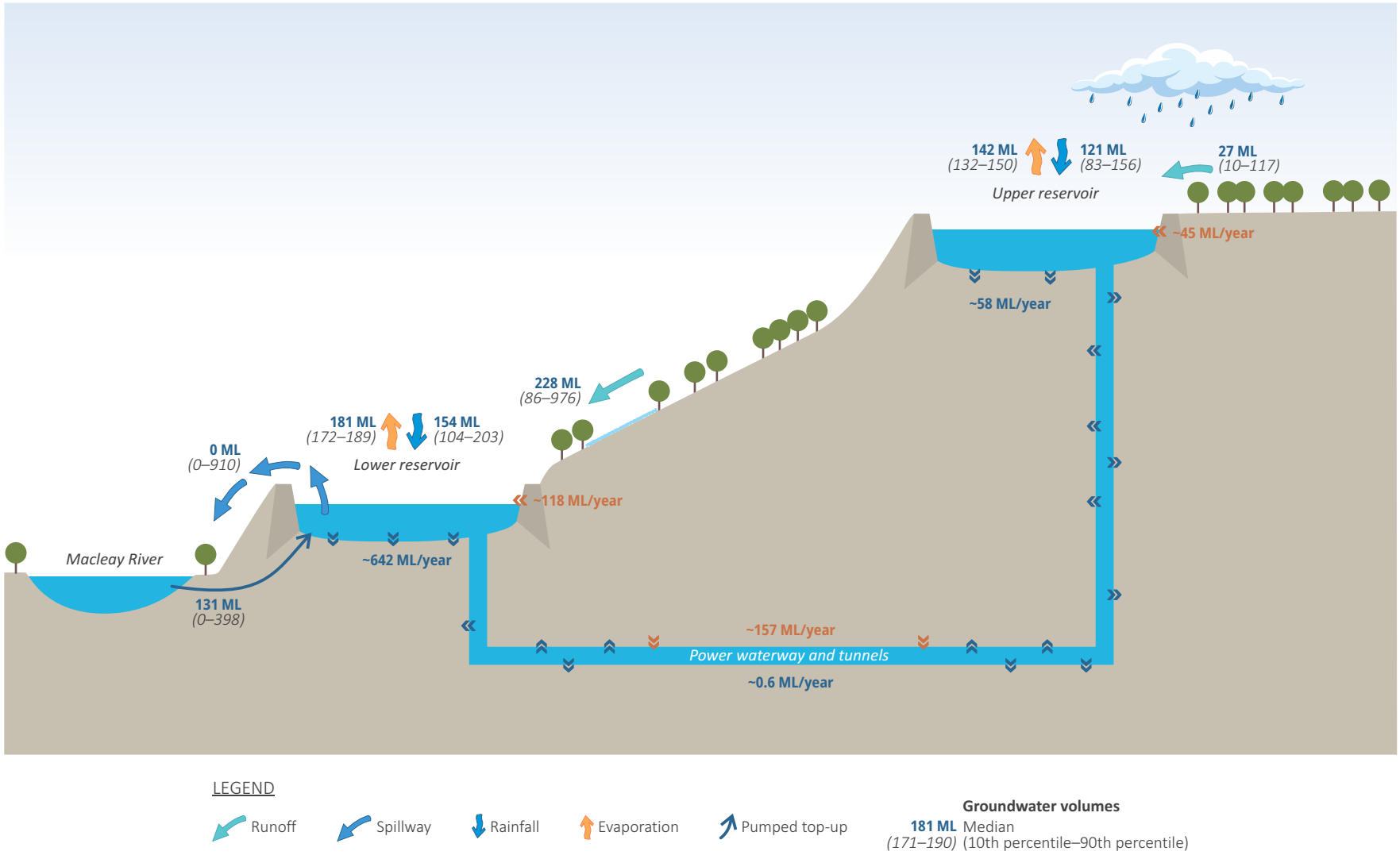
The base case groundwater inflow and outflow estimates have been applied to inform the operational phase water balance. The groundwater impact assessment in Appendix M of the EIS (EMM, 2022a) notes the groundwater model predictions are based on several conservative assumptions including:

- The modelling does not consider actual design, management or mitigating activities (ie grouting, concrete lining and steel lining) which may reduce the overall volume of groundwater intercepted by the underground infrastructure.
- The hydraulic parameters applied to the Macleay River floodplain alluvium are conservative and assume significant permeability and flow. However, the entire unit may not behave like this, with some parts expected to be much less permeable with storage also expected to be constrained by thickness.

The influence of the adopted groundwater model outputs on the operational water balance model results is discussed in Section 7.2.3v.

7.2.3 Water balance results

The predicted annual water balance results are shown in Figure 7.1. The results present the median (i.e. 50th percentile) annual volumes for key water balance components as well as the 10th percentile and 90th percentile results to provide an indication of the range of values expected due to possible variations in rainfall. The 10th percentile results are representative of the result at which 10% of the modelled outputs were less than. Similarly, the 90th percentile represents the result at which 90% of the modelled outputs were less than. It should be noted that the results are compiled from all 52 model realisations and do not represent a single climatic scenario/realisation (e.g. the 10th percentile results do not represent conditions in a 10% rainfall year).



Annual predicted water transfers

OMPS Pty Ltd

Oven Mountain Pumped Hydro – Surface water assessment

Figure 7.1

A summary of the median annual inflows and outflows is presented in Table 7.1. Results have been rounded to the nearest 1 ML/year.

Table 7.1 Summary of median predicted water inputs and outputs

Element	Volume (ML/year)
Inflows	
Rainfall on dam and reservoir surface	275
Catchment runoff	256
Groundwater inflows	320
Additional baseflow contributions[1]	29
Top-up from Macleay River	131
Total inflows	**1,011**
Outflows	
Evaporation from dam and reservoir surface	323
Groundwater outflows	700
Discharge to Macleay River	0
Total outflows	**1,023**
Change in storage	**-12**
Balance	**0**

Notes: 1. A portion of the losses (due to leakage) from the upper dam and reservoir to the groundwater system is expected to flow into the lower dam and reservoir as additional baseflow contributions.

The water balance model results presented in Table 7.1 indicate rainfall and catchment runoff into the dams and reservoirs is the greatest source of inflows to the system, representing 52% of median total inflows. Groundwater and Macleay River top-up represent 32% and 13% of median total inflows respectively. Additional baseflow contributions to the lower dam and reservoir resulting from losses to the groundwater system from the upper dam and reservoir make up a relatively minor (3%) proportion of total system inflows.

Groundwater outflows (due to leakage) from the reservoirs and dams account for 68% of median total outflows while evaporative losses account for 32% of median total outflows. Discharges from the lower dam and reservoir spillway are not predicted to occur for median conditions.

i Operational discharges

Overflows (via the spillway) from the lower dam and reservoir will occur when inflows exceed the available storage capacity. The water balance model was used to estimate overflow volumes from the lower dam and reservoir spillway during operation of the Project. The probability of overflows occurring during operation of the Project are presented on a monthly basis in Figure 7.2.

The results are presented as the range between the minimum and 10th percentile, 10th percentile and 25th percentile, 25th percentile and median, median and 75th percentile, 75th percentile and 90th percentile, and 90th percentile and maximum values.

It should be noted the results represent the probability of particular overflow volume occurring in any given month and do not represent the distribution of discharge over the course of a year.

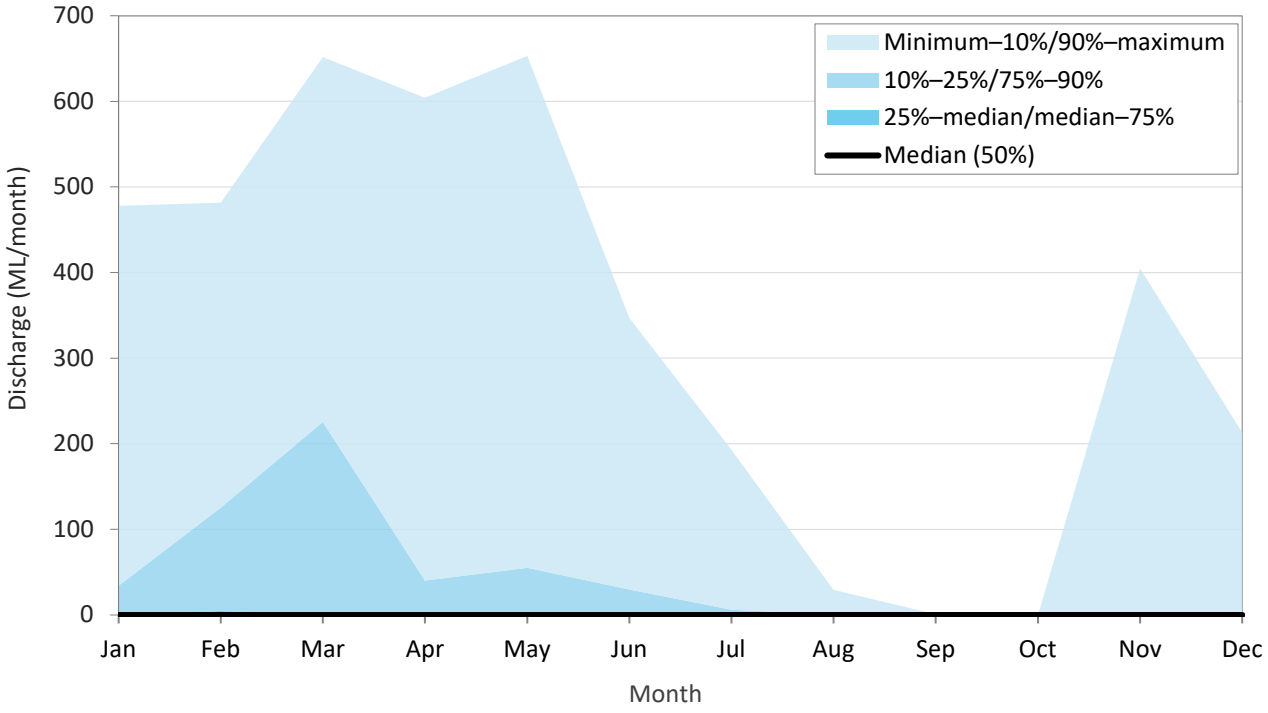


Figure 7.2 Overflow from the lower dam and reservoir spillway

The results in Figure 7.2 indicate:

- Overflows are more likely to occur during summer and autumn with little to no overflows predicted to occur in winter and spring. This is a result of larger rainfall totals and subsequent runoff volumes that occur during summer and autumn as described in Section 4.4.2.
- Overflows that occur from January to June are predicted to be less than 200 ML/month in 90% of overflow events, except March which experienced an overflow event of 225 ML/month. Overflows from July to December occurred in less than 10% of model runs with no overflows observed in September and October in any model run.

Overflows from the lower dam and reservoir spillway are predicted to occur in 45% of years, typically during years with above average rainfall. The maximum annual overflow volume was estimated at 1,400 ML/year.

ii Operational top-up

Periodic operational top-up is required to offset system losses due to evaporation and leakage to the groundwater system. It is proposed to source operational top-up water from the Macleay River via pump and pipeline. The water balance model was used to estimate operational top-up requirements.

Operational top-up was triggered in the water balance model when the volume of water in the upper and lower dams and reservoirs decreased below 98% of the total system storage volume. It should be noted the 98% top-up trigger is only applicable to the water balance model and that the actual top-up trigger applied during operations may differ.

Operational top-up was also subject to the extraction and CTP rules described in Section 5.5.4 whereby the 50th percentile streamflow (597 ML/day) in the Macleay River was maintained (i.e. top-up only allowed during high flow conditions). The resulting operational top-up volumes are presented on a monthly basis in Figure 7.3.

It should be noted the results represent the probability of a particular operational top-up volume being extracted in any given month and do not represent the distribution of top-up over the course of a year.

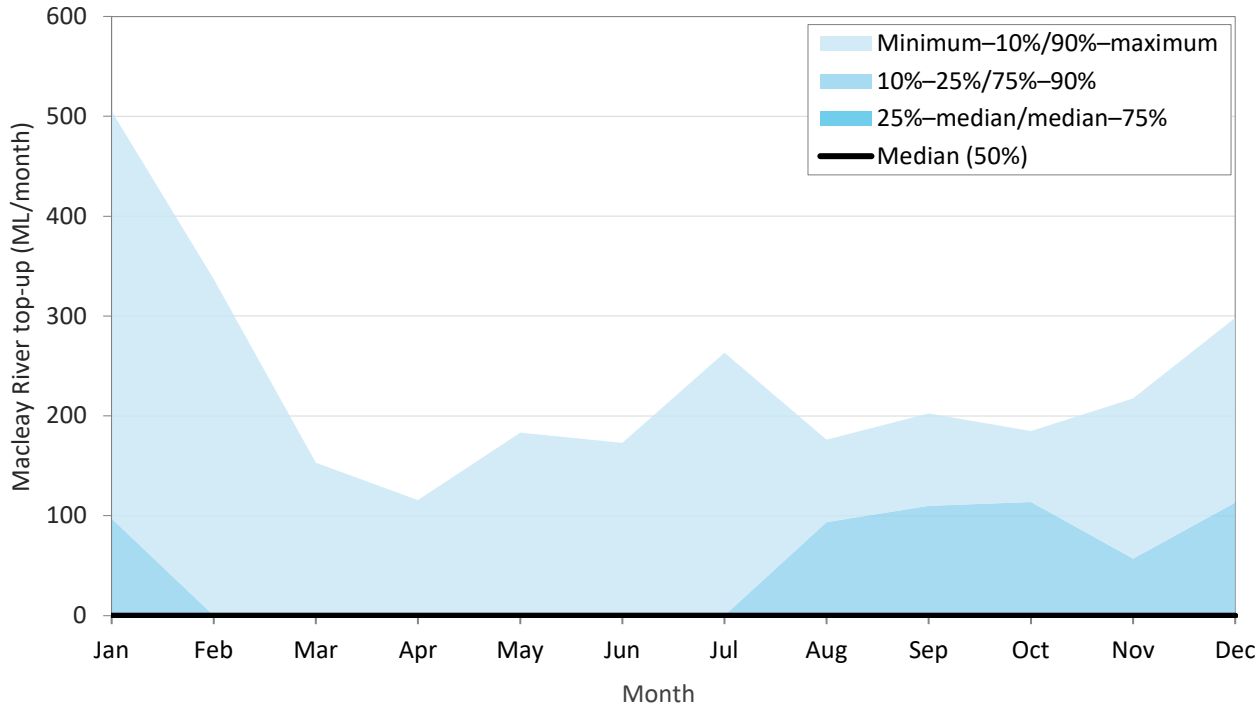


Figure 7.3 Operational top-up requirements

The results in Figure 7.3 indicate:

- Operational top-up primarily occurs in spring and early summer due to:
  - system losses (primarily due to leakage to the groundwater system) that occur during winter and early spring which are not readily offset by local catchment rainfall and runoff
  - greater streamflow volumes in the Macleay River in late spring and summer allowing top-up to occur.
- Less operational top-up is predicted to occur in later summer and autumn as local catchment rainfall and runoff is typically larger at this time of year, offsetting system losses.
- Operational top-up from August to January is predicted to be less than 100 ML/month in 90% of top-up events. Operational top-up from February to July occurred in less than 10% of model runs.

Operational top-up is predicted to be required in 66% of years, typically during years with below average rainfall. No operational top-up is predicted to occur in the remaining 34% of years. The maximum annual top-up volume was estimated at 710 ML/year. It would take approximately eight days of pumping at 86.4 ML/day to achieve the maximum annual top-up volume of 710 ML/year. Operational top-up will generally occur for less than 4 days per year when required.

iii Security of water supply

The pumped hydro system must contain a minimum of about 5,200 ML of available water within the upper and lower dams and reservoirs to operate at full generation capacity. The lower dam and reservoir is designed to contain an additional 900 ML drought reserve (increasing the available capacity to 6,100 ML[2]) to provide security of supply during extended dry periods when operational top-up from the Macleay River would not be possible (due to the proposed CTP rules).

The water balance model was used to investigate storage levels within the system to assess the risk of water availability during operation of the Project. The available stored water within the system that can be used for energy generation is presented on a monthly basis in Figure 7.4. The assumed operational top-up trigger and lower limit of the drought reserve are also shown for context.

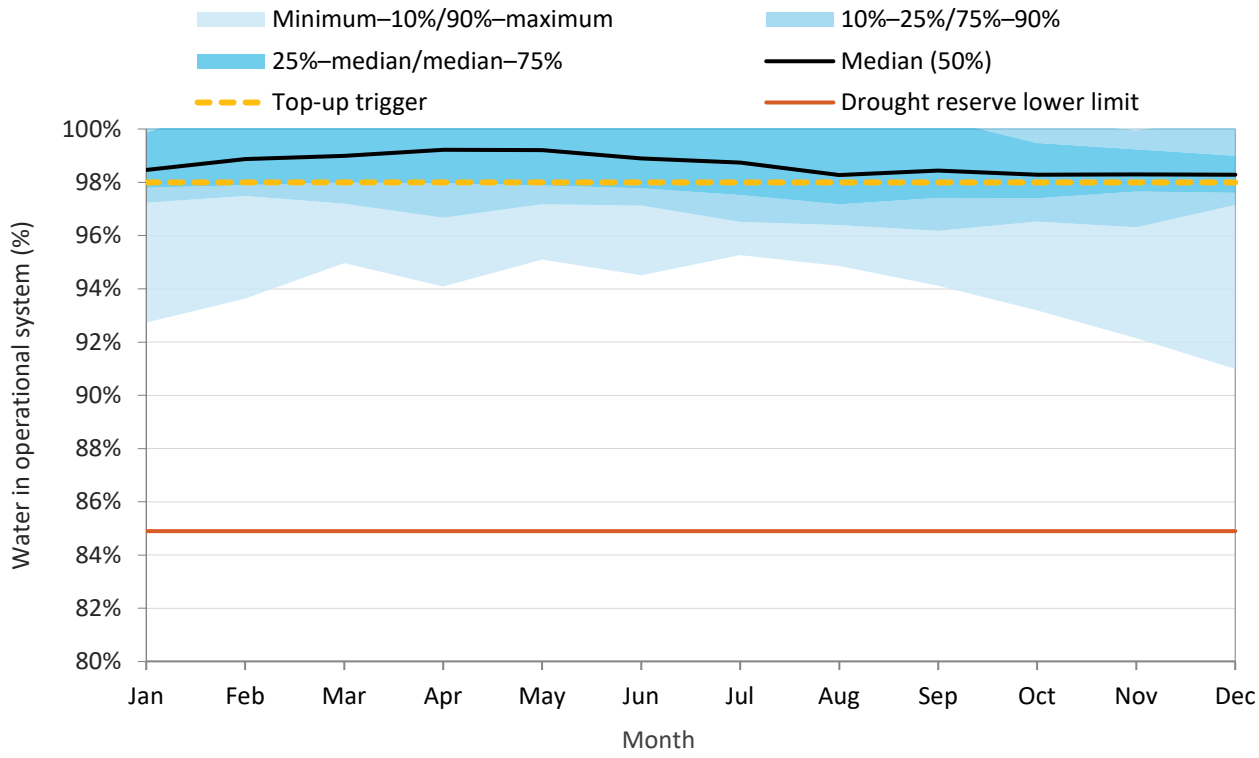


Figure 7.4 Available stored water in the system

The results in Figure 7.4 indicate:

- The Project is not predicted to run out of water during operations with the drought reserve providing sufficient volume to account for extended dry periods and limitations to extracting operational top-up water from the Macleay River.
- The lowest storage volume that occurred in the modelled scenarios is just above 91% of the total available capacity (6,100 ML) which is approximately 6% (360 ML) above the lower limit of the drought reserve, indicating there is redundancy within the proposed drought reserve volume at least when considering the variability captured in the past 52 years of climate record.

[2] The lower dam and reservoir contains an additional 400 ML of dead storage that cannot be used for energy generation which results in a total reservoir capacity of 6,500 ML.

- The available storage volume is typically (median values) above the assumed top-up trigger value (98%) indicating that sufficient streamflow is generally available within the Macleay River to allow operational top-up to occur as needed.

iv Water licensing requirements

Water take during operations will occur due to the interception of local catchment runoff by the Project dams and reservoirs and via extraction from the Macleay River for operational top-up. The water balance model was used to calculate licensing requirements associated with water take during operations. Water licensing requirements were calculated based on a 'water year' (i.e. July to June) rather than calendar year as was done for all other water balance results described in this section. The water year was used for licensing requirements to better align with the water allocation and account management rules provided in Attachment A.

The water balance model predicts 838 ML/year (80th percentile) water take will occur during operations, comprised of 612 ML/year intercepted runoff and 226 ML/year operational top-up. It should be noted that no specific policy exists for calculating licensing requirements that include the interception of local catchment runoff. Licensing the 80th percentile value is considered a reasonable approach given the expected variation in annual runoff volumes and the annual carry over rules defined in the Macleay WSP under water allocation and account management (refer to Attachment A).

The proportion that intercepted runoff and operational top-up contribute to the overall annual water take volume varies from year to year with operational top-up making up a smaller portion (if at all) in high rainfall years and larger portion in low rainfall years. Generally, water take for operational top-up is offset by lower water take via the interception of local catchment runoff and vice versa. Hence, the 80th percentile of the combined water take mechanisms has been applied to obtain the 838 ML/year licensing requirement rather than the 80th percentile of the individual components.

A breakdown of the water licensing volumes is shown in Figure 7.5.

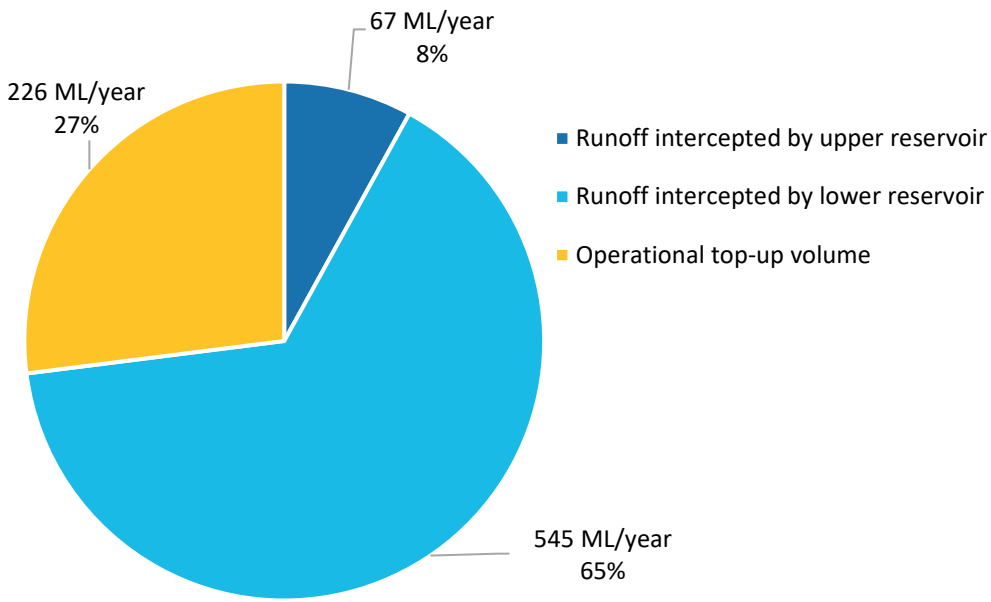


Figure 7.5 Breakdown of water licensing volumes

v Influence of predicted groundwater model inflows and outflows

The operational water balance results are strongly influenced by the predicted groundwater model (EMM 2022a) results which estimate an ongoing net deficit (i.e. system loss) of 380 ML/year. The groundwater impact assessment in Appendix M of the EIS (EMM 2022a) notes the groundwater model is conservative and likely overestimating impacts (refer to Section 7.2.2iv). The following changes to the water balance model results are expected if observed groundwater inflows and outflows are different to predicted values:

- If less groundwater is intercepted by the Project or more water is lost (due to leakage) from the system, discharge from the lower dam and reservoir spillway will decrease in frequency and volume and operational top-up requirements will increase in frequency and volume.

- If more groundwater is intercepted by the Project or less water is lost (due to leakage) from the system, discharge from the lower dam and reservoir spillway will increase in frequency and volume and operational top-up requirements will decrease in frequency and volume.

The water balance model was modified to remove all groundwater inflows and outflows to investigate the influence of groundwater on the operational system. In the absence of groundwater inflows and outflows, operational top-up was predicted to occur in less than 1% of modelled scenarios with a maximum requirement of 175 ML/year. This implies that rainfall and runoff from the local catchment are generally sufficient to offset system losses (evaporation) in the absence of leakage to the groundwater system in all but the driest 1% of years in the assessed period of record. It is therefore recommended water take volumes (and hence licensing requirements) be recalculated should any future work be completed to revise or refine the groundwater modelling.

vi Potential influences of climate change

Climate change has the potential to impact the Project by affecting the volume of water that is available for use during operations. Predicted climate change impacts for the north coast region, including the Macleay River catchment, are provided by the NSW Office of Environment and Heritage (OEH, 2014; OEH, 2015). Climate change predictions are provided for near future (2020–2039) and far future (2060–2079) scenarios. The following trends are predicted to occur that may impact the Project operational water balance:

- Rainfall is predicted to increase during autumn and spring and decrease during summer and winter in the near future. Rainfall is predicted to increase in all seasons except winter, which is predicted to decrease, in the far future.

- Temperature (and hence potential evaporation rates) is predicted to increase in all seasons for both near future and far future climate conditions. More frequent hot days (temperature above 35°C) are also predicted to occur.

- Runoff (and hence streamflow) is predicted to increase during autumn, winter and spring and decrease in summer during the near future. Runoff is predicted to increase in all seasons except winter, which is expected to decrease, in the far future.

In general, future climate predictions lean towards an increase in rainfall and runoff for the Macleay River catchment. However, it should be noted that while the above impacts to climate change represent the likely change based on the available data, significant variation occurs within the climate change predictions particularly regarding rainfall and runoff which may experience either wetting or drying conditions depending on the climate model being referenced. There is consensus across the modelling that temperature will increase in the near and far future.

The above predicted changes to near and long-term climate are expected to have the following impact on the operational water balance:

- Increased temperature and more frequent hot days are anticipated to increase evaporation losses from dam and reservoir surfaces particularly during summer. This may result in an increase in operational top-up volumes if the additional losses are not offset by a corresponding increase in rainfall and runoff.
- Increased rainfall and runoff are expected to increase the volume of water intercepted by the Project, reducing the frequency and volume of operational top-up but increasing the frequency and volume of overflows from the lower dam and reservoir spillway. Increased rainfall and runoff are also expected to increase streamflow in the Macleay River, improving access to operational top-up water when required.
- Decreased rainfall and runoff are expected to decrease the volume of water intercepted by the Project, increasing the frequency and volume of operational top-up but decreasing the frequency and volume of overflows from the lower dam and reservoir spillway. Decreasing rainfall and runoff are also expected to decrease streamflow in the Macleay River, which would limit access to operational top-up water when required.

The additional evaporation losses associated with hotter temperatures may be offset by the interception of rainfall and local catchment runoff in a wetting climate (i.e. increased rainfall and runoff). In a drying climate, increased evaporation rates may further exacerbate water availability issues.

The water balance model results presented in Section 7.2.3iii indicate the proposed drought contingency volume (900 ML) is sufficient to allow operations to continue at 100% capacity under historical and current climate conditions. The water balance model predicted approximately 360 ML would still be available in the drought contingency storage during the driest conditions modelled. This indicates there is still some redundancy in the system to account for the variation in future climate predictions including longer and more severe dry periods.

7.3 Impacts to streamflow regime

7.3.1 Overview

Operation of the Project has the potential to result in the following impacts to streamflow:

- changes to the frequency and volume of local inflows to Fingerboard Crossing Creek and the Macleay River due to the upper and lower dams and reservoirs
- increased streamflow resulting from permanent changes in land use and discharges from the operational stormwater management system
- increased streamflow due to overflows from the lower dam and reservoir spillway during energy generation
- increased streamflow due to discharge from the lower dam and reservoir during emergency dewatering
- reduced streamflow resulting from water extraction to supply operational activities (i.e. top-up)
- changes to the streamflow response in Watercourse 1 and Watercourse 2 as a result of altering the landscape to facilitate spoil emplacements.

This section assesses impacts to the streamflow regime of minor watercourses and the Macleay River during operation of the Project.

7.3.2 Dams and reservoirs

i Flows within Fingerboard Crossing Creek

The upper dam and reservoir will impound approximately 12% of the Fingerboard Crossing Creek catchment. Streamflow immediately downstream of the dam wall will cease during operations. The relative impact to streamflow will decrease moving downstream along the creek as additional catchment area contributes flow.

The water balance model described in Section 7.2 was used to develop flow duration curves at the junction of several tributaries to Fingerboard Crossing Creek for existing and proposed conditions. The existing and proposed flow duration curves are compared in Figure 7.6.

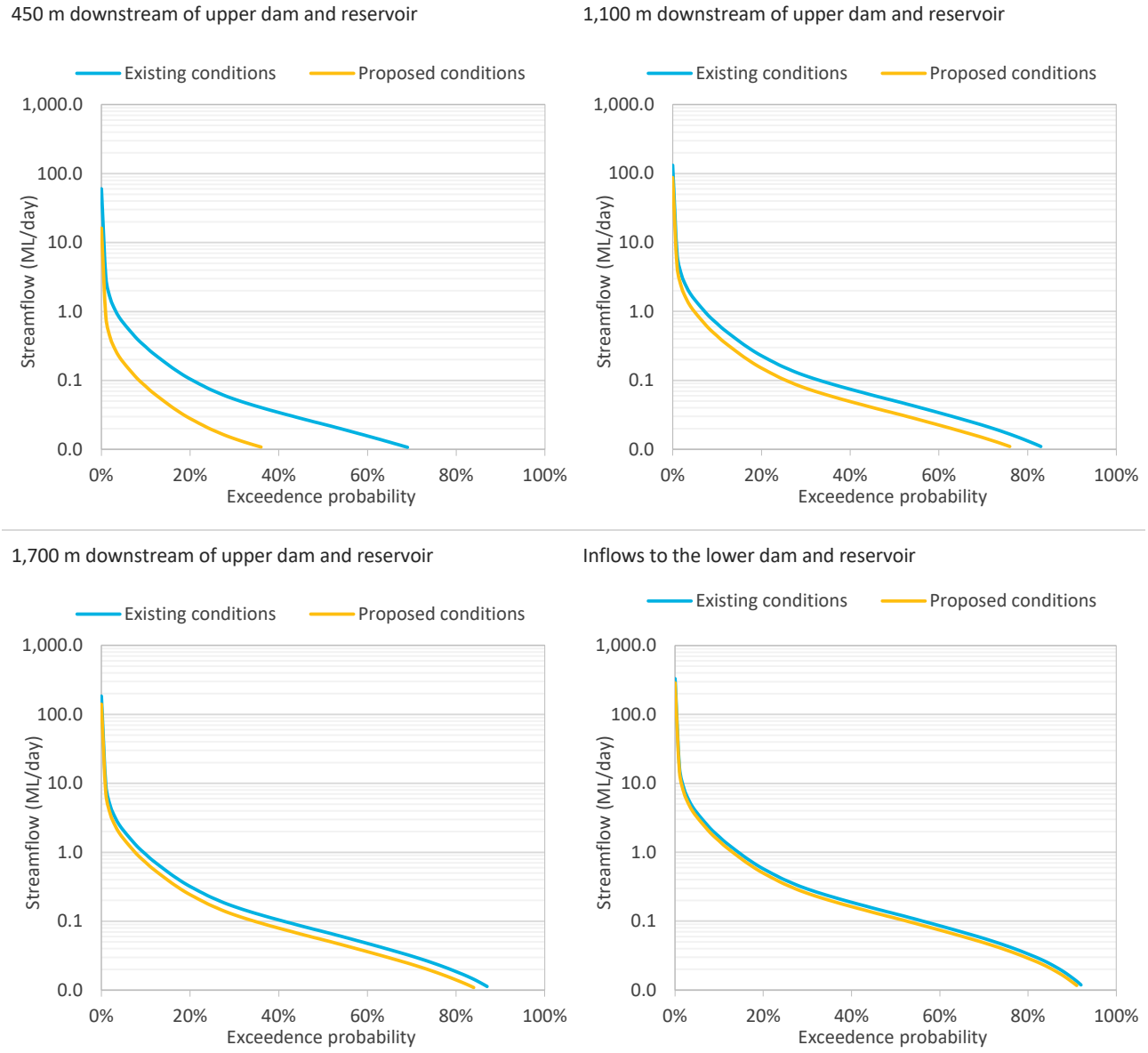


Figure 7.6 Impacts to streamflow in Fingerboard Crossing Creek

The following impacts are predicted:

- a 73% reduction to streamflow is predicted 450 m downstream of the upper dam and reservoir
- a 34% reduction to streamflow is predicted 1,100 m downstream of the upper dam and reservoir
- a 24% reduction to streamflow is predicted 1,700 m downstream of the upper dam and reservoir
- a 13% reduction to streamflow is predicted to enter the lower dam and reservoir compared to what would occur (to the dam wall) under existing conditions.

The above streamflow impacts do not consider increased baseflow resulting from maintaining water in the upper dam and reservoir. The impact of increased baseflow is considered to be relatively minor compared to the portion of flow that occurs from runoff during and following rainfall. Regardless, impacts to baseflow within Fingerboard Crossing Creek and other watercourses across the Project area during operations are assessed in Section 7.7.

ii Inflows to the Macleay River

The water balance model results described in Section 7.2.3 indicate most of the local catchment runoff from Fingerboard Crossing Creek will be captured within the Project dams and reservoirs to offset losses due to evaporation and leakage to the groundwater system.

During extended wet periods or significant rainfall events, overflows from the lower dam and reservoir spillway are predicted to occur at similar rates to existing conditions. Streamflow in the Macleay River is expected to also be elevated under such circumstances and any inflows from Fingerboard Crossing Creek would be rapidly incorporated into the river flow.

The Fingerboard Crossing Creek catchment makes up 0.03% of the overall Macleay River catchment and is anticipated to contribute a proportionate volume of streamflow. Due to the substantial difference in catchment size between the two watercourses, impacts (whether reduced or increased flow) to the Macleay River streamflow regime as a result of impounding Fingerboard Crossing Creek are considered negligible.

7.3.3 Spillway operation

i During local catchment rainfall events

The Project will be operated in a way that allows excess inflow to the reservoirs to overflow via the lower dam spillway. The following processes are expected to occur during and following a rainfall event:

- When the lower reservoir storage level is below the FSL, direct rainfall onto the reservoir surface and inflows from the Fingerboard Crossing Creek catchment will be captured in the reservoir and no overflows will occur to the downstream environment.
- When the lower reservoir storage level is at the FSL, direct rainfall onto the reservoir surface and inflows from the Fingerboard Crossing Creek catchment will overflow (via the spillway) to the downstream environment.

Once the lower reservoir storage level reaches the FSL, overflow volumes are expected to be similar to those experienced from the existing Fingerboard Crossing Creek catchment (ie inflows equal outflows). Attenuation of flows within the lower reservoir is predicted to result in decreased peak flow rates compared to existing conditions. The peak flow rate during the 1% AEP event is predicted to reduce from 57 m^3/s to 10 m^3/s while the peak flow in the probable maximum flood (PMF) event is predicted to reduce from 361 m^3/s to 149 m^3/s.

ii During energy generation

During energy generation water will be transferred from the upper dam and reservoir to the lower dam and reservoir at a rate of about 120 m^3/s. In the absence of inflows from the local catchment, water that is transferred during energy generation will be captured entirely within the lower dam and reservoir. Inflows from the local catchment that occur during the pumping and generation cycle will be displaced by inflows from the power waterway (i.e. during generation) at a later time, causing overflows via the lower dam spillway at a rate of up to 120 m^3/s. The rate at which water overflows the lower dam spillway will be a function of the volume of local catchment runoff intercepted.

The capacity of the lower dam and reservoir to attenuate overflows from the spillway during energy generation has not been assessed quantitatively. However, the following processes are expected to occur:

- discharge rates for most local catchment inflows are expected to be relatively small with a significant portion of the generation inflow rate attenuated within the lower reservoir; and
- discharge rates for larger less frequent inflow events will be somewhat attenuated up to a certain inflow volume after which the discharge rate will equal the generation inflow rate of 120 m^3/s.

The volume of water intercepted by the Project reservoirs is expected to be less than 20 ML/day for approximately 99% of the time. Overflows under these conditions and the resulting impact to the Macleay River streamflow are anticipated to be negligible.

The water balance results indicate larger inflow rates (up to 330 ML/day) occur much less frequently. The volume of local catchment runoff required to negate the attenuation effects of the lower reservoir and cause the spillway to overflow at the maximum generation inflow rate of 120 m^3/s is unknown. Should such conditions occur, streamflow within the Macleay River may become temporarily elevated at, and immediately downstream of the Fingerboard Crossing Creek confluence. The resulting flows in the Macleay River would be approximately equivalent to the 1 year ARI Macleay River flood. Peak flow rates would rapidly decrease moving downstream as flows are attenuated by the Macleay River channel.

Risks associated with the lower dam spillway discharges could be mitigated through operational procedures where the generation capacity of the Project is temporarily reduced to avoid overflows occurring following large local catchment runoff events. Operational procedures to mitigate this will be developed in the future detailed design phase of the Project.

7.3.4 Emergency dewatering

A permanent low-level outlet is required to allow the lower dam and reservoir to be dewatered in a safe manner should an emergency such as potential dam failure be identified. The diversion tunnel constructed to bypass flows around the lower dam and reservoir during construction will be retained to provide emergency dewatering functionality during operation of the Project. A smaller diameter conduit (in the order of 600 mm diameter) will be installed within the diversion tunnel to facilitate dewatering during operations. The conduit would discharge water at a rate of 1–2 m^3/s and take 40–50 days to dewater the reservoir.

Rapid drawdown from the upper dam and reservoir will be possible via the power waterway, which could completely dewater the upper reservoir in 12 hours. Hence, no formal dewatering structure is proposed for the upper reservoir. In the event the power waterway tunnel cannot be used to dewater the upper dam and reservoir, drainage pumps on backup power will be utilised.

The need to dewater the lower dam and reservoir may be rainfall independent and could occur during periods of both high and low streamflow in the Macleay River. The largest impact on streamflow would occur if dewatering were required when the Macleay River is experiencing low flow conditions. A dewatering rate of 2 m^3/s would increase streamflow in the Macleay River by:

- 160% under typical low flow (10^{th} percentile) conditions (1.2 m^3/s)
- 30% under median (50^{th} percentile) flow conditions (6.9 m^3/s)
- 4% under typical high flow (90^{th} percentile) conditions (45 m^3/s).

While emergency dewatering may increase streamflow in the Macleay River from 1.2 m^3/s to 3.2 m^3/s (160% increase) during typical dry conditions, the increased flow rate would still be relatively minor compared to typical flows in the Macleay River and would be short-term (i.e. 40–50 days). Hence, no impacts that are typically associated with increased streamflow such as erosion, changes to geomorphology, or flooding are expected.

It should be noted that while emergency dewatering needs to be considered, the risk of emergency dewatering occurring during operations is considered very low. Routine monitoring of the dam embankments and associated infrastructure (in accordance with any dam safety requirements) is expected to identify and mitigate any structural or operational issues in advance of needing to undertake emergency dewatering.

7.3.5 Water extraction

i Overview

Operational top-up will be required to offset system losses such as evaporation and leakage. Local catchment runoff is expected to be sufficient to replenish system losses under typical climate conditions. However, an alternative water source is required during extended dry periods when system losses substantially exceed local catchment runoff volumes. It is estimated up to 710 ML/year of top-up water will periodically be required during operations. It is proposed to source this water from the Macleay River via pump and pipeline.

ii Extraction conditions

It is proposed to source operational top-up water from the Macleay River via the initial storage fill pump and pipeline described in Section 5.5.3. Pumping would occur at rates of up to 1 m^3/s and be subject to the same CTP rules (i.e. high-flow-only access) for the initial storage fill take as described in Section 5.5.4. It is estimated that operational top-up would take several days to complete once pumping commences.

Given that operational top-up will generally be required during and following extended dry periods within the local catchment, it is also reasonable to assume dry conditions may also be occurring across the broader Macleay River catchment. Hence, it is likely there will be insufficient streamflow in the Macleay River to allow operational top-up to occur at higher pump rates while still satisfying the proposed extraction conditions.

To mitigate the risk of not being able to access top-up water during low streamflow conditions, operational top-up may also be sourced at lower pump rates (say 1–2 ML/day) utilising the existing CTP triggers in the Macleay WSP. Extracting operational top-up water at lower pump rates would provide greater security of supply during periods of low flow.

iii Contingency measures to manage system losses

Operational top-up requirements will be met using higher pump rates when streamflow in the Macleay River is elevated and lower pump rates when streamflow is reduced. The staged pumping approach is aimed at providing a security of supply under a range of conditions. There is still a residual risk that streamflow in the Macleay River recedes below 'very low flow' conditions and the CTP trigger of 13 ML/day for extended periods of time. The following contingency measures could be implemented if there is insufficient streamflow in the Macleay River to allow for operational top-up:

- supplement operational top-up requirements with groundwater resources
- temporarily reduce the Project generation capacity to below 100%.

As future streamflow conditions, climate conditions, and energy market are unknown and difficult to predict, the most appropriate contingency measure(s), if required, would be determined during Project operation.

iv Streamflow impacts

The water balance model results presented in Section 7.2.3 indicate operational top-up is predicted to be required in 66% of years to offset water that is lost from the Project dams and reservoirs into the adjoining groundwater system. Extraction for operational top-up will be subject to the same CTP conditions proposed for the initial storage fill and is therefore expected to result in similar streamflow impacts during pumping. However, substantially lower volumes are required to meet operational top-up requirements with streamflow impacts only expected to occur for several days rather than several months. The following impacts to streamflow regime are anticipated:

- The maximum annual top-up volume of 710 ML/year represents 0.07% of the average annual streamflow volume in the Macleay River adjacent to the Project area.
- A maximum potential streamflow reduction of 12.6% occurs at a streamflow of 683.4 ML/day, when the full 86.4 ML/day extraction rate can be achieved while maintaining the 50th percentile streamflow of 597 ML/day. The impact of the proposed extraction on streamflow magnitude decreases as the observed streamflow increases.
- Operational top-up is predicted to occur in up to 8 days per year with 50% of years requiring less than three days of operational top-up. No operational top-up is predicted in 34% of years.
- Streamflow impacts are expected to decrease with distance downstream as runoff from the downstream catchment progressively forms a larger portion of observed streamflow.
- No impacts are anticipated during low streamflow conditions due to the proposed CTP rules.

7.3.6 Spoil emplacements

The proposed spoil emplacements have the potential to impact streamflow regimes by changing catchment land use (and hence the rainfall runoff response) and altering watercourse alignments to accommodate the final landform. This section assesses potential impacts to streamflow regimes resulting from the proposed spoil emplacements.

i Change of land use

Spoil from the lower dam and reservoir works will be placed in two separate emplacements on Watercourse 1. The total lower dam and reservoir spoil emplacement area (7.0 ha) represents approximately 18% of the Watercourse 1 catchment area (38 ha). Spoil from the upper dam and reservoir will be placed at the top of the Watercourse 2. The total upper dam and reservoir spoil emplacement area (7.8 ha) represents approximately 5% of the Watercourse 2 catchment area (172 ha).

ii Impacts to streamflow regime

It is expected that most direct rainfall onto the spoil emplacements will percolate downwards through the rock landform where it will accumulate in low points in the underlying topography before flowing down gradient and exiting via seeps along the toe of the emplacement. Surface water runoff from the emplacements is not anticipated due to the predicted permeability of the rock void space.

There is potential for water that collects at the base of the rock landform to infiltrate into underlying shallow groundwater systems. However, infiltration rates into the shallow groundwater system are anticipated to be relatively minor.

A delayed streamflow response is anticipated immediately downstream of the emplacements as rainfall will percolate through the rock before contributing to the watercourse. Streamflow impacts will be greatest at the toe of the emplacement and decrease moving downstream as the remaining catchment area contributes inflows to the watercourse. Suitable drainage channels will be incorporated into the emplacement designs to cater for local seepage and runoff and direct this to receiving watercourses.

No impacts to Macleay River streamflow are predicted given the relatively small area impacted by spoil emplacements compared to the Macleay River catchment.

iii Watercourse diversions

Watercourse diversions may be required to pass upstream flows around spoil emplacement. Watercourse diversions are not anticipated to change the volume of streamflow but may result in minor delays to peak flow if longer flow paths are established. Watercourse diversions around spoil emplacements are not predicted to result in any material impacts to streamflow regimes within the downstream watercourses or the Macleay River.

7.4 Impacts to surface water quality

7.4.1 Overview

Operation of the Project has the potential to result in the following impacts to water quality:

- increased sedimentation in receiving waters due to stormwater discharges from permanent infrastructure areas
- changes to the ambient water quality of Fingerboard Crossing Creek and the Macleay River due to discharges from the lower dam and reservoir spillway
- changes to the ambient water quality of the Macleay River due to indirect effects of reduced streamflow due to water extraction
- increased concentrations of dissolved metals in receiving waters due to seepage from spoil emplacement areas.

This section assesses impacts to the water quality of minor watercourses and the Macleay River during operation of the Project.

No discharges from the upper dam and reservoir are predicted to occur during operations of the Project. Hence, water quality impacts associated with upper dam and reservoir discharges are not assessed in the sections below.

7.4.2 Stormwater discharges

The proposed stormwater management measures described in Section 5.3.2 are expected to mitigate potential water quality risks associated with stormwater discharges during operation. Hence, no material impacts to receiving waters are expected.

7.4.3 Discharges from the lower dam and reservoir

Discharges from the lower dam and reservoir will occur due to overflows from the spillway (refer to Section 7.3.3) and from the low-level outlet to facilitate emergency dewatering (refer to Section 7.3.4). The water quality of discharges is expected to reflect the quality of water contained within the overall system. This section identifies water quality risks to the Project dams and reservoirs, describes the expected water quality of discharges, and assess impacts to receiving watercourses.

i Risks to dam and reservoir water quality

Most of the water stored in the system will be sourced from the Macleay River (via pump and pipeline) and runoff from the Fingerboard Crossing Creek catchment and is therefore expected to be of similar quality to the existing surface water environment. However, several factors associated with operation of the Project have the potential to affect the quality of water contained in the system.

Water quality risks that may affect the quality of water stored in the Project dams and reservoirs are summarised in Table 7.2.

Table 7.2 Risks to reservoir water quality

Water quality risk	Description	Risk to water quality	Mitigation
Contamination of stormwater runoff	Stormwater runoff from some operational areas will discharge to the Project dams and reservoirs (typically via minor drainage lines).	Sediment and hydrocarbons	Stormwater management is described in Section 5.3.2.
Contamination of intercepted groundwater	Groundwater intercepted by the 'dry' underground works such as the power station and access tunnels may contact contaminants such as oil and grease prior to being discharged to the lower dam and reservoir.	Hydrocarbons	Intercepted groundwater will be treated for hydrocarbons prior to discharge to reservoir.
Increased groundwater discharge	Groundwater inflow to the reservoirs and underground works are predicted to occur at increased rates compared to groundwater discharge to local watercourses under existing conditions. Hence, the Project reservoirs may contain a larger portion of groundwater than would occur from the natural catchment.	pH, salinity, nutrients, metals	Tunnel lining proposed in sections to reduce volume of groundwater intercepted.
Decomposition of vegetation	Inundated vegetation will decompose overtime releasing nutrients into the reservoirs.	Nutrients (nitrogen and phosphorus).	Potential vegetation removal from within reservoir inundation extent.

Table 7.2 Risks to reservoir water quality

Water quality risk	Description	Risk to water quality	Mitigation
Erosion of soil within the inundation footprint	Soil within the dam and reservoir inundation areas will be subject to erosion as a result of frequent and rapid changes in water level. This may lead to elevated sediment loads in the reservoirs up until the point where all residual soil has been stripped (refer to Section 7.9.2).	Sediments	Mitigation is considered impractical so it is recommended to allow areas covered with soil to erode to hard rock, after which time this impact will cease (refer to Section 7.9.2).
Eutrophication and algal blooms	The build-up of nutrients within the reservoirs can lead to eutrophication and an increased risk of algal blooms.	Increased algae growth and decreased dissolved oxygen levels.	Frequent complete mixing of reservoir water with each generation cycle.
Thermal stratification	Water temperature gradients can develop within deep, static bodies of water causing the lower portion of the waterbody to be substantially colder than the surface.	Decreased water temperature (cold water pollution) in receiving waters.	Frequent complete mixing of reservoir water with each generation cycle.

ii Expected water quality of discharge

Discharges from the lower dam and reservoir are anticipated to have similar water quality to the water contained within the operational system. Water within the system will primarily comprise of:

- water that is pumped from the Macleay River for initial storage fill (particularly in the early years of operation)
- direct rainfall onto the Project dams and reservoir surfaces
- runoff from the upstream Fingerboard Crossing Creek catchment
- groundwater that is intercepted by the dams and reservoir or underground works.

The water balance results presented in Section 7.2.3 indicate that on average rainfall and local catchment runoff make up most (52%) of the total inflows to the system while groundwater and operational top-up from the Macleay River contribute 32% and 13% of total system inflows respectively.

Groundwater inflows may result in temporary and localised elevated salinity, nutrient, and iron concentrations which are observed to slightly exceed the WQO values and ambient receiving water quality concentrations (refer to Section 6.4.4iii). Substantial mixing (as part of operations) with inflows from the local catchment and Macleay River is expected to dilute the groundwater contribution so that residual concentrations are similar to the WQOs and ambient receiving water quality.

The erosion of soil within the dam and reservoir inundation areas may lead to an increase in suspended sediment in the reservoirs during the early years of operations. The resulting impacts to reservoir water quality are predicted to cease once the soil has been eroded to bedrock. After which, discharge water quality is expected to be similar to water quality within Fingerboard Crossing Creek and the Macleay River under existing conditions.

iii Impacts to receiving watercourses

Overflows containing elevated sediment loads may occur during the initial years of operations. Overflows are predicted to occur during and following rainfall when sediment loads within Fingerboard Crossing Creek and the Macleay River would be naturally elevated. Furthermore, it is expected that any sediment laden water that enters the Macleay River will be significantly diluted by river flows and will rapidly dissipate. The risk of discharging sediment laden water is expected to cease once soil within the dam and reservoir inundation areas has been eroded to bedrock.

Once the inundated soil has all been eroded, discharges from the lower dam and reservoir are anticipated to have similar water quality to that which occurs naturally from the Macleay River and Fingerboard Crossing Creek. Hence, no material water quality impacts are expected to occur due to discharges resulting from emergency dewatering or overflows from the lower dam and reservoir spillway.

Water quality monitoring is proposed for the Project dams and reservoirs during operations (refer to Chapter 9) to monitor and respond to unforeseen water quality risks. Residual water quality impacts could be mitigated through operation procedures where the generation capacity of the Project is temporarily reduced to avoid discharges occurring while water quality risks are addressed. Operational procedures to mitigate water quality risks will be developed in the future detailed design phase of the Project.

7.4.4 Risks associated with spoil emplacements

Discharge from the spoil emplacements is predicted to primarily occur as a result of direct rainfall which percolates through the rock matrix and discharges at the toe of each emplacement as seepage. Water that passes through the spoil emplacements has the potential to leach metals and other constituents from the rock. The leachate water quality results described in Section 6.4.4ii indicate dissolved metals concentrations were generally below or similar to the laboratory detection limits except for:

- aluminium which ranged between 2.4 mg/L and 4.2 mg/L
- iron which ranged between 1.0 mg/L and 5.9 mg/L.

It should be noted that actual concentrations within seepage from the emplacements may vary from the values observed in the leachate testing. Hence, the leachate testing results have been used to identify water quality risks associated with the spoil emplacements rather than as a predictor of expected water quality. The following potential changes to water quality are possible:

- The water quality immediately downstream (i.e. at the toe) of the spoil emplacements may have elevated concentrations of aluminium and iron compared to the WQOs and ambient water quality of receiving watercourses. This may result in a long-term change to the existing water quality in Watercourse 1 and Watercourse 2 at the location of the emplacements.
- The relative water quality impact is expected to decrease moving downstream along Watercourse 1 and 2 due to dilution.
- Any seepage that enters the Macleay River would be significantly diluted and is therefore unlikely to materially change the existing water quality. It is noted that seepage is most likely to occur during and following rainfall when flows in the Macleay River are already elevated.

The spoil emplacement area within Watercourse 1 represents approximately 18% of the total watercourse catchment area. The spoil emplacement area within Watercourse 2 represents approximately 5% of the total watercourse catchment area. It is estimated that seepage from Watercourse 1 and Watercourse 2 emplacement areas may be diluted by up to five and 20 times respectively before discharging to the Macleay River.

The total emplacement area in Watercourse 1 and Watercourse 2 represents less than 0.01% of the Macleay River catchment upstream of the Project area. Streamflow in the Macleay River is anticipated to be three to four orders of magnitude greater than the local catchment inflows during and following rainfall, when seepage is most likely to occur. Hence, any residual elevated metals concentrations within inflows to the Macleay River from Watercourse 1 and Watercourse 2 are expected to rapidly mix and dissipate.

7.4.5 Indirect impacts due to water extraction

Extracting water from the Macleay River for operational top-up has the potential to indirectly impact water quality due to reduced streamflow. Impacts may include increased turbidity and temperature and decreased dissolved oxygen concentrations and mixing of nutrients. Several follow-on effects may also result from changes to water quality including eutrophication and potential formation of algal blooms.

Water quality impacts resulting from reduced streamflow are more likely to occur under low flow conditions when flows are shallower and there is less turnover of water in pool sections. Extracting operational top-up water under high flow (above 50th percentile) conditions is expected to maintain sufficient throughflow to minimise any water quality impacts resulting from stagnant or low flowing water.

A reduction in streamflow depth can result in increased water temperatures due to increased solar heating. The operational top-up extraction is estimated to result in a maximum 0.05 m (or 5%) reduction in streamflow depth. Given the relatively minor decrease in water depth, it is not anticipated any material changes to water temperature would occur as a result. Furthermore, the impact to both streamflow and resulting water quality such as temperature will decrease moving downstream from the extraction location as additional catchment areas contribute flows to the Macleay River. Any residual impact is only expected to occur for several days at a time consistent with extractions.

7.5 Impacts to environmental receptors

Impacts to environmental receptors during operations are expected to be similar to the construction phase impacts and are summarised as follows:

- The maximum estimated water level reduction of 0.05 m (or 5% of streamflow depth) in the Macleay River is anticipated to have minimal impacts on local habitat availability. Water level impacts are predicted to decrease as the observed streamflow increases. Predicted impacts to depth and habitat availability will also rapidly reduce moving downstream as additional catchment area contributes to streamflow in the river.
- No material impacts to fish passage are predicted as it is proposed to extract operational top-up under high flow conditions (50th percentile) when it is expected that sufficient flow will be available to allow fish movement over riffle sections and other potential barriers.
- Maintaining the 50th percentile streamflow value (597 ML/day) is expected to minimise disruption of flow cues by allowing low and moderate streamflow events (i.e. less than 597 ML/day) to pass downstream unimpacted by the Project.
- For species that rely on higher streamflow cues (i.e. greater than 50th percentile), the maximum streamflow reduction is 12.6% which generally only occurs when extraction first commences or immediately prior to CTP conditions being triggered.
- Any residual impacts will only occur for several days per year (if at all) when extraction is occurring.

The fish screening installed on pump infrastructure during construction (refer to Section 6.5.2) will be maintained during operations to mitigate the potential risk of aquatic species being caught in the pumps. Hence no pump infrastructure related impacts are anticipated.

7.6 Impacts to downstream water users

7.6.1 Water availability

Extracting water for operational top-up is not expected to impact the security of water supply to downstream users as:

- The maximum annual extraction volume in a given year (710 ML/year) represents on average 0.07% of the annual streamflow volume adjacent to the Project area and hence water available to downstream users.
- It is proposed to maintain the 50th percentile streamflow in the Macleay River (ie 597 ML/day) when extracting water at higher rates (up to 86.4 ML/day), thus no impacts to downstream water security are expected during periods of low flow.
- High-flow-only access means there will still be a minimum of 597 ML/day available for downstream users when water for operational top-up is being extracted. The minimum available streamflow of 597 ML/day is expected to be sufficient to meet downstream water demand.
- Extraction is not proposed when streamflow is below the 235 ML/day used to define KSC town water supply restrictions (refer to Attachment A). Hence, an increase in the time and frequency water restrictions occur is not expected as a result of the Project.
- The proportion of streamflow extracted, and associated impacts decrease with distance downstream of the extraction site as the contributing catchment increases.
- Any residual impacts will only occur for several days per year (if at all) when extraction is occurring and are considered minor.

7.6.2 Water quality

Water that is discharged from the Project during operation may have elevated concentrations of sediment, nutrients and some metals (refer to Section 7.4). Project discharges that exceed the ambient water quality of the Macleay River have the potential to impact the quality of water extracted by downstream users.

Project discharges during operations are not expected to result in material impacts to the quality of water extracted by downstream users as:

- substantial dilution is anticipated to occur in the Macleay River at, and immediately downstream of, the point of discharge
- further dilution is expected to occur moving downstream as the contributing catchment to the river increases (refer to Section 6.6.2)
- discharges from the lower dam and reservoir are primarily predicted to occur during and following rainfall when sediment loads within the Macleay River would be naturally elevated and hence minimal impacts to the ambient water quality are anticipated.

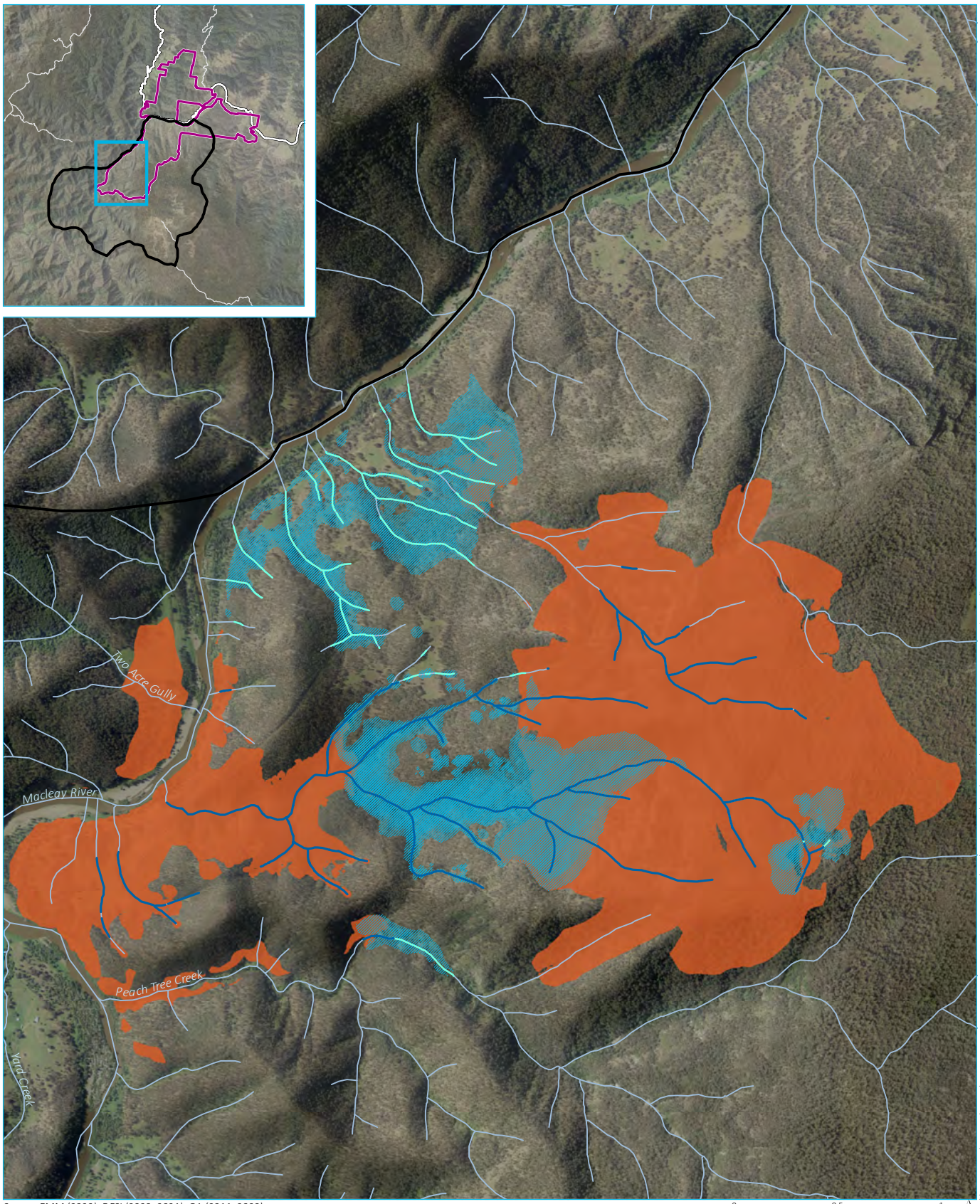
7.7 Impacts to groundwater and connected surface water systems

Groundwater modelling (EMM, 2022a) indicates both groundwater drawdown and mounding are predicted to occur during the operational phase of the Project. Groundwater mounding is attributed to the storage of water within the Project dams and reservoirs providing a constant source of recharge into the groundwater system which subsequently discharges to nearby watercourses. The groundwater mounding is predicted to result in an net increase in baseflow to watercourses across the Project area during operations.

Baseflow to the Macleay River and minor watercourses is predicted to increase by 212 ML/year and 152 ML/year, respectively. Elevated groundwater levels are also predicted to result in a further 37 ML/year streamflow remaining within the Macleay River which under existing conditions would have flowed into the adjacent groundwater system during high flow events.

The change represents an approximate 3% increase in baseflow from the Project area to the Macleay River compared to existing conditions, and an approximate 2% increase in baseflow from the Project area to minor watercourses compared to existing conditions.

Baseflow increases to minor watercourses are anticipated to be greatest for watercourses closest to the Project dams and reservoirs. Watercourses that are predicted to experience groundwater drawdown and mounding during the operational phase of the Project are identified in Figure 7.7.



Source: EMM (2022); DFSI (2020, 2021); GA (2011, 2020)

0 0.5 1 km

GDA 1994 MGA Zone 56

N

KEY

- Area potentially affected by groundwater drawdown
- Area potentially affected by groundwater mounding
- Watercourse potentially impacted by groundwater mounding
- Watercourse potentially affected by groundwater drawdown
- Groundwater model domain
- Watercourse/drainage line
- Kempsey-Armidale Road (refer to inset)

Watercourses with potential for baseflow impacts during operations

Oven Mountain Pumped Hydro Energy Storage Project
Surface water assessment
OMPS Pty Ltd
Figure 7.7

EMM creating opportunities

\\emmsvr1\EMM3\2021\J210465 - OMPS EIS - Generation Component\GIS\02_Maps_EIS_SWA\SWA0023_WatercourseswithBaseflowImpacts_20221208_02.mxd 16/12/2022

7.8 Flooding regime

7.8.1 Fingerboard Crossing Creek

Hydraulic modelling was completed to assess impacts to flood regimes in Fingerboard Crossing Creek as a result of impounding the upper portion of the catchment with the upper dam and reservoir. The flood assessment considered the portion of Fingerboard Crossing Creek between the upper and lower dams and reservoirs. No modelling was completed downstream of the lower dam and reservoir as flood regimes in the downstream portion of Fingerboard Crossing Creek will be controlled by spillway discharge during operation rather than the rainfall runoff response. The Fingerboard Crossing Creek flood assessment has been used to describe flooding impacts in this section and is provided in Attachment E.

The flooding depth, extent and velocity within Fingerboard Crossing Creek will decrease as a result of the Project due to the upper dam and reservoir capturing all runoff upstream of the dam wall, up to the PMF event. Predicted changes to flood depth and velocity along Fingerboard Crossing Creek are generally higher in the upper portions of the watercourse due to the proportionally larger reduction in contributing catchment area.

Impacts to flooding depth, extent and velocity for all modelled events are summarised in Table 7.3. The potential impacts to the geomorphology of Fingerboard Crossing Creek as a result of the change in flood regime is provided in Section 7.9.3ii. Flood mapping for several key events is provided in Attachment E.

Table 7.3 Predicted impacts to flooding in Fingerboard Crossing Creek

AEP event	Reduction in flood extent (ha)	Reduction to upper reach flood depth (m)	Reduction to lower reach flood depth (m)	Reduction to upper reach flood velocity (m/s)	Reduction to lower reach flood velocity (m/s)
63.2%	0.8	0.05–0.15	0.02–0.10	0.7–1.2	0.1–0.2
50%	0.9	0.05–0.15	0.02–0.12	0.9–1.3	0.1–0.3
20%	0.9	0.05–0.15	0.03–0.13	0.8–1.3	0.2–0.4
5%	1.0	0.1–0.3	0.05–0.15	0.9–1.8	0.3–0.5
1%	1.0	0.1–0.4	0.05–0.2	1.0–2.0	0.4–0.7
0.2%	1.0	0.2–0.5	0.1–0.2	2.0–3.0	0.5–0.7

7.8.2 Macleay River

Impacts to the Macleay River flooding regime during operation will primarily occur as a result of Project infrastructure that is within the Macleay River limit of flooding. The following aspects of the Project will be located within the Macleay River limit of flooding during operation of the Project:

- Macleay River pump facility
- the access road from the lower dam and reservoir to Georges Junction
- the eastern access road
- the Macleay River bridge crossing.

Flooding impacts associated with the above infrastructure are expected to remain the same during operation as for the construction phase of the Project described in Section 6.8.2. In general, Project infrastructure is expected to result in minimal localised impacts to flooding with the relative flood impact anticipated to reduce in scale with an increase in flood magnitude.

Flood risk management procedures to respond to restricted site access that may occur due to inundation of the Macleay River bridge crossing during operations will be documented within a Project specific FMP (refer to Section 5.10).

7.8.3 Minor watercourses

No known flooding information exists for the minor watercourses across the Project area. Several minor watercourse crossings will be constructed as part of the network of site access roads which may result in minor localised flood impacts immediately upstream of each crossing.

7.8.4 Preliminary dam break assessment

A preliminary dam break assessment was undertaken for the Project feasibility design (SMEC, 2022), to provide an initial understanding of dam break risk. The modelled scenarios were limited to 'sunny day' failures with a breach mechanism via overtopping. A formal dam break study will be undertaken in accordance with the Australian National Committee on Large Dams (ANCOLD*) Guidelines on the Consequence Category for Dams* (2012) during future detailed design of the Project.

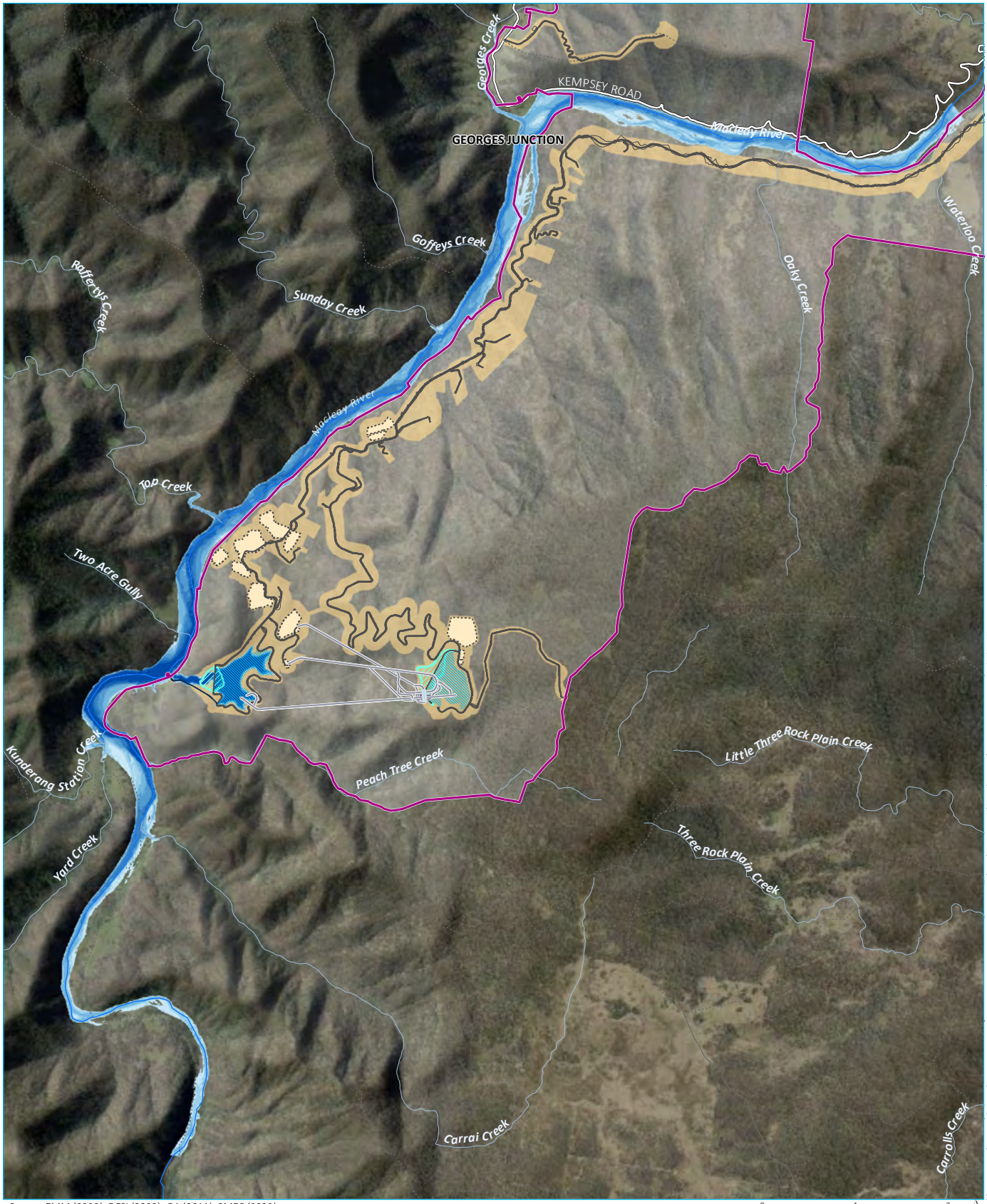
In the case of a dam break from the upper dam and reservoir, the total volume of water occurring from the dam breach will be balanced by the equivalent space in the lower dam and reservoir. Hence, all flows will be captured within the lower dam and reservoir and no impacts to the Macleay River are predicted (SMEC, 2022).

A dam break of the lower dam and reservoir will flow into the Macleay River via Fingerboard Crossing Creek. Initially, dam breach flows are predicted to flow in both downstream and, to a small extent, upstream directions along the Macleay River.

Flows in the upstream direction towards East Kunderang Homestead peak 17 minutes after the breach, where the water surface level is predicted to reach 150 m AHD before reversing direction and travelling downstream. Dam breach flows in the upstream direction are primarily contained within the Macleay River main channel and floodplain. The East Kunderang Homestead is expected to remain flood free as it is situated above the peak dam break flood level.

In the downstream direction, dam breach flows in the Macleay River are approximately equivalent to the 1% AEP flood event, where flooding is primarily contained within the channel banks away from key infrastructure. The magnitude of the dam break flood wave decreases as it travels downstream so that the water surface level in the Macleay River is predicted to reach 130.5 m AHD downstream of Georges Junction, which is approximately equivalent to the moderate flood level at the Macleay River at D/S Georges River stream gauge defined by the BoM (BoM, 2022b). Following a lower reservoir dam breach, the Macleay River is predicted to return to normal flow conditions in approximately one hour.

A dam break flood within the Macleay River is approximately equal to natural floods and is therefore unlikely to affect the downstream communities of Lower Creek and Bellbrook (SMEC, 2022). The flood extent resulting from a breach in the lower dam and reservoir is shown in Figure 7.8.



Source: EMM (2022); DFSI (2020); GA (2011); SMEC (2022)

0 1 2 km

GDA 1994 MGA Zone 56

N

\\emmsvr1\EMM3\2021\J210465 - OMPS EIS - Generation Component\GIS\02_Maps_EIS_SWA\SWA024_DamBreakFloodScenatio_20221213_02.mxd 13/12/2022

KEY

Project area
Construction envelope
Initial storage fill pump infrastructure

Project operational elements
Underground power station complex
Tunnels, portals, intakes, shafts
Permanent road
Surface works
Reservoir
Dam wall

Existing environment
Macleay River
Watercourse/drainage line
Kempsey-Armidale Road
Minor road
Vehicular track

Depth (m)
< 1
1 - 2
2 - 4
4 - 6
6 - 8
8 - 10
> 10

Dam break scenario flood extents

Oven Mountain Pumped Hydro Energy Storage Project
Surface water assessment
OMPS Pty Ltd
Figure 7.8

EMM
creating opportunities

7.8.5 Potential influences of climate change

Climate change predictions indicate the frequency and magnitude of high intensity rainfall events are likely to increase in the future. As a result, the frequency and magnitude of significant flood events is also expected to increase. No climate change specific flood modelling has been undertaken for the Project. Hence, the influence of climate change on Project related flooding aspects has been assessed qualitatively with the key impacts summarised as follows:

- No material changes to flooding regimes in Fingerboard Crossing Creek are expected due to climate change as impounding the upper portion of the catchment results in a reduction to flood flows. An increase in the frequency and magnitude of high intensity rainfall events may offset some of the geomorphological impacts associated with reducing flood flows in the creek (refer to Section 7.9.3ii).
- Site access via the Macleay River bridge and along the Eastern Access Road may become restricted more frequently and for longer periods of time.
- All Project infrastructure including the lower dam and reservoir are located above the 0.01% AEP Macleay River flood level and while extreme flood events are predicted to occur more frequently, flooding impacts resulting from these large events are still expected to be minimal and localised.
- The lower and upper dams and reservoirs are designed to safely convey the present day PMF event flood flows from the local contributing catchment. Climate change influences may cause the magnitude of the PMF event flood flow to exceed the dam and reservoir design criteria, increasing the risk of dam failure. The risk of overtopping due to an event larger than the present day PMF could be mitigated through management measures such as maintaining similar storage levels in both reservoirs to increase the individual dam and reservoir storage capacity to capture a larger proportion of inflows.

In general, the influence of climate change on flooding regimes is anticipated to primarily impact the frequency and duration of site access restrictions. Flood risk management procedures during operation of the Project, including those to respond to restricted site access, will be documented within a Project specific FMP. The FMP should include contingency measures to account for longer periods of site access restrictions due to flooding.

7.9 Impacts to geomorphology

7.9.1 Overview

Changes to streamflow regime (refer to Section 7.3) are the primary driver for potential impacts to geomorphology. The nature of the adjustments is difficult to predict as morphology is dependent on the interaction between hydrology and sediment supply. The following potential geomorphic impacts are described in this section:

- impact of erosion within the upper and lower dam and reservoir inundation areas due to frequent and rapid drawdown of water level
- impacts to the geomorphology of Fingerboard Crossing Creek resulting from impounding portions of the catchment with the upper and lower dams and reservoirs
- impacts to the geomorphology of the Macleay River resulting from extracting water for operational top-up and reducing sediment and bed load inflows by impounding Fingerboard Crossing Creek.

Further detail on the impacts described in this section are provided in the geomorphology assessment undertaken by Fluvial Systems (Gippel, 2022) included as Attachment B.

7.9.2 Erosion of soil within dams and reservoirs

Operation of the upper and lower dams and reservoirs will involve frequent and rapid variation of water levels between FSL and MOL. This process is anticipated to progressively strip soil material from the side slopes within the reservoirs, leaving a surface of bedrock or resistant weathered regolith. The estimated volumes of soil that could potentially be stripped from within the reservoirs is estimated at 40,514 m^3 for the upper dam and reservoir and 50,725 m^3 for the lower dam and reservoir. The estimated soil volumes represent 0.8% of the total storage volume of the upper and lower dams and reservoirs.

The eroded coarse fraction of the soil is expected to settle in the base of the reservoirs, potentially raising the MOL. Most of the suspended fine silt and clay material released to the upper reservoir is anticipated to be transferred downstream to the lower reservoir via the power waterway. A proportion of the fine sediment sourced from erosion within the lower dam and reservoir will settle to the base of the reservoir, some will remain in circulation between the lower and upper dams and reservoirs, and the rest would eventually be discharged to the Macleay River during overflows from the lower dam and reservoir spillway.

The change in dam and reservoir capacity or MOL will be minor due to the relatively small volume of soil that may be subject to erosion compared to the large capacity of the dams and reservoirs. Erosion within the dam and reservoir footprint will cease once all the inundated soil is stripped from the reservoir side slopes.

7.9.3 Impacts to Fingerboard Crossing Creek

i Trapping of sediment within the dams and reservoirs

Trapping of sediments by dams interrupts the sediment balance of downstream watercourses, which may result in negative impacts on the aquatic environment and coastal areas to which the watercourses ultimately discharge. The upper and lower dams and reservoirs will retain all coarse bed material generated within Fingerboard Crossing Creek, denying this natural contribution of bed load to the reaches downstream of the reservoirs, and from Fingerboard Crossing Creek to the Macleay River.

The sudden reduction in coarse bed load (gravel, cobble, and boulder-sized material) to Fingerboard Crossing Creek downstream of the reservoirs is expected to result in scour of the bed material from the bed of the creek downstream, without replacement by sediment delivered from upstream, thereby lowering the channel bed and removing the most mobile fractions of the bed material. Lowering the bed could lead to greater concentration of discharge within the channel, increasing the capacity of the creek to further scour bed sediments. Reduced bed load supply but ongoing bed material transport will, over time, lead to incision of the bed down to bedrock outcrops and large boulders, with some gravel and cobble material persisting in the spaces between boulders and bedrock outcrops. Fingerboard Crossing Creek (refer to Section 4.3.1ii) has low geomorphic fragility, which means that the incision process will be limited by the creek's natural resistance to change.

Given the small catchment areas contributing to the dams and reservoirs, sediment loads would be small relative to reservoir capacities, so loss of reservoir capacities due to sediment trapping would be a minor impact over the expected operational lifespan of the Project.

ii Hydraulics of Fingerboard Crossing Creek

The hydraulic modelling of Fingerboard Crossing Creek described in Section 7.8.1 was used to inform an assessment of geomorphic impacts. The upper dam and reservoir will impound a portion of Fingerboard Crossing Creek catchment resulting in a reduction in flood flow depth and bed shear stress along the downstream sections of the watercourse. The bed shear stress and depth are both predicted to remain frequently high enough to mobilise fines, sands, gravels, cobbles, and some boulder-sized material.

The change in hydraulic characteristics is anticipated to result in the section of watercourse immediately downstream of the upper dam and reservoir becoming geomorphologically dormant due to a lack of flow and sediment supply. Further downstream, natural inflow and sediment supply will maintain fundamental geomorphic processes, but at a reduced intensity. This will lead to contraction of the active channel width and depth of Fingerboard Crossing Creek between the upper and lower dams and reservoirs.

iii Spells analysis

Spells analysis was undertaken to characterise the relative impact of the Project on the frequency, duration and interval between events that are likely to be associated with geomorphological channel maintenance processes. The analysis indicates Fingerboard Crossing Creek will experience a decline in the magnitude, frequency and duration of flows that contribute to channel maintenance processes. This could impact ecological processes and communities that depend on maintenance of these processes at their natural rates. The impact will decrease moving downstream as natural inflow and sediment supply will maintain fundamental geomorphic processes, but with minor reduction in magnitude, frequency and duration.

iv Impacts downstream of lower dam and reservoir

The lower dam and reservoir will reduce the frequency and volume of flows to the 400 m section of Fingerboard Crossing Creek that is between the reservoir and the Macleay River. The lower dam and reservoir will also act as a barrier to the natural transfer of coarse bed material from the catchment to this reach.

The reduction in bed load downstream of the lower dam and reservoir could increase the risk of scour of sand, gravel and cobble-sized material from the bed, leading to coarsening of the bed material, and a degree of incision. Unlike upstream of the lower dam and reservoir, where the creek flows through granodiorite lithology, this lower section of creek flows through conglomerate. Scour of the unconsolidated bed material could shift the character of the bed to conglomerate bedrock, but the hard rock should constrain the degree of bed incision.

The lower portion of Fingerboard Crossing Creek is expected to be frequently inundated by streamflow events in the Macleay River. These frequent Macleay River events would supply gravel and cobble material to the bed of the lower 136 m of Fingerboard Crossing Creek independently of the transport of bed load sourced from the creek catchment. Hence, the lower portion of Fingerboard Crossing Creek is expected to be less impacted by the reduction in bed load transported downstream of the lower dam and reservoir.

7.9.4 Impacts to the Macleay River

i Operational top-up

Extraction for operational top-up is predicted to result in a maximum reduction in flow depth of 0.05 m (refer to Section 6.3.7v), which represents a 5% change in depth from a streamflow rate of 683.4 ML/day (0.95 m depth) to a streamflow rate of 597 ML/day (0.90 m depth). The reduction in water depth due to extraction is expected be associated with a similar, relatively small, reduction in bed shear stress. This implies a reduction in the likelihood, spatial extent, or particle size range of bed sediment mobilisation at times of water extraction from the river.

The overall impact of water extraction on sediment transport processes in the Macleay River will be to create conditions that emulate a slightly drier period with lower flood peaks. This would have a minor short-term impact, and a negligible long-term impact, on sediment transport processes within the river.

ii Reduction in sediment and bed load material

Fingerboard Crossing Creek catchment makes up 0.03% of the overall Macleay River catchment and is anticipated to contribute a proportionate volume of streamflow (refer to Section 7.3.2ii). The creek is also likely to contribute a slightly higher than proportional load of coarse sediment and slightly lower than proportional load of suspended sediment, due to local variation in topographic and land use characteristics that control sediment delivery over the broader Macleay River catchment.

Due to the substantial difference in catchment size between Fingerboard Crossing Creek and the Macleay River, impacts to the Macleay River as a result of impounding Fingerboard Crossing Creek are considered negligible at the catchment scale and minor at the local scale near the junction of Fingerboard Crossing Creek with the Macleay River.

7.10 Summary of residual impacts

Residual impacts during operation of the Project are summarised in Table 7.4.

Table 7.4 Summary of residual impacts – operational phase

Impact category	Impact mechanism	Potential impact	Proposed mitigation measures	Residual impact
Streamflow regime	Water extraction from the Macleay River	Reduced streamflow in the Macleay River due to water take for operational top-up.	• High-flow-only access approach to be applied to initial storage fill water take whereby the 50th percentile streamflow value of 597 ML/day will be maintained. • Pumping to cease if 30-day streamflow total below 5-year ARI value of 1,936 ML. • No extraction during first seven days of first flow event greater than 50th percentile streamflow value following extended dry period or drought.	• Water take for operational top-up represents 0.1% of annual streamflow volume on average. • The water take results in maximum 12.6% streamflow reduction for short periods of time. • The magnitude of residual impacts decreases downstream as inflows from additional catchment areas contribute a larger portion of streamflow. • Any residual impacts are expected to be short-term (several days). • The above streamflow impacts are not expected to impact water availability for downstream water users.
	Impounding Fingerboard Crossing Creek	Reduced streamflow within Fingerboard Crossing Creek and the Macleay River	• Lower dam and reservoir to be operated to allow inflows in excess of storage capacity to overflow downstream via the spillway.	• Streamflow reduction in Fingerboard Crossing Creek ranges from 100% immediately downstream of the upper dam and reservoir to 13% at the lower dam and reservoir. • Negligible impacts to the Macleay River due to the relative size difference between catchments.
	Groundwater drawdown/ mounding	Impacts to baseflow contributions to minor watercourses and the Macleay River	• Tunnel grouting and lining proposed to reduce groundwater interception and subsequent drawdown impacts.	• A minor increase in baseflow is predicted to occur to several minor watercourses and the Macleay River during operation of the Project.
Water quality	Lower dam and reservoir discharges	Overflows from spillway increase sediment loads in receiving watercourse.	• Increased sediment loads associated with erosion of soil in the dam and reservoir inundation area is impractical to mitigate. • Operational management measures may be implemented to prevent overflows if sediment levels are sufficiently elevated.	• Overflows containing elevated sediment loads may occur during the initial years of operations but would be rapidly diluted within the Macleay River. • The risk of discharging sediment laden water is expected to cease once soil within the dam and reservoir inundation areas has been eroded to bedrock.

Table 7.4 Summary of residual impacts – operational phase

Impact category	Impact mechanism	Potential impact	Proposed mitigation measures	Residual impact
	Spoil emplacements	Seepage from spoil emplacements impacts receiving water quality.	• Runoff from upstream areas will be diverted to minimise the volume of water that contacts the emplacements. • Spoil emplacements will be vegetated with cover crops and appropriate native species where practical.	• Elevated aluminium and iron concentrations are expected in the receiving watercourse immediately downstream of the spoil emplacements. • Seepage from emplacements is anticipated to be diluted by 5–20 times prior to discharging to the Macleay River. • Elevated metals are expected to rapidly mix and dissipate int the Macleay River hence impacts are expected to be localised and short-term.
Environmental receptors	Water extraction from the Macleay River	Reduced water availability to downstream environment.	• Water take will be subject to a range of CTP rules aimed at protecting environmental receptors. • Water quality monitoring is proposed to identify and respond to potential indirect water quality impacts which may impact environmental receptors.	• High-flow-only is expected to minimise disruption to flow cues by allowing low and moderate streamflow events to pass downstream untouched. Only a small portion (up to 12.6%) of higher streamflow events will be extracted. • The maximum estimated water level reduction of 0.05 m (or 5% of stream depth) is not anticipated to have a material impact on habitat availability, fish passage or water quality (e.g. temperature).
	Impounding Fingerboard Crossing Creek	Impounding Fingerboard Crossing Creek blocks fish passage along watercourse	• None	• The lower dam and reservoir will unavoidably block fish passage along Fingerboard Crossing Creek. The resulting impacts to aquatic species are described in the aquatic ecology assessment (Stantec, 2022) in Appendix I of the EIS
Flooding	Macleay River bridge	Impacts to flood level and extent	• Bridge design to provide adequate waterway area to pass flood flows and minimise flood impacts.	• Flood level increases are expected to be minor and are not anticipated to result in a material increase in flood inundation on adjoining properties or Kempsey-Armidale Road. • Impacts of the crossing are expected to reduce in scale with the increase in flood magnitude.

Table 7.4 Summary of residual impacts – operational phase

Impact category	Impact mechanism	Potential impact	Proposed mitigation measures	Residual impact
	Dam break	Increased flood risk downstream of Project	• A formal dam break study will be undertaken in accordance with the Australian National Committee on Large Dams (ANCOLD*) Guidelines on the Consequence Category for Dams* (2012) during future detailed design of the Project.	• Upper dam breach flows are predicted to be captured within the lower dam and reservoir and are not anticipated to flow in to the Macleay River. • Lower dam breach flows in the Macleay River are approximately equivalent to the 1% AEP flood event, where flooding is primarily contained within the channel banks away from key infrastructure. • The Macleay River is predicted to return to normal flow conditions in approximately one hour.
Geomorphology	Reduced sediment and bed load to downstream watercourse	Changes to the geomorphology of Fingerboard Crossing Creek	• Mitigation of geomorphic impacts resulting from the Project is impractical. The recommended alternative is to allow geomorphic adjustments to the altered flow and sediment regimes to proceed.	• Minor impacts to the geomorphology of Fingerboard Crossing Creek are anticipated but will be limited by the creek's natural resistance to change. • The reduction in sediment transport from Fingerboard Crossing Creek to the Macleay River is negligible at the catchment scale and minor at the local scale. • Water extraction is expected to result in minor short-term impacts (i.e. during extraction and negligible long-term impacts to sediment transport processes in the Macleay River.

8 Cumulative impacts

8.1 Overview

This chapter provides consideration of the Project's potential to generate cumulative impacts in the region related to surface water resources.

The *Cumulative Impact Assessment Guidelines for State Significant Projects* (DPE, 2022d) are part of the Rapid Assessment Framework introduced in 2021, aimed at improving the assessment of major projects in NSW. The scoping phase for OMPS preceded the implementation of these guidelines and as such, a scoping assessment for cumulative impacts was not performed at the time. The EIS has therefore performed a screening exercise of future projects, focusing on key matters that could be materially affected, to inform the cumulative impact assessment (EIS Section 6.16).

The Project is located within the Armidale Regional Council LGA. The cumulative impact assessment has considered other future projects (on the DPE Major Projects Planning Portal) that have the potential to interact with the Project, within the following spatial extent:

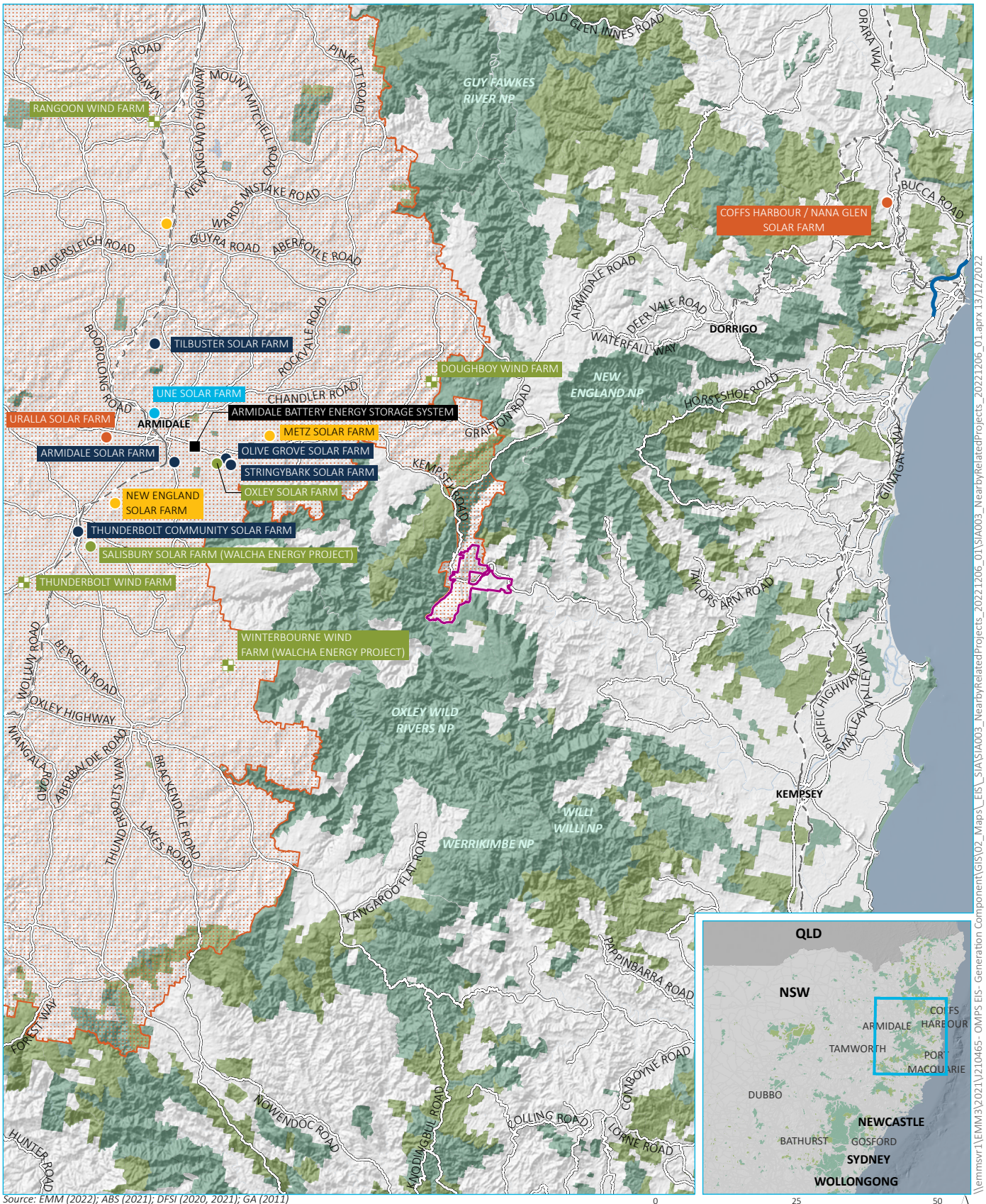
- within the Armidale Regional LGA
- within Kempsey Shire LGA
- within Walcha Council LGA
- within 70 km of the Project area.

The following projects shown on Figure 8.1, and within the above domain, were considered in the cumulative impact assessment:

- Doughboy Wind Farm (SSD-9161599) – 30.5 km north of the Project area
- Winterbourne Wind Farm (SSD-10471) – 37 km south-west of the Project area
- Metz Solar Farm (SSD-7931) – 40.5 km north-west of the Project area
- Stringybark Solar Farm (DA 112-2019) – 45.5 km north-west of the Project area
- Olive Grove Solar Farm (DA 17-2020) – 46 km north-west of the Project area
- Oxley Solar Farm (SSD-10346) – 47 km north-west of the Project area
- Armidale Battery Energy Storage System (SSD-23515853) – 52 km north-west of the Project area
- Armidale Solar Farm (DA-164-2019) – 54 km north-west of the Project area
- New England Solar Farm (SSD-9255) – 61 km north-west of the Project area
- Salisbury Solar Farm (SSD-10347) – 62 km west of the Project area
- Thunderbolt Community Solar Farm (DA-8-2021) – 67.5 km west of the Project
- Tilbuster Solar Farm (SSD-9619) – 68 km north-west of the Project area.

8.2 Consideration of cumulative impacts related to surface water resources

The projects identified in Section 8.1 are primarily within the Macleay River catchment, located upstream of the Project. Solar, battery, and wind energy projects are typically associated with minor, localised impacts to the receiving surface water environment. Hence, impacts to surface water resources as a result of these projects are unlikely to interact with those associated with the OMPS Project due to distance, nature, and scale of the proposed projects (i.e. no operational interaction). Therefore, no cumulative impacts to surface water resources are expected due to the Project.



Source: EMM (2022); ABS (2021); DFSI (2020, 2021); GA (2011)

KEY

- Project area

Energy infrastructure projects

- Battery- In Planning
- Solar- Approved
- Solar- In Planning
- Solar- Operational
- Solar- Under Construction
- Solar- Withdrawn
- Wind- In Planning

- Coffs Harbour City bypass (indicative location)

Renewable energy zones

- New England

Existing environment

- Rail line
- Major road
- NPWS reserve
- State forest

Major Projects in surrounding region

Oven Mountain Pumped Hydro Energy Storage Project
Surface water assessment
OMPS Pty Ltd
Figure 8.1

EMM creating opportunities

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9 Surface water monitoring plan

9.1 Overview

This chapter describes an indicative surface water monitoring program to be implemented during construction and as required during operation of the Project. The primary objectives of the monitoring program are to:

- provide additional monitoring of baseline conditions
- enable the effectiveness of water quality controls to be assessed
- identify and quantify potential impacts to water quality
- identify and quantify potential impacts to streamflow
- enable compliance with relevant consent and licence conditions to be assessed.

9.2 Monitoring program

The monitoring program will be developed as part of the Project SWMP following Project approval, if granted. The development of the monitoring program will include:

- determination of ongoing monitoring locations
- determination of frequency of required monitoring (typically would include continuous, regular interval and event-based monitoring)
- development of a targeted analytical suite
- formalisation of a reporting strategy for water quality monitoring results.

The monitoring program includes requirements to monitor weather, streamflow, treated wastewater quantity and quality, process water quantity and quality, stormwater quality and receiving water quality. The recommended monitoring program and indicative monitoring locations are summarised in Table 9.1.

The monitoring program will be used to identify and respond to any residual impacts that may occur during construction and operation of the Project. The response to potential impacts will be developed and documented via a suitable TARP within the SWMP, with the monitoring results used as a trigger.

The Project monitoring program will be subject to continuous review and improvement over time as described in Section 9.2.3.

Table 9.1 Surface water monitoring framework

Monitoring category	Project phase	Objectives	Monitoring locations	Monitoring method
Weather	• Construction • Operation	• Record rainfall and other meteorological conditions for the Project area.	• Location to provide representative meteorological data for Project area.	• Review options to install and operate a weather station.
Streamflow	• Construction • Operation	• Measure continuous streamflow downstream of proposed water take locations.	• Existing WaterNSW Macleay River at D/S Georges River Junction (206024) stream gauge.	• Monitor real-time stream gauge observations at existing WaterNSW gauge.
Receiving water quality	• Construction	• Monitor receiving water quality to: – establish baseline conditions – identify impacts to water quality.	• Receiving waters upstream and downstream of discharge locations, including: – Macleay River at the confluence with Fingerboard Crossing Creek. – Macleay River downstream of proposed construction works.	• A minimum of 12 samples per year will be collected from each monitoring location. • Sampling will be undertaken during baseflow, wet weather and after wet weather conditions. • All samples will be analysed for a comprehensive suite of parameters.[1]
Process water quantity	• Construction	• Measure all process water uses, sources and controlled discharge volumes. • Measure compliance with WAL entitlements.	• All process water use points including water used for tunnelling and at CBP. • Tunnel dewatering location. • Water extraction from Macleay River (construction and initial storage fill). • Controlled discharges to Macleay River and tributaries.	• Cumulative flow meters will be installed at all monitoring locations. • Meter readings will be recorded monthly.
Process water quality	• Construction	• Monitor the quality of treated process water.	• Process water discharge locations.	• Sampling will be undertaken monthly. • All samples analysed for a comprehensive suite of parameters.[1]
Wastewater quantity	• Construction	• Monitor the quantity of treated wastewater discharges.	• Wastewater treatment plant outlet.	• Cumulative flow meters will be installed at all monitoring locations. • Meter readings will be recorded monthly.
Wastewater quality	• Construction	• Monitor the quality of treated wastewater discharges.	• Wastewater treatment plant outlet.	• Sampling will be undertaken monthly. • All samples analysed for typical contaminants of potential concern in treated wastewater.

Table 9.1 Surface water monitoring framework

Monitoring category	Project phase	Objectives	Monitoring locations	Monitoring method
Stormwater quality	• Construction	• Monitor the quality of water within sediment basins.	• Construction area sediment basin(s).	• A minimum of 12 samples per year will be collected from each monitoring location when basins are overflowing. • All samples analysed for a comprehensive suite of parameters[1].
Emplacement quality	• Construction	• Monitor the quality of seepage and runoff from the spoil emplacements.	• Downstream of emplacements.	• A minimum of 12 samples per year will be collected from each monitoring location. • Sampling will be undertaken during baseflow, wet weather and after wet weather conditions. • All samples will be analysed for a comprehensive suite of parameters[1].
Reservoir top-up quantity	• Operation	• Measure the volume of water extracted for operational top-up.	• Macleay River extraction location.	• Cumulative flow meter will be installed.
Reservoir water quantity	• Operation	• Monitor upper and lower reservoir storage volume.	• Monitoring locations to be determined during detailed design.	• Continuous reading from a calibrated pressure sensor.
Reservoir water quality	• Operation	• Monitor the quality of water within the upper and lower reservoirs.	• Monitoring locations to be determined during detailed design.	• Samples will be collected from each monitoring location on a monthly basis. Sampling frequency may decrease over time as an understanding of reservoir water quality is developed. • All samples to be analysed for a comprehensive suite of parameters including algal cell counts[1].

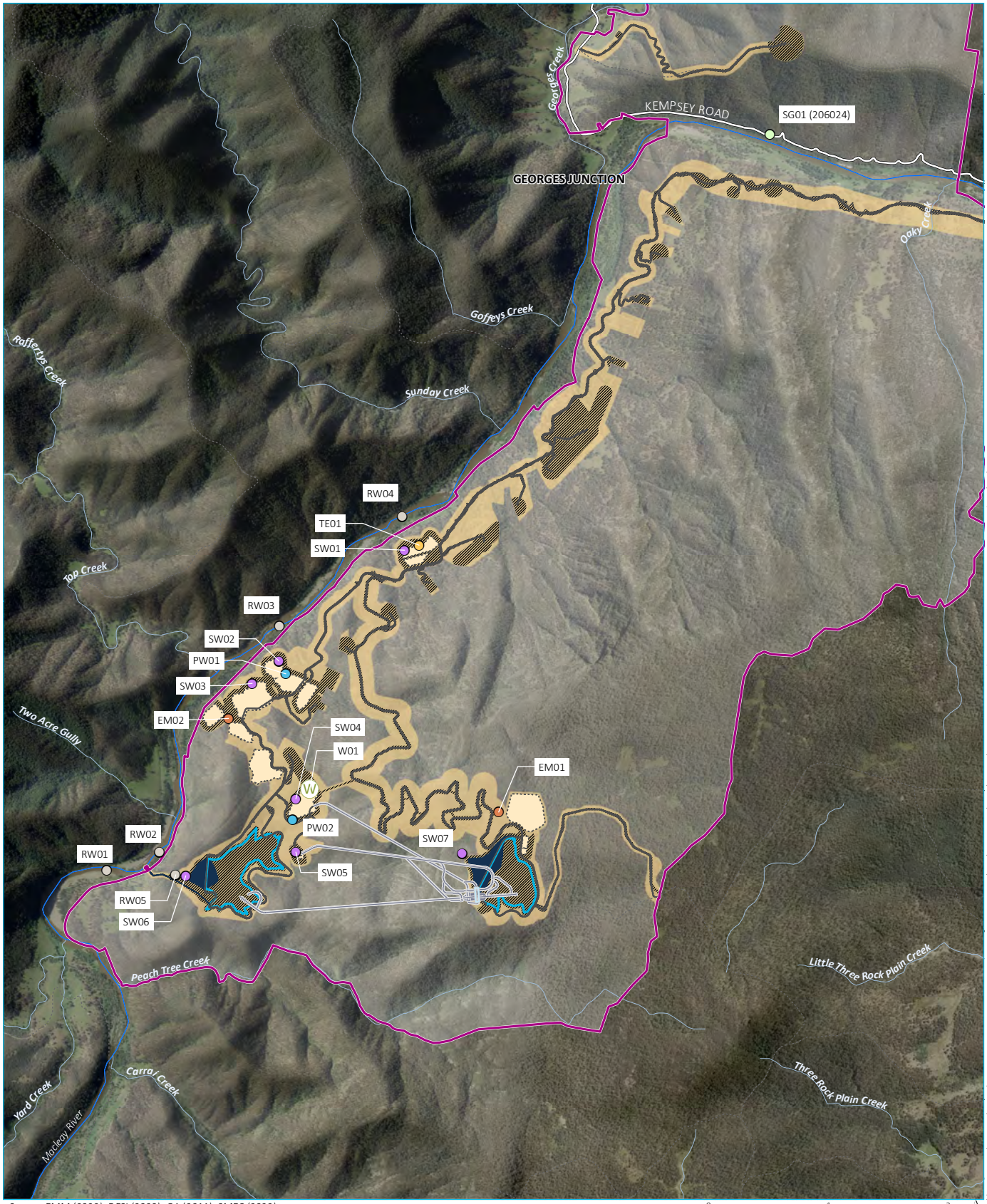
Notes: 1. Refer to Section 9.2.2 for more information on the monitoring regime, sampling analytes and analysis methods.

9.2.1 Monitoring locations

Proposed monitoring locations are described in Table 9.2 and shown in Figure 9.1. The proposed monitoring locations are indicative and may change during the construction and operational planning phases of the Project.

Table 9.2 Surface water monitoring locations

ID	Location	Comment
Weather		
W01	Within Project area	A weather station will be installed in a location that provides representative meteorological data for Project area and is readily accessible (e.g. the switchyard).
Stream gauge		
SG01	Macleay River	Refers to the Macleay River at D/S Georges River Junction stream gauge.
Receiving water		
RW01	Macleay River	Upstream of the Fingerboard Crossing Creek confluence.
RW02	Macleay River	Downstream of the Fingerboard Crossing Creek confluence.
RW03	Macleay River	Downstream of CBP controlled discharge location.
RW04	Macleay River	Downstream of accommodation camp treated wastewater discharge location.
RW05	Fingerboard Crossing Creek	Immediately downstream of lower reservoir footprint.
Process water		
PW01	CBP	Treated wastewater from the CBP will be discharged to the receiving environment (via a water treatment plant).
PW02	Tunnel portal sediment basin outlet	Water dewatered from the underground workings will be discharged to the receiving environment (via a sediment basin).
Stormwater		
SW01	Accommodation camp	Receives runoff from the accommodation camp.
SW02	Works Area 1	Receives runoff from CBP and stockpiles.
SW03	Works Area 2	Receives runoff from the mechanical and electrical workshop pad.
SW04	ECVT portal	Receives runoff from the ECVT portal.
SW05	MAT portal	Receives runoff from the MAT portal.
SW06	Lower reservoir and dam	Receives runoff from the lower reservoir and dam construction area.
SW07	Upper reservoir and dam	Receives runoff from the upper reservoir and dam construction area.
Spoil emplacements		
EM01	Lower reservoir emplacement	Downstream of lower reservoirs spoil emplacement area.
EM02	Upper reservoir emplacement	Downstream of lower reservoirs spoil emplacement area.
Treated effluent		
TE01	Accommodation camp	Treated effluent from the STP will be discharged to the receiving environment.



Source: EMM (2022); DFSI (2020); GA (2011); SMEC (2022)

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KEY

- Project area
- Disturbance footprint
- Construction envelope
- Initial storage fill pump infrastructure

Project operational elements

- Underground power station complex
- Tunnels, portals, intakes, shafts
- Permanent road
- Surface works
- Reservoir
- Dam wall

Proposed surface water monitoring location

- Process water
- Receiving water
- Spoil emplacements
- Stormwater
- Stream gauge
- Treated effluent
- Weather station

Existing environment

- Macleay River
- Watercourse/drainage line
- Kempsey-Armidale Road
- Vehicular track

Proposed surface water monitoring locations

Oven Mountain Pumped Hydro Energy Storage Project
Surface water assessment
OMPS Pty Ltd
Figure 9.1

EMM creating opportunities

9.2.2 Monitoring regime and methods

An indicative monitoring regime is provided for each monitoring category in Table 9.3. Details of the proposed sampling analytes and analysis methods are provided in Table 9.4. All water quality monitoring is to be undertaken in accordance with *Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales* (EPA, 2022).

Table 9.3 Indicative monitoring regime

	Water quantity		Water quality		
Frequency	**Monthly**	**Continuous**	**Monthly**	**Wet weather – daily**	**Wet weather – quarterly**
Method	**Flow meter**	**Gauge**	**Comprehensive**	**Basic**	**Comprehensive**
Weather		✓			
Streamflow		✓			
Receiving water			✓		✓
Process water	✓		✓		
Stormwater				✓	✓
Spoil emplacements			✓		✓
Effluent	✓		✓		
Reservoir		✓	✓		

Table 9.4 Indicative monitoring methods

Category	Proposed sampling analytes	Analysis method
Basic monitoring		
Physico-chemical	Temperature, pH, electrical conductivity, turbidity, dissolved oxygen	To be measured in the field using a portable water quality meter.
Inspection	Visual inspection	Inspection of erosion and sediment controls and downstream drainage
Comprehensive monitoring[1]		
Physico-chemical	Temperature, pH, electrical conductivity, turbidity, dissolved oxygen	To be measured in the field using a portable water quality meter
	Total suspended solids, total dissolved solids, total hardness	Analysis to be undertaken by a NATA certified laboratory
	BTEX, total recoverable hydrocarbons, and oil and grease	
Major ions	Calcium, chloride, fluoride, sodium, magnesium, potassium, sulphate	

Table 9.4 Indicative monitoring methods

Category	Proposed sampling analytes	Analysis method
Nutrients	Ammonia, oxidised nitrogen, total kjeldahl nitrogen, total nitrogen, reactive phosphorus and total phosphorus	
Metals (dissolved)	Aluminium, arsenic, antimony, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc	
Comprehensive monitoring (treated wastewater discharges)		
Oxygen Demand	Chemical oxygen demand, biological oxygen demand	Analysis to be undertaken by a NATA certified laboratory
Biological	Total plate count, E Coli, faecal coli form	

Notes: 1. Comprehensive analysis suite may be reduced for analytes that are consistently below laboratory detection limits.

9.2.3 Monitoring program review

The monitoring program will be periodically reviewed to assess whether the objectives identified in Section 9.1 are being achieved and allow for continuous improvement. Review of the monitoring program may include but would not be limited to:

- Ongoing review of monitoring data – monitoring frequency may be increased or decreased depending on the outcomes of the data review.
- Revising the number and location of monitoring locations to better represent construction and operation activities as they progress.
- Revising the monitoring methods to include additional analytes where necessary or reducing the number of analytes that are consistently below detection limits.

Any material updates to the monitoring program will be captured within the Project SWMP.

10 Water licensing strategy and approvals

10.1 Overview

Most of the Project area is within the Macleay Gorges Water Source (refer to Figure 3.1) and although there is sufficient water (median of 793 GL/year) within the Macleay River adjacent to the Project area, there are insufficient licences within this water source (2 ML of tradeable access licences) to account for the Project surface water take. Several alternative water licensing options have been considered in developing the proposed Project water licensing strategy including:

- sourcing water from the Macleay Valley Water Source via trade or pump and pipeline infrastructure
- trading of surface water entitlements from upstream water sources
- groundwater share entitlements
- access to water in the Macleay Gorges Water Source via a SPAL.

This chapter describes the surface water licensing requirements for the Project including water take mechanisms, the volume of entitlement required, licensing options and preferred strategy, and the proposed regulatory pathway to obtain the required entitlements. While groundwater share entitlements are considered as an option to meet construction and operational water demand, groundwater licensing requirements (due to interception or abstraction) are not described in this section. The proposed licensing pathway to obtain any required groundwater entitlements is presented however to provide a complete picture of the Project water licensing strategy. Further details on groundwater licensing requirements are provided in the groundwater impact assessment (EMM, 2022a) in Appendix M of the EIS.

There is significant complexity in navigating the relevant administrative water regulations and obtaining the required approvals and licences under the current legislative framework. The water licensing strategy presented in this section is the culmination of two years' work (EMM, Water Assessment: Water Licence Options – supporting information, 2020; EMM, Oven Mountain Pumped Hydro: Downstream town water security potential, 2021) including ongoing engagement with regulators such as NSW DPE Water and NSW DPI Fisheries (refer Section10.6), the commencement of new regulatory provisions (refer to Section 3.2.2), and preparation of the Project EIS.

10.2 NSW water legislation and policies for licensing water

10.2.1 Overview

OMPS is required to licence water that is either taken or intercepted in accordance with the WM Act. This includes water taken for use as well as water intercepted and managed as a result of Project activities. OMPS is required to hold WALs in each affected water source to account for all water extracted and intercepted. The following surface water take mechanisms require licensing:

- water sourced from the Macleay River via pumps and pipelines
- the capture of runoff from the local catchment
- streamflow losses due to groundwater drawdown.

The WALs and associated shares need to be held for the water year in which the impact occurs. All shares and WALs do not need to be held prior to the Project approval, as some effects do not occur for years after construction and operation commences. However, a valid pathway needs to be demonstrated to show the shares can be obtained. Valid pathways for obtaining the required licence shares are described in Section 10.7.

10.2.2 Water access licences

Water users can acquire new or increase their existing water entitlements through a number of different avenues. The options available are different for each water source depending on the number of users, and the sustainability of the water source. For the water sources specific to the Project, the options for obtaining entitlements include controlled allocation orders (CAO), dealings and trading, and a SPAL.

i Controlled allocation orders

A CAO is the mechanism for granting new water access licences for water sources with unassigned water. Unassigned water is the portion of the extraction limit specified by the WSP that has not already been allocated to water users. Controlled allocations are a competitive process and are specified in an Order published in the NSW Government Gazette. Relevant information, such as water sources, amounts of water made available and minimum prices, are made publicly available during the controlled allocation process.

ii Dealings and trade

Water sources are classified as “fully committed” when the sum of entitlements and the water reserved to meet basic landholder rights is equal to, or above, the extraction limit specified by the WSP. In fully committed water sources, entering the water trading market is the generally accepted pathway to securing entitlements. Most water sources within NSW are fully committed. WALs, licence shares, and water allocations can be traded. The most common dealings include:

- entitlement trade (known as a ‘permanent trade’), which entitles the new owner to accrue all future allocations made to the purchased licence or shares
- allocation trade (known as a ‘temporary trade’), which are a ‘one-off’ trade of actual water in accounts.

iii Specific purpose access licences

The use of water associated with a SPAL is for a specific period and purpose, and if granted, would be extinguished at completion of the activity. Water taken under a SPAL can only be used for the specific purpose for which the licence was granted.

The NSW Government has recently amended Part 2, Division 1 of the Water Regulation to create a new category of SPAL for the construction and initial storage fill for pumped hydro projects in unregulated river water sources (clauses 5(1)(k) and 10(1)(o)). Applications can be made for this SPAL type. This amendment facilitates the development of pumped hydro projects that form a component of the NSW Government’s Renewable Energy Action Plan.

Before an application for a SPAL can be made, the following are required:

- approval under the EP&A Act
- amendments to the relevant WSP to establish the rules for managing SPALs.

WSP amendments must be made by the NSW Minister for Water, with the concurrence of the NSW Minister for the Environment. The primary amendments are to provide available water determinations for the SPAL and to specify the allocation account management and dealing rules for the SPAL type.

Both the granting of the SPAL and the amendment of the applicable WSP are subject to the principles and other requirements of the WM Act. The Minister cannot grant a SPAL unless they are satisfied that 'adequate arrangements are in force to ensure that no more than minimal harm will be done to any water source as a consequence of water being taken from the water source under the licence' (section 63 (2) of the WM Act).

10.2.3 Exemptions

i Water Management Act authorisations

The Project's key authorisation required for water licensing under the WM Act is for the SPAL for construction and initial storage fill. As the Project is classified as CSSI, clause 5.23 of the EP&A Act exempts the Project from requiring:

- A water use approval under Section 89 of the WM Act, which authorises the holder to use the water taken for a specified purpose at a specified location.
- A water management work approval under Section 90 of the WM Act, which authorises the holder to construct and use a work to take water from a river, lake or aquifer at a specified location.
- An activity approval (other than an aquifer interference approval) under section 91 of the WM Act, which authorises the holder to carry out a specified controlled activity at a specified location in, on or under waterfront land (defined as the bed of any river, lake or estuary and the land within 40 m of the riverbanks, lake shore or estuary mean high water mark).

The intent of the above clauses is for the applicant to avoid the need to seek duplicate approvals.

ii Water management dams

Water management dams are proposed to manage runoff from construction disturbance areas, construction pads and the accommodation camp. The capture of surface water runoff in the water management dams is considered to be excluded works under the Water Regulation, Schedule 1, item 3 (dams solely for the capture, containment or recirculation of drainage). Accordingly, no WAL is required for the capture of surface water in management dams.

iii Recirculated water

The Project will circulate water between the lower and upper dams and reservoirs to generate electricity. This closed system approach could be defined as 'take' under the provisions of the WM Act, given that the water is being pumped from, then returned to a water source. The recirculation of water in pumped hydro-electricity schemes is exempt from water licencing requirements under the Water Regulation, Schedule 4, item 11A if the water was originally taken under:

a) an access licence, or

b) a basic land holder right.

All water contained in the Project dams and reservoirs will be taken under an access licence or basic land holder right. Hence, the recirculation of water between the Project dams and reservoirs is exempt from water licensing requirements.

10.2.4 Summary of legislative requirements

The key approval required for water licensing under the WM Act is for the SPAL for initial storage fill and construction use. Once the SPAL is granted, the licence will need to be linked to works that are approved under the EP&A Act assessment. The Project would then obtain miscellaneous works approvals for water related infrastructure (i.e. pumps and bores).

While not on the Macleay River, the lower and upper reservoirs are classified as 'in-river' dams as they are located on third and second order watercourse reaches of Fingerboard Crossing Creek respectively. The design, operation, and potential impacts associated with the structures will be assessed under the provisions of the EP&A Act. Placing the reservoirs off stream is not an option due to topographical constraints.

10.3 Water entitlements

10.3.1 Existing water access licences

OMPS currently hold the following water entitlements:

- 22-unit shares of unregulated river access licences in the Yarrowitch River Water Source
- 232-unit shares of aquifer access licences in the New England Fold Belt Coast Groundwater Source.

OMPS will permanently trade the 22-unit shares in the Yarrowitch River Water Source to the Macleay Gorges Water Source to meet Project water licensing requirements (refer to Section 10.4).

10.3.2 Harvestable rights potential

As the upper dam and reservoir impounds two first order tributaries to Fingerboard Crossing Creek, harvestable rights may be applied to the interception of surface water runoff from the upper reservoir local catchment during construction and operation. The MHRDC for the Project is 200 ML based on the proposed operational landholding area of 2,000 ha. Hence, 200 ML/year could be intercepted by the upper reservoir under harvestable rights. Water licences will need to be acquired to account for intercepted volumes in excess of 200 ML/year.

10.4 Water licence requirements

10.4.1 Construction and initial fill

Construction water requirements are estimated to be 365 ML/year over the approximate five-year construction program while an initial one-off storage fill volume of 6,500 ML is also required (refer to Section 5.5.2). It is proposed to achieve the initial storage fill within a 12 month period. The average time to complete this one-off event is expected to be approximately six months. However, a longer initial fill period (up to two years) may be required if dry or drought conditions are experienced during the construction period.

A breakdown of water licensing requirements over the five-year construction program is provided in Table 10.1. For the purposes of determining licencing requirements, it is assumed the initial storage fill will occur within a 12-month (i.e. one water year) period.

Table 10.1 General construction and initial storage fill water access licence requirements

Construction year	General construction water	Initial storage fill	Annual total
1	365 ML	-	365 ML
2	365 ML	-	365 ML
3	365 ML	-	365 ML
4	365 ML	6,500 ML	6,865 ML
5	365 ML	-	365 ML
Total requirement			**8,325 ML**

The maximum annual water requirement (6,865 ML) is shown to occur during the initial storage fill period while 365 ML/year is required in all other construction years. The total volume required for general construction and initial storage fill is estimated at 8,325 ML.

It is proposed to apply a nominal 20% buffer to the total SPAL volume to account for potential losses or an extended construction program. Hence, it is proposed to apply an upper limit of 10,000 ML to the SPAL to cover the full construction period. The streamflow impact assessment associated with water extraction under the SPAL (refer to Section 6.3.7) described is still considered valid for a total SPAL volume of 10,000 ML as the CTP conditions and maximum annual extraction volume of 6,865 ML/year remain unchanged.

10.4.2 Operational water take

Water will be required for several activities during operations including fire-fighting water, power station operation, potable water for office facilities, and periodic top-up of the Project reservoirs. Water licences will need to be obtained for the following operational water take mechanisms:

- extraction of water from the Macleay River via pumps and pipelines for operational top-up
- interception of local catchment runoff by the upper and lower dams and reservoirs.

The water balance results presented in Section 7.2.3 predict 838 ML/year (80th percentile) water take will occur during operations. It should be noted that no specific policy exists for calculating licensing requirements that include the interception of local catchment runoff. Licensing the 80th percentile value is considered a reasonable approach given the expected variation in annual runoff volumes and the annual carry over rules defined in the Macleay WSP under water allocation and account management (refer to Attachment A).

The water balance model results indicate 67 ML/year of this water take is associated with the interception of local catchment runoff by the upper dam and reservoir. This component of the operational water take will be exempt from licensing under the 200 ML/year harvestable rights potential applicable to the Project (refer to Section 10.3.2).

10.4.3 Decommissioning

It is proposed to maintain the upper and lower dams and reservoirs upon decommissioning of the Project (EMM, 2022d). Once decommissioned, the reservoirs will continue to intercept local catchment runoff. Water entitlements will be required to account for any residual water take following decommissioning. It is proposed to maintain the licenses obtained for the interception of local catchment runoff by the lower dam and reservoir (545 ML/year) following decommissioning of the Project. It is assumed harvestable rights will still be applicable to the interception of local catchment runoff by the upper dam and reservoir following decommissioning. Hence, the interception of local catchment runoff by the upper dam and reservoir (67 ML/year) has not been included in the decommissioning licensing requirement calculations.

10.5 Licensing options

10.5.1 Sourcing water from the Macleay Valley Water Source

Most of the Project infrastructure and hence construction activities occur in the Macleay Gorges Water Source. The northern portion of the Project area is in the Macleay Valley Water Source.

The trading of a surface water share entitlement from the downstream Macleay Valley Water Source either on a temporary or permanent basis (or a combination of both) has been investigated. The Macleay WSP allows trade from the Macleay Valley Water Source (and other downstream water sources) provided the entitlement in the target water source does not increase (no net gain). In the case of the Macleay Gorges Water Source, the total water entitlement is 2 ML and hence insufficient water could be traded from downstream to meet general construction and initial storage fill requirements (up to 6,865 ML/year) and satisfy the no net gain trading rule.

An amendment to the Macleay WSP would be required to allow a larger volume of water entitlements to be traded from a downstream water source into an upstream water source. This may set an unfavourable precedence of allowing trade (even for a one-off event such as initial storage fill) from downstream to upstream.

While the northern portion of the Project area is in the Macleay Valley Water Source, the Project reservoirs are approximately 8 km upstream, in the Macleay Gorges Water Source. The installation of a pump and pipeline to extract water from the Macleay Valley Water Source and transfer it to the Project reservoirs is considered impractical due to construction constraints. Furthermore, there is only 3,379 ML of tradable water within the Macleay Valley Water Source that can be purchased from existing unregulated river WAL holders (refer to Section 4.5). Should the 3,379 ML be fully traded for the Project, it would be insufficient to meet the 6,865 ML/year requirement and would also take all available water out of the system for use by others.

Sourcing water from the Macleay Valley Water Source is not considered a viable option for general construction purposes and initial storage fill due to insufficient allowable trade volumes.

Trading water within the Macleay Valley Water Source is a viable option to meet water demand for construction of the Eastern Access Road.

10.5.2 Trading from upstream water sources

The Macleay WSP allows for the trade of surface water entitlements into the Macleay Gorges Water Source from a specific list of upstream water sources (refer to Attachment A). Trade may be on a temporary or permanent basis (or a combination of both) and is not restricted to the no net gain principle applied to trading from the downstream Macleay Valley Water Source. However, sufficient water entitlements need to be available and a willingness to trade needs to be established in the upstream water sources.

A review of upstream water sources that can trade into the Macleay Gorges Water Source indicates 7,693 ML of water entitlements existed across 16 water sources in the 2021/2022 water year. Most of these water entitlements are spread across the Commissioners Waters (2,086 ML), Gara River (1,065 ML), Salisbury Waters (1,470 ML), Tia River (703 ML), and Yarrowitch River (759 ML) water sources.

The maximum annual Project water demand during construction of 6,865 ML/year is approximately 90% of the total upstream tradeable volume of 7,693 ML. As with trading from Macleay Valley Water Source, trading the volume required to meet general construction and initial storage fill demand would take most of the available water out of the system for use by others. Impacts on local economies and jobs dependent on this water may be significant. It may also be impractical to achieve the required water entitlement via trade due to the large number of dealings that would be required, and the likelihood of attracting the required number of willing sellers is low.

Trading from upstream water sources is a viable option to meet water requirements during operations and decommissioning.

10.5.3 Groundwater

This option would involve acquiring aquifer access licences or water allocations totalling 6,865 ML from the NEFBC Groundwater Source. This pathway exists via CAO and/or in combination with the trading of groundwater entitlements and allocations within the water source.

The 2021 CAO released 1,739 ML of groundwater entitlements within the NEFBC Groundwater Source while the 2020 CAO released 1,529 ML. Larger releases have occurred in previous years (4,985 ML in 2017), however, it is not known how much water will be made available in future CAOs. It is expected that it would take several years to secure sufficient groundwater entitlements to meet the initial storage fill requirement.

One groundwater bore (GW307320) is registered within the study area, located in the western catchment. The bore has intercepted a moderate yield (5 L/s) from within the shallow fractured rock groundwater system, providing typically fresh water for domestic use. Groundwater supply within the regional fractured rock groundwater system is typically low, with practical supply contingent on intercepting the infrequent fracture networks within the geology.

If the yield at GW307320 provides an indication of the groundwater resource close to Project area, a pump rate of 5 L/s (0.4 ML/day) would require at least 89 bores operating over a six-month period to extract the estimated 6,500 ML needed for the initial storage fill. The construction of 89 bores would require a substantial disturbance footprint and is likely to have greater environmental impacts compared to taking water from the Macleay River under high flow conditions.

More information on the groundwater resource (e.g. shallow and deep aquifers) underlying the Project area would also be required to assess the potential use of groundwater for the initial storage fill.

Despite the presence of groundwater that would be available via the current regulatory pathways, the use of the underlying groundwater resources for construction and initial storage fill is not considered a viable option. The comparatively low yield of the resource means a substantial bore field would need to be installed to achieve the initial storage fill within the proposed 12 month period.

Groundwater could be a supplementary supply to meet construction water demand on an as needed basis.

10.5.4 Access to Macleay Gorges Water Source via a SPAL

The NSW Government recognises the difficultly faced by pumped hydro-electric projects to obtain enough water licence entitlements to meet general construction and initial storage fill requirements through the water market (DPIE, Water access licence requirements for pumped hydro-electricity generation schemes: Fact sheet, 2021). In recognition of these difficulties, the regulatory pathway for this water take was recently introduced by the NSW Government through amendments to the Water Regulation (refer to Section 3.2.2i).

Due to the substantial volume (up to 6,865 ML/year) and one-off nature of the construction and initial storage fill water requirement, the water take could be authorised under the SPAL category 'unregulated river pumped hydro-electricity generation (construction and initial storage fill) access licence' as defined in the Water Regulation. Accessing surface water from the Macleay Gorges Water Source under a SPAL is considered the only feasible option to meet construction and initial storage fill requirements as there is no other feasible regulatory pathway available for the Project to secure the 6,865 ML/year volume required.

To authorise a SPAL, Section 61 (2) of the WM Act requires there to be no more than minimal harm to the water source, the environment, and other water users (DPIE, Water access licence requirements for pumped hydro-electricity generation schemes: Fact sheet, 2021).

10.6 Licensing consultation

OMPS and EMM have worked constructively with the NSW Government through the early stages of Project development and prior to the recent amendment of the Water Regulation, to determine the pathway to gaining a SPAL and to resolve potential regulatory barriers to hydropower development in NSW. A summary of agency consultation is provided in Table 10.2.

Table 10.2 Summary of consultation on water licensing matters

Regulatory authority	Date	Consultation topics and outcomes
NSW DPE Water	Meetings July 2021, October 2021, and February 2022 Ongoing correspondence since 2021	• Project background including water requirements and availability. • Use of a SPAL for construction and initial storage fill requirements. • Proposed SPAL extraction conditions and associated streamflow impacts. • Regulatory amendments required to allow OMPS to apply for and take water under a SPAL. • WSP amendments to include SPAL category and other consequential provisions. • OMPS/EMM to develop options for defining when the SPAL would be cancelled. • OMPS/EMM to further consider potential impacts to aquatic species in consultation with NSW DPE Water (Sciences). • OMPS/EMM to consult with coastal planning divisions of various agencies. • NSW DPE Water maintaining communication lines with Natural Resources Access Regulator (NRAR).

Table 10.2 Summary of consultation on water licensing matters

Regulatory authority	Date	Consultation topics and outcomes
NSW DPE Water (Sciences)	August 2021	• Project background including water requirements and availability. • Use of a SPAL for construction and initial storage fill requirements. • Need for the Macleay River to recharge/recover following dry periods. • Impacts to aquatic species (including Australian Bass) need to meet 'no more than minimal harm' criteria. • OMPS/EMM to present potential impacts to Australian Bass and other aquatic species to NSW DPI Fisheries. • Commitment to consult with NSW DPE Water and NSW DPI Fisheries over the fish screen design moving forward and into detail design.
NSW DPI Fisheries	September 2021 February 2022	• Project background including water requirements and availability. • Proposed SPAL extraction conditions and associated streamflow impacts. • Australian Bass is relevant but not the only species that migrate or rely on specific flow cues within the Macleay River. • It is likely there will be some species migrating or relying on flow cues all year round and so seasonal restrictions may not lead to best outcome. • General support of maintaining the 50th percentile streamflow value. • Discussion on coastal planning aspects of the SPAL.
NSW DPE Biodiversity and Conservation	February 2022	• Project background including water requirements and availability. • Use of a SPAL for construction and initial storage fill requirements. • Proposed SPAL extraction conditions and associated streamflow impacts. • Discussion on coastal planning and WSP aspects of the SPAL.

10.7 Project licensing strategy

This section provides an overview of the overall Project water licensing strategy to demonstrate a feasible regulatory pathway is available for all Project water take. Project water take elements and the proposed water licensing pathways for each are described below:

- **General construction and initial storage fill** – Water take for general construction and initial storage fill is proposed to be authorised by a SPAL, as provided for in Part 2, Division 1 of the WM Act. The licence application is for a one-off initial fill of 6,500 ML plus construction water requirements of 365 ML/year over an expected five-year construction timeframe.

- **Eastern Access Road construction** – The Eastern Access Road is in the Macleay Valley Water Source and is expected to be established in the early stages of construction. Water for the construction of the Eastern Access Road will be sourced from the Macleay River via pumps and pipelines. Water take will be met by trade from existing unregulated river access entitlements in accordance with the conditions and access rules outlined in the Macleay WSP.

- **Interception of local catchment runoff** – Intercepted surface water runoff will be met by trade from existing upstream unregulated river access entitlements in accordance with the conditions and access rules outlined in the Macleay WSP. Harvestable rights (at 10%) may also be applied to the interception of surface water runoff from the upper dam and reservoir local catchment during construction and operation.

- **Streamflow losses due to groundwater drawdown** – Streamflow losses due to groundwater drawdown will be met by trade from existing upstream unregulated river access entitlements in accordance with the conditions and access rules outlined in the Macleay WSP.

- **Baseflow losses due to groundwater drawdown** – Baseflow losses due to groundwater drawdown will be licensed where required via CAO. The total groundwater entitlement required for the Project is described in the groundwater impact assessment (EMM, 2022a) in Appendix M of the EIS.

- **Groundwater interception/extraction** – Groundwater intercepted by the underground workings and extracted via supply bores will be licensed via CAO. OMPS successfully secured 232 ML of groundwater entitlement from the NEFBC Groundwater Source via the 2021 CAO. The total groundwater entitlement required for the Project is described in the groundwater impact assessment (EMM, 2022a) in Appendix M of the EIS.

- **Operational water requirements** – Operational water take will be met by trade from existing unregulated river access entitlements upstream of the Macleay Gorges Water Source in accordance with the conditions and access rules outlined in the Macleay WSP. Operational water take will be sourced from the Macleay River via pump and pipeline.

An overview of the Project water licensing strategy including water take mechanisms, corresponding water licensing pathways, and status is shown in Figure 10.1.

Figure 10.1
Overview of water licensing strategy

Oven Mountain Pumped Hydro Energy Storage Project
OMPS Pty Ltd

GOVERNMENT REGULATOR ABBREVIATIONS

DPE– The NSW Department of Planning and Environment

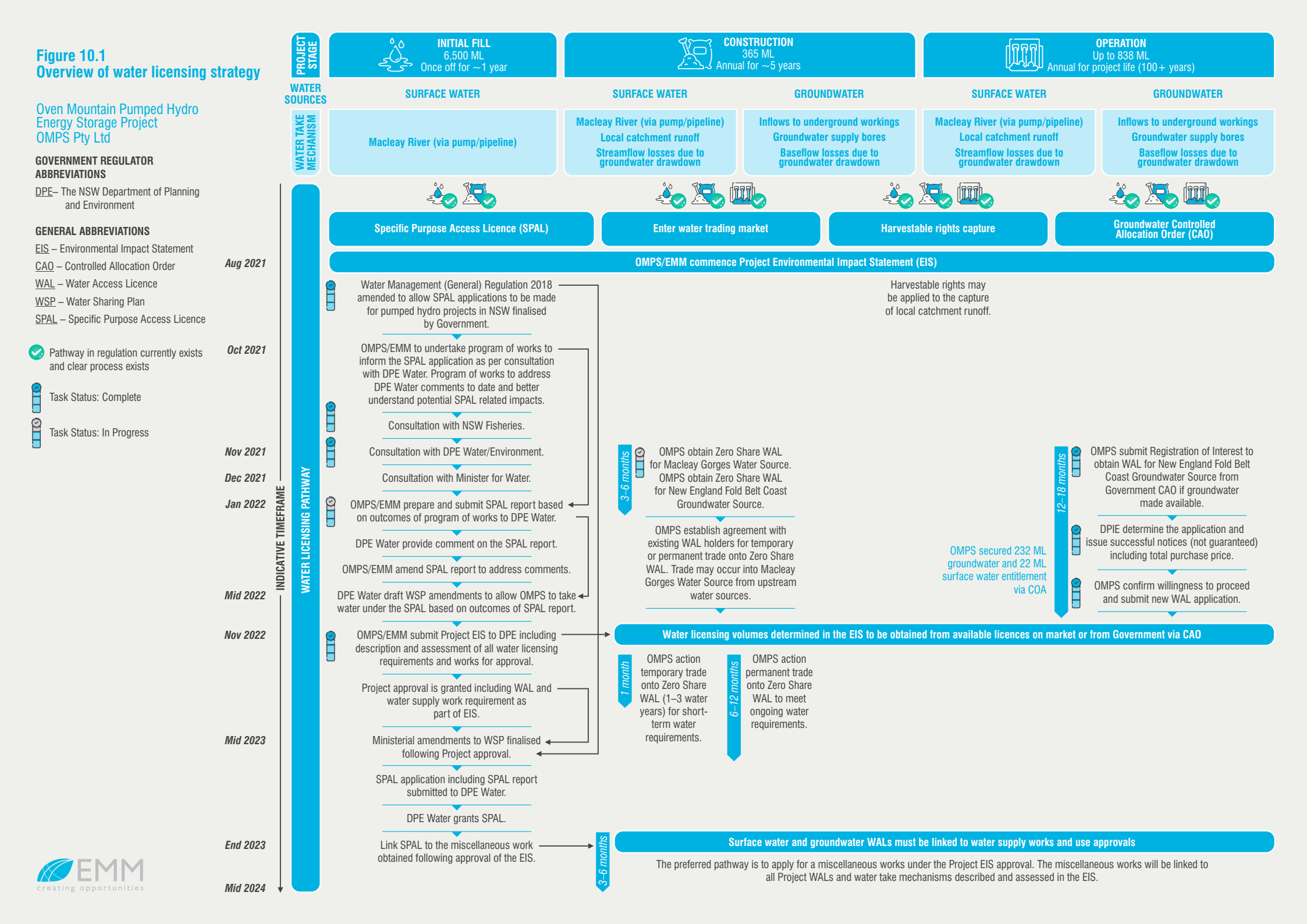
GENERAL ABBREVIATIONS

EIS – Environmental Impact Statement
CAO – Controlled Allocation Order
WAL – Water Access Licence
WSP – Water Sharing Plan
SPAL – Specific Purpose Access Licence

Pathway in regulation currently exists and clear process exists

Task Status: Complete

Task Status: In Progress



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10.8 Licensing summary

It is proposed to licence the water required for general construction use and initial storage fill via a SPAL, as provided for in the Water Regulation. Several other licensing pathways are proposed to account for all other Project water take. A summary of the Project water licensing strategy for both construction and operation phases is presented in Table 10.3.

Table 10.3 Water access licence requirements

Water source	Water take	Licensing pathway	Volume
Construction phase			
Macleay Gorges Water Source	General construction water and initial storage fill	Specific Purpose Access Licence as provided for in Part 2, Division 1 of the WM Act.	10,000 ML[1]
	Streamflow losses due to groundwater drawdown	Trade from existing unregulated river access entitlements.	33 ML/year
Macleay Valley Water Source	Eastern access road construction water	Trade from existing unregulated river access entitlements.	Up to 1 ML/day
Operational phase			
Macleay Gorges Water Source	Operational top-up	Trade from existing unregulated river access entitlements.	226 ML/year
	Local catchment runoff intercepted by upper dam and reservoir	Harvestable rights[2]	67 ML/year
	Local catchment runoff intercepted by lower dam and reservoir	Trade from existing unregulated river access entitlements.	545 ML/year
Decommissioning			
Macleay Gorges Water Source	Incidental interception of local catchment runoff	Licences obtained to account for the interception of local catchment runoff to be maintained to account for passive water take by retained reservoirs.	545 ML/year[3]

Notes: 1. Total SPAL volume includes estimated required volume of 8,325 ML plus 20% contingency to account for potential losses or an extended construction program.
2. Water take under harvestable rights is exempt from licensing requirements.
3. It is assumed the 67 ML/year intercepted by the upper dam and reservoir will be exempt under harvestable rights following decommissioning

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Abbreviations

Abbreviation	Definition
°C	degrees Celsius
µg/L	micrograms per litre
µS/cm	microsiemens per centimetre
ADWG	Australian Drinking Water Guidelines
AEP	annual exceedance probability
AHD	Australian Height Datum
AIP	Aquifer Interference Policy
Alinta Energy	Alinta Energy Pty Ltd
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZG	Australian and New Zealand Governments
ARI	average recurrence interval
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ARR 2019	Australian Rainfall and Runoff
AWBM	Australian Water Balance Model
BoM	Bureau of Meteorology
CBP	concrete batching plant
CEMP	Construction Environmental Management Plan
CFRD	concrete faced rockfill dam
COA	controlled allocation orders
CSSI	critical State Significant Infrastructure
CTP	cease to pump
DGVs	default guideline values
DPE	NSW Department of Planning and Environment
DPI	NSW Department of Primary Industries
DPIE	NSW Department of Planning, Industry and Environment
DS Act	*NSW Dams Safety Act 2015*
DS Regulation	*NSW Dams Safety Regulation 2019*
ECVT	emergency, cable, ventilation tunnel
EIS	environmental impact statement
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPA	NSW Environmental Protection Authority

Abbreviation	Definition
EPL	environmental protection licence
ESCP	Erosion and Sediment Control Plan
FM Act	*Fisheries Management Act 1994*
FMP	Flood Management Plan
FRMM	Flood Risk Management Manual
FSL	full supply level
GDEs	groundwater dependent ecosystems
GL	gigalitre
GL/year	gigalitres per year
GRA	Gondwana Rainforests of Australia
Groundwater WSP	*Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016*
ha	hectares
HES	high efficiency sediment
HVAC	heating, ventilation and air conditioning
ISB	isolated phase busbar
km	Kilometre
km^2	square kilometres
KSC	Kempsey Shire Council
kV	Kilovolt
kW	Kilowatt
L/person/day	litres per person per day
LGA	Local Government Area
LOL	lowest operating level
m	metre
m^3/s	cubic metre per second
Macleay WSP	*Water Sharing Plan for the Macleay Unregulated and Alluvial Water Sources 2016*
MAT	main access tunnel
MHRDC	maximum harvestable right dam capacity
ML	megalitre
ML/day	megalitre per day
ML/year	megalitres per year
$ML/year/km^2$	megalitres per year per square kilometre

Abbreviation	Definition
mm	millimetre
mm/year	millimetres per year
MOL	minimum operating level
MW	megawatt
NEFBC	New England Fold Belt Coast
NEM	National Energy Market
NRAR	Natural Resources Access Regulator
NSW	New South Wales
NTU	nephelometric turbidity units
OMPS	OMPS Pty Ltd
PHGW	pumped hydro-electric and generation works
PMF	probable maximum flood
POEO Act	*Protection of the Environment Operations Act 1997*
POEO Regulation	*Protection of the Environment Operations (General) Regulation 2021*
REZ	Renewable Energy Zone
RFO	river flow objective
SEARs	Secretary's Environmental Assessment Requirements
SPAL	specific purpose access licence
SSTV	site-specific trigger value
STP	sewage treatment plant
SWMP	Soil and Water Management Plan
TARP	trigger action response plan
TWS	town water supply
VT	voltage transformer
WAL	water access licence
Water Regulation	*Water Management (General) Regulation 2018*
WM Act	*Water Management Act 2000*
WQO	water quality objectives
WSP	water sharing plan

Attachment A

Summary of water sharing plan rules

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A.1 Overview

Surface water sources in the Project area are managed under the *Water Sharing Plan for the Macleay Unregulated and Alluvial Water Sources 2016* (Macleay WSP). The Macleay Valley and Macleay Gorges water sources are relevant to the Project. The following sections describe the available water entitlements, access rules, licence conversion rules, and dealing (trading) rules outlined in the Macleay WSP for the Macleay Gorges and Macleay Valley water sources.

A.2 Available water, basic rights, and access licences

The requirements for basic landholder rights and licensed surface water take for the Macleay Gorges and Macleay Valley water sources are summarised in Table A.1.

Table A.1 Macleay WSP – available water, basic rights, and licence shares

Water take category	Water access rights	
	Macleay Gorges Water Source	Macleay Valley Water Source
Basic landholder rights (at time plan Gazetted)		
Domestic and stock rights	14 ML/year	483 ML/ year
Native title	0 ML/year	0 ML/year
Water access licences (2021/2022 water year)		
Domestic and stock access licences	0 ML/year	8 ML/ year
Local water utility access licences	0 ML/year	10,141 ML/ year
Unregulated river access licences	2 unit shares	3,379 unit shares
Unregulated river (high flow) access licences	N/A	0[1] ML/year
Aquifer access licences	0 unit shares	281 unit shares
Total water access rights	**16 entitlement units**	**14,292 entitlement units**

Notes: 1. Macleay Valley Water Source and Aspley River Water Source are the only water sources within the Macleay WSP which have been identified as suitable for unregulated river (high flow) access licences.

The total water access rights in the Macleay Gorges Water Source (16 units) is substantially less than in the Macleay Valley Water Source (14,292 units). Most of the Macleay Valley Water Source rights are held by Kempsey Shire Council for town water supply (TWS).

A.3 Access rules – non-town water supply

WSPs for unregulated rivers typically use specific controls on extraction, such as cease to pump (CTP) rules, as a means of protecting the water resource, its dependent ecosystems, and basic landholder rights during periods of low streamflow. CTP rules require access licence holders to cease pumping when streamflow falls below a certain level. The rationale for CTP rules is that during drier climatic periods when streamflow is naturally low, river health is at risk due to deteriorating water quality, diminishing refugia for water dependant fauna, and increased competition for extraction.

The access rules for non-TWS licensed extraction in the Macleay Gorges and Macleay Valley water sources under the Macleay WSP are outlined in Table A.2.

Table A.2 Macleay WSP – non-town water supply licensed access rules

Access rules	Macleay Gorges Water Source	Macleay Valley Water Source
Access rules for surface waters		
Cease to pump[1]	13 ML/day	Years 1–3: 13 ML/day Years 4–6: 19 ML/day Years 7–10: 30 ML/day
Daily pumping restrictions	N/A	Pumping limited to: • 6 hours/day when streamflow is less than or equal to 40 ML/day (down to the CTP) at the reference point. • 10 hours/day when streamflow is more than 40 ML/day and less than or equal to 60 ML/day at the reference point.
Reference point	Macleay River downstream of Georges River gauge (206024).	Macleay River at Turners Flat gauge (206011).
Access rules for natural off-river pools		
Cease to pump	Pumping is not permitted when the water level in that natural off-river pool is lower than its full capacity[2].	Pumping is not permitted when the water level in that natural off-river pool is lower than its full capacity[2].
Reference point	Individual natural off-river pool.	Individual natural off-river pool.
Access rules for aquifers		
Cease to pump	Nil	Nil
Reference point	Not required	Not required

Notes: 1. This rule applies to all extraction from rivers and creeks in this water source including natural in-river pools within the channels of rivers and creeks.
2. 'Full capacity' can be approximated by the pool water level at the point where there is no visible flow into and out of that pool.

The Macleay Gorges Water Source includes a CTP trigger of 13 ML/day (defined as 'very low flow'), which applies to all licensed extraction from rivers and creeks including natural pools within channels of rivers and creeks. There are no daily pumping restrictions specified.

The Macleay Valley Water Source similarly includes a CTP trigger at very low flows which applies to all non-TWS licensed extraction from rivers and creeks including natural in-river pools within channels of rivers and creeks. For this water source however, the definition of very low flow changes over the life of the WSP. This approach allows licence owners to adapt their extraction requirements in advance of more stringent limits and will effectively retain more water in the river over time. Daily pumping restrictions have also been specified for these extractions.

A.4 Access rules – town water supply

Specific access rules for surface water and alluvial aquifers apply to the four local water utility access licences held by the local water authority (Kempsey Shire Council). These bespoke CTP rules are linked to the water level in the Steuart McIntyre Dam and specified flows at the Macleay River at Turners Flat gauge. The TWS access rules defined in the Macleay WSP are summarised in Table A.3.

While the TWS access rules are not directly relevant to the Project water take, the extraction of water for Project activities has the potential to reduce streamflow volumes and increase the frequency at which daily flow restrictions are experienced.

Table A.3 Macleay WSP – town water supply access rules

Volume of water in Steuart McIntyre Dam	Daily extraction restrictions
Greater than 60%	When flow at the Macleay River at Turners Flat gauge (206011) is: • equal to or greater than 235 ML/day, water must not be taken under a local water utility access licence in an amount greater than 32 ML/day • less than 235 ML/day, water must not be taken under a local water utility access licence in an amount greater than 8.5 ML/day.
Equal to or less than 60%	When flow at the Macleay River at Turners Flat gauge (206011) is: • equal to or greater than 235 ML/day, water must not be taken under a local water utility access licence in an amount greater than 32 ML/day • less than 235 ML/day and equal to or greater than 62 ML/day, water must not be taken under a local water utility access licence in an amount greater than 20 ML/day • less than 62 ML/day, water must not be taken under a local water utility access licence in an amount greater than 8.5 ML/day unless water restrictions are in place for Kempsey Shire.

A.5 Conversion to a new licence category

In many coastal unregulated rivers in NSW there is significant competition for water during dry periods. Incentives were created aimed at encouraging extraction during times of higher flows rather than at times of low flow.

Clause 62 of the Macleay WSP includes an incentive to allow unregulated river access licences that are converted to high-flow-only access to be granted additional volumes of water. The plan states that for every unit of unregulated river access licence entitlement surrendered, five units of unregulated river (high flow) access licence entitlement will be granted. The high flow access commences at the 50th percentile streamflow (ie the flow that is exceeded on 50% of days) at the reference point.

The Macleay Valley and Apsley River water sources have been identified as suitable for unregulated river (high flow) access licences. The total amount of unregulated river (high flow) access licence in the Macleay Valley Water Source and Aspley River Water Source must not exceed 5,000 and 429-unit shares (equivalent to 5,000 ML and 429 ML) respectively.

A.6 Water allocation and account management

Water usage by individual licence holders is managed through water allocation accounts. Water is credited to the account at the start of the water year and debited from the account as water is extracted throughout the water year. The Macleay WSP outlines unused water allocation may be carried over from one year to next in accordance with the following:

- the maximum amount that may be carried over is 100% of the access licence share component; and
- water take over any consecutive three-year period does not exceed the sum of water allocations for those three years.

Water access for the Project will be subject to water allocation and management rules.

A.7 Dealing (trading) rules

Dealing (trading) rules are in place to encourage development of a water market that allows businesses to grow and contract whilst recognising and protecting the needs of the environment and third-party interests.

In the Macleay WSP, trading from downstream water sources is permitted if the total licensed entitlement in the water source does not increase (no net gain). Trading from specified upstream water sources is permitted on a one for one basis. The trading rules for the Macleay Gorges and Macleay Valley water sources are summarised in Table A.4.

Table A.4 Macleay WSP – trading rules

Trading rules	Condition	To Macleay Gorges Water Source	To Macleay Valley Water Source
Into water source[1]	Permitted, only if the total licensed entitlement in the receiving water source does not increase (no net gain)	From: Christmas Creek, Coastal Macleay, Collombatti Creek, Dungay Creek, Dyke Creek, Euroka Creek, Five Day Creek, Gills Bridge Creek, Georges River, Hickeys Creek, Macleay Valley, Mungay Creek, Nulla Nulla Creek, Toorumbee Creek, Warbro Creek, Stockyard Creek	From: Christmas Creek, Coastal Macleay, Collombatti Creek, Dungay Creek, Euroka Creek, Gills Bridge Creek
	Permitted, subject to assessment	From: Apsley Gorge, Apsley River, Bakers Creek, Blue Mountain Creek, Chandler Gorge, Chandler River, Commissioners Waters, Gara River, Green Gully, Kunderang Creek, Malpas Dam, Oaky River, Salisbury Waters, Styx River, Tia River, Yarrowitch River	From: Apsley Gorge, Apsley River, Bakers Creek, Blue Mountain Creek, Chandler Gorge, Chandler River, Dyke River, Commissioners Waters, Five Day Creek, Gara River, Georges River, Hickeys Creek Green Gully, Kunderang Creek, Malpas Dam, Macleay Gorges, Mungay Creek, Nulla Nulla Creek, Toorumbee Creek, Warbro Creek, Stockyard Creek Oaky River, Salisbury Waters, Styx River, Tia River, Yarrowitch River
Within water source	Subject to assessment	Permitted	Permitted

Notes: 1. Current policy provides for a no net gain trading rule or from upstream water sources to apply to the water source.

Attachment B

Geomorphology assessment

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Oven Mountain Pumped Hydro Project

Geomorphology Assessment

Dr Christopher J Gippel

December 2022

OMPS Pty Ltd

FLUVIAL SYSTEMS

Oven Mountain Pumped Hydro Project

Geomorphology Assessment

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Executive Summary

Introduction

OMPS Pty Ltd (OMPS) is proposing to develop the Oven Mountain Pumped Hydro Energy Storage Project (the Project), an off-river pumped hydro energy storage system (referred to as the 'pumped hydro system') located approximately half-way between Kempsey and Armidale adjacent to the Macleay River in northern NSW. The Project is located within the New England Renewable Energy Zone (REZ) and the Armidale Regional Local Government Area (LGA), proximate to its border with Kempsey Shire LGA. At a basic level, the Project will consist of upper and lower water reservoirs, an underground tunnel connecting them, and a hydro-electric power station connected to the national energy market (NEM) that is capable of generating or consuming electricity. The expected operational lifespan of the Project is in excess of 100 years.

This geomorphology assessment report is an attachment to the Project's Surface Water Assessment, which is a component of the environmental impact statement (EIS), and should be read in conjunction with it. The Secretary's environmental assessment requirements (SEARs) issued for the Project did not specifically include a requirement to investigate geomorphology, channel, watercourse, stream, sediment or other terms usually associated with geomorphology. However, the SEARs included requirements to assess potential impacts on aquatic biodiversity, which is dependent on geomorphic and hydrologic character of streams, and water.

The purpose of this report is to contribute the geomorphology sub-component of the surface water component to the EIS for the Project, with a focus on characterisation of the fluvial geomorphologic forms and processes of Fingerboard Crossing Creek and Macleay River in the vicinity and assessment of the potential impacts of the Project on these forms and processes.

This report comprises: (i) description of the data and the methodology used in the assessment, (ii) characterisation of the existing geomorphic environment, (iii) assessment of the potential impact of the Project on the geomorphic environment, and (iv) recommendations for mitigation measures and the monitoring program required to measure the performance of the mitigation measures.

The main area of interest for this report is the catchment of Fingerboard Crossing Creek and the Macleay River downstream of Fingerboard Crossing Creek junction within the Project area.

Modification of the hydrological regimes of Fingerboard Crossing Creek and Macleay River, described in the Surface Water Assessment, would be the drivers of impacts to fluvial geomorphic forms and processes within these watercourses. The following key potential impacts of the Project on watercourse geomorphic forms and processes were identified for investigation in this report:

Initial reservoir filling

- Reduction of storm event magnitudes in the Macleay River by up to 86.4 ML/d for flows exceeding 597 ML/d. The geomorphic impact of this hydrological change could be reduced frequency of mobilisation of coarse bed material as well as reduced flow depth and thus reduced area of hydraulic habitat.

Long term operation

- Physical loss of two reaches of channel of Fingerboard Crossing Creek, as well as minor tributaries, within the dam wall and reservoir inundation footprints of the upper and lower dams.

- Loss of the contributing catchment upstream of the upper dam, reducing the source area for runoff, bed material and suspended sediment to Fingerboard Crossing Creek. This would essentially shift the head of the creek to downstream of the upper dam wall, reducing the magnitude and duration of storm event flows and associated sediment loads in the creek downstream to the point where the creek meets the upper extent of the area inundated by

the lower dam reservoir. The geomorphic impact of this hydrological change could be reduced frequency of mobilisation of coarse bed material within the creek channel, as well as reduced flow depth, and thus reduced area of hydraulic habitat.

- The flow regime of Fingerboard Crossing Creek downstream of the lower dam would be impacted by reduced magnitude and duration of storm event flows and increased duration of cease to flow. Flow would spill downstream only when the lower dam was at FSL (full supply level) and was receiving inflows from the catchment, and the peak of those flow hydrographs would be attenuated by the reservoir storage. The geomorphic impact of this hydrological change could be reduced frequency of mobilisation of coarse bed material within the creek channel, as well as reduced flow depth, and thus reduced area of hydraulic habitat. In addition, the lower dam would act as a barrier to the natural transfer of coarse bed material from the catchment to this reach. It is planned to offset losses due to evaporation from the open water surfaces of the reservoirs through periodic top-up by pumping water from the Macleay River. The water balance results indicate overflows from the lower dam will occur in only 45% of years, typically during higher than average rainfall years. This is primarily a result of the assumption that the reservoirs will be allowed to draw down to approximately 100 ML below full supply before top-up occurs. Drawdown results from interception of rainfall and runoff from the local catchment not fully offsetting the substantial evaporation and leakage losses. Thus, the 400 m long section of Fingerboard Crossing Creek downstream of the lower dam to the Macleay River junction will probably dry out or be at very low flow in most years, only receiving runoff from the catchment downstream of the dam, which is very small, combined with minor baseflow emanating from seepage within the reservoir.

- The upper and lower reservoirs would retain all coarse bed material generated within Fingerboard Crossing Creek, denying this natural contribution of bedload to the reaches downstream of the reservoirs, and from Fingerboard Crossing Creek to the Macleay River. If a dam reduces sediment supply but maintains a river's hydraulic and hydrologic capacity to transport sediment, the river could widen and/or incise; conversely, if a dam reduces a river's hydraulic and hydrologic capacity to transport sediment and check the growth of instream vegetation, the river could aggrade. In both cases, the quality of instream hydraulic habitat would change. Riverine and estuarine ecosystems that rely on the supply of sediment and associated nutrients from upstream for normal functioning could be impacted by this geomorphic impact.

- Operation of the upper and lower reservoirs would involve frequent and rapid variation of water levels between FSL and minimum operating level (MOL), a process that would likely progressively strip the soil A and B horizon material from the side slopes within the reservoirs, leaving a surface of bedrock or resistant weathered regolith. The eroded coarse fraction of the soil would settle in the base of the reservoirs, potentially raising the MOLs. Most of the suspended fine silt and clay material released to the upper reservoir would be transferred downstream to the lower reservoir via the power waterway (tunnel). A proportion of the fine sediment sourced from reservoir erosion suspended within the lower reservoir would settle to the base of the reservoir, some would remain in circulation between the lower and upper reservoirs, and the rest would eventually be flushed downstream to the Macleay River during times of spill. The above-described process would cease when all of the inundated soil A and B horizon material was stripped from the reservoir side slopes.

In consideration of the potential impacts of the Project on watercourse geomorphic forms and processes, a number of variables were assessed, including those measured using digital spatial data - primary and derived, field observation, and hydrological and hydraulic modelling undertaken for the Surface Water Assessment. The field investigation was conducted on 12, 13 and 14 July 2022 and included walking the entire length of Fingerboard Crossing Creek, and recording observations at twenty sites on the creek system.

Existing environment

The elevation of the Fingerboard Crossing Creek catchment varied from 138 m to 978 m AHD, with slope varying up to 90° on cliff lines. The catchment has a steep, rugged topography with deep valleys.

The mapped HydroLines within the Fingerboard Crossing Creek catchment were generally a poor fit to the detailed topography defined by the digital elevation model (DEM).

An auto-generated drainage network of the Fingerboard Crossing Creek catchment was derived to emulate the HydroLine network. Field inspection confirmed that the auto-generated stream lines followed the channel thalwegs.

Fingerboard Crossing Creek is First Order over the first 100 m of chainage, Second Order from 100 m to 1800 m chainage, and Third Order from 1800 m to 4171 m chainage at the junction with the Macleay River.

Native vegetation, classified as tree cover, is intact over the vast majority of Fingerboard Crossing Creek catchment.

The Global Forest Change (GFC) data indicated that in 2000 the vast majority of Fingerboard Crossing Creek catchment was under tree cover, although the density of canopy cover was variable. The upstream half of the catchment was covered with dense trees, mostly exceeding 70% cover, while the lower half of the catchment was covered with less dense trees, mostly in the range 20 – 70% cover. The drainage network had high tree canopy cover on both sides of the riparian zones, with the exception being the short reach downstream of the proposed lower dam wall, which had high tree canopy cover on the right (northern) side, but the southern side had low tree canopy cover.

A significant proportion of the Fingerboard Crossing Creek catchment was affected by loss of tree canopy cover in the bushfires of 2019/20, but in terms of percent of area burned it was less impacted than the Project area, and most of the burn was low severity. The field inspection found that the geomorphic character of Fingerboard Crossing Creek showed no signs of typical bushfire impact, such as excessive fine sediment deposition in the bed. Had storm runoff events following the 2019/20 fire impacted catchment and creek channel geomorphic processes, then by July 2022 the creek had recovered to its expected natural condition.

Apart from a small section of the lower part of the Fingerboard Crossing Creek catchment in conglomerate lithology, the catchment was in granodiorite.

Given the dominantly granodiorite lithology and steepness of the topography, as expected, the majority of the of Fingerboard Crossing Creek catchment was covered with thin, poorly structured Rudosols and Tenosols soil type.

The depth of the A and B horizons of the soil varied up to 1.2 m over the catchment of Fingerboard Crossing Creek. The A and B horizons of the soils within the proposed reservoirs were mostly less than 0.8 m deep. The depth of the regolith varied up to 8.9 m over the catchment of Fingerboard Crossing Creek. The regolith within the proposed upper reservoir area was up to approximately 3 m deep, while the depth of the regolith within the proposed lower reservoir area was shallow.

A wide range of bed material size was observed at most field sites on Fingerboard Crossing Creek. Mud was uncommon, found only at one site. Sand was also uncommon, found only at two sites. Gravel and cobble were present at a majority of sites, as were boulder and bedrock. The general pattern of dominant bed material was bedrock and boulder from the headwaters down to the proposed lower reservoir, while cobble was the dominant bed material in the lower part of the creek.

Long profiles of thalweg elevation and slope revealed that Fingerboard Crossing Creek was moderately steep in the headwater area, and very steep downstream of the cliff at 1050 m chainage to approximately 1800 m chainage. From this point to the Macleay River junction, the slope progressively declined. The long profile of estimated maximum pool depth suggested frequent but shallow pools, which generally aligned with the field observations.

The Macleay River in the vicinity of the Project area and for a distance 9.7 km downstream of Fingerboard Crossing Creek junction, has been classified by the River Styles Spatial Layer for New South Wales *PCVS Bedrock controlled gravel*, good condition, moderate fragility and conservation recovery potential. Fingerboard Crossing Creek was assessed to comprise two River Styles. The upper creek from its head down to the cliff line at chainage 1070 m, was classified *CVS Headwater,* good condition, low fragility and conservation recovery potential. The lower creek, from chainage 1070 m to the junction at Macleay River, was classified *CVS Gorge,* good condition, low fragility and conservation recovery potential.

Impacts

Some drainage lines will be displaced by burial and submergence due to the Project dam walls and reservoirs. The lengths of these displaced drainage lines were 1842 m of the mainstem of Fingerboard Crossing Creek and 2,059 m of minor tributaries.

The estimated volumes of soil A and B horizons that would potentially be eroded from unexcavated areas within the reservoirs were 40,514 m^3 for the upper reservoir and 50,725 m^3 for the lower reservoir. If all of this soil within the reservoirs was eroded and eventually settled to the bases of the reservoirs, there would be no net change in capacity at the reservoir FSLs, but the MOLs could be raised by the slightly elevated bases. If all soil eroded from within the reservoirs became suspended in the water columns it would likely find its way downstream, ultimately to the Macleay River, and the reservoir capacities would be increased. The actual impact would likely lie between these two extremes, but regardless, the change in dam capacity or MOL would be minor due to the thin soils and relatively small areas of soil exposed to erosion. Including mechanical removal of all soil from unexcavated areas within the reservoirs as part of the construction method would avoid these potential impacts.

Whilst there is very little literature concerning sediment dynamics of pumped storage hydro systems, it can be hypothesised that in the case of the Project, excavation within the reservoirs, and initial filling with river water sourced at times of high flow when turbidity is likely to be elevated, means that initial operation is likely to involve circulation of water containing suspended sediment. Storm events are likely to periodically deliver turbid water to the reservoirs, and pumping operations could maintain silts and clays in suspension for extended periods of time.

The upper and lower reservoirs will trap all inflowing bed load, and a high proportion of the inflowing suspended load. Given the small catchment areas of the reservoirs, sediment loads would be small relative to reservoir capacities, so loss of reservoir capacities due to sediment trapping would be a minor impact over the expected operational lifespan of the Project of 100+ years.

The consequences of a sudden reduction in coarse bed load (gravel, cobble and boulder-sized material) to Fingerboard Crossing Creek downstream of the reservoirs will be scour of the bed material from the bed of the creek downstream, without replacement by sediment delivered from upstream, thereby lowering the bed and removing the most mobile fractions of the bed material. Lowering the bed could lead to more concentration of discharge within the channel, increasing the capacity of the creek to scour bed sediments. Reduced bed load supply but ongoing bed material transport will, over time, lead to incision of the bed down to bedrock outcrops and large boulders, with some gravel and cobble material persisting in sheltered spaces between boulders and bedrock outcrops. The Gorge River Style of Fingerboard Crossing Creek has low geomorphic fragility, which means that the incision process will be limited by the creek's natural resistance to change. Loss of gravels and cobbles from the bed substrate could have implications for biota that utilise this material as an element of habitat.

Under existing conditions, gravels and cobbles would be frequently mobilised in at least some part of the cross-section all the way along the Fingerboard Crossing Creek. For all modelled flood event average exceedance probability (AEP) profiles (63.2%AEP, 50%AEP, 20%AEP, 5%AEP and 1%AEP events), peak bed shear stress (BSS) was considerably higher than the threshold to mobilise all cobbles and finer material (256 N/m^2) along the most of the creek's length, with values commonly exceeding 1000 N/m^2. Gravels and cobbles are common on the bed of Fingerboard Crossing Creek,

suggesting active supply of bed material from hillslopes and active downstream transport. The very high BSS values do not necessarily mean that large boulders metres in diameter would be mobilised by storm flow events. Over most of the creek's length the flow depth would be too shallow to fully submerge large boulders, and large boulders are often wedged in position by bedrock or other boulders.

With the Project operational, the BSS threshold to mobilise all cobbles and finer material was exceeded along the majority of the length of Fingerboard Crossing Creek for the 63.2%AEP and 50%AEP events and along the entire length of Fingerboard Crossing Creek for the 20%AEP, 5%AEP and 1%AEP events. This suggests that while the Project will reduce BSS and depth along the length of Fingerboard Crossing Creek for all modelled flood event profiles, both the BSS and depth will be frequently high enough to mobilise fines, sands, gravels, cobbles and some boulder-sized material.

The results of hydraulic modelling suggest that with the Project operational, Fingerboard Crossing Creek immediately downstream of the upper dam, lacking flow and sediment supply, will become geomorphologically dormant. Further downstream, natural inflow and sediment supply will maintain fundamental geomorphic processes, but at a reduced intensity. This will lead to contraction of the hydraulically and geomorphologically active channel width and depth.

Spells analysis was undertaken for flows exceeding the 63.2%AEP event magnitude, estimated from a mean daily flow time series using the *annual maximum series*. This analysis was undertaken for the 132 year long mean daily time series modelled for the outlets of sub-catchments, for the existing scenario and with the Project operational. The results suggested that, with the Project operational, Fingerboard Crossing Creek downstream of the upper dam will experience a decline in the magnitude, frequency and duration of flows that contribute to channel maintenance processes. This could impact ecological processes and communities that depend on maintenance of these processes at their natural rates. Further downstream, natural inflow and sediment supply will maintain fundamental geomorphic processes within Fingerboard Crossing Creek, but with minor reduction in magnitude, frequency and duration.

The flow regime of Fingerboard Crossing Creek downstream of the lower dam would be impacted by reduced magnitude and duration of storm event flows and increased duration of cease to flow. Flow would spill downstream only when the lower dam was at FSL and was receiving inflows from the catchment, and the peak of those flow hydrographs would be attenuated by the reservoir storage. It was estimated that overflows from the lower dam would occur in only 45% of years, typically during higher than average rainfall years. The geomorphic impact of this hydrological change could be reduced frequency of mobilisation of coarse bed material as well as reduced flow depth and thus reduced area of hydraulic habitat. In addition, the lower dam would act as a barrier to the natural transfer of coarse bed material from the catchment to this reach.

The dam-filling phase of the Project will involve reduction of storm event magnitudes in the Macleay River by up to 86.4 ML/d for flows exceeding 597 ML/d. The geomorphic impact of this hydrological change could be reduced frequency of mobilisation of coarse bed material as well as reduced flow depth and thus reduced area of hydraulic habitat.

At the Macleay River at Downstream of Georges River Junction gauge, the available rating curve data suggests that extraction of water during the dam filling phase would cause a maximum reduction in depth of 0.05 m. The reduction in water depth due to extraction of water would be associated with a similar, relatively small, reduction in bed shear stress. This implies a reduction in the likelihood, spatial extent, or particle size range of bed sediment mobilisation at times of water extraction from the river. The overall impact of water extraction on sediment transport processes in the Macleay River would be to create conditions that emulated a slightly drier period with lower flood peaks. This would have a minor short-term impact, and a negligible long-term impact, on sediment transport processes.

The Surface Water Assessment noted that Fingerboard Crossing Creek catchment makes up 0.03% of the overall Macleay River catchment, and it was anticipated to contribute a proportionate volume of streamflow. The creek is also likely to contribute a slightly higher than proportional load of coarse sediment and slightly lower than proportional load of suspended sediment. Due to the substantial

difference in catchment size between Fingerboard Crossing Creek and the Macleay River, impacts (whether reduced or increased flow combined with reduced coarse and suspended sediment load) to the Macleay River as a result of impounding Fingerboard Crossing Creek are considered negligible at the catchment scale and minor at the local scale of the vicinity of the junction of Fingerboard Crossing Creek with the Macleay River.

Mitigation and monitoring

Mitigation of the potential geomorphic impacts of the Project would be impractical. The recommended alternative is to allow geomorphic adjustments to the altered flow and sediment regimes to proceed. The watercourses are formed in bedrock, the resistance of which limits the extent of geomorphic adjustment that can take place. Bushfires can cause temporary acceleration of sediment release from catchments, and this risk should be minimised using an appropriate management plan.

It is not practical to directly measure coarse bed material transport. Accelerated scour of coarse bed material from the channel of Fingerboard Crossing Creek could be monitored by repeated LiDAR surveys but this would not serve a critical purpose, as mitigation of this process would not be practical. Water quality monitoring is proposed for the Project dams and reservoirs during operations to monitor and respond to unforeseen water quality risks. This monitoring will include suspended sediment. Data from downstream of the lower dam, if measured with adequate frequency to capture data from reservoir spills, will monitor residual suspended sediment not deposited within the Project reservoirs, and released to the Macleay River.

Monitoring of dam sedimentation will effectively monitor the capture by the Project of fine and coarse sediment released within the catchment. The rate of sedimentation is expected to be low, so a sounding survey every 10 years will be adequate.

1 Introduction

1.1 The Project

OMPS Pty Ltd (OMPS) is proposing to develop the Oven Mountain Pumped Hydro Energy Storage Project (the Project), an off-river pumped hydro energy storage system (referred to as the 'pumped hydro system') located approximately half-way between Kempsey and Armidale adjacent to the Macleay River in northern NSW. The Project is located within the New England Renewable Energy Zone (REZ) and the Armidale Regional Local Government Area (LGA), proximate to its border with Kempsey Shire LGA.

Figure 1 and Figure 2 provide the regional and local context of the Project respectively.

At a basic level, the Project will consist of upper and lower water reservoirs, an underground tunnel connecting them, and a hydro-electric power station.

The Project has been declared by the New South Wales (NSW) Government to be critical State significant infrastructure (CSSI) under the NSW Environmental Planning and Assessment Act 1979 (EP&A Act). Infrastructure projects are declared to be CSSI if, in the opinion of the NSW Minister for Planning, they are essential to the State for economic, environmental, or social reasons. By providing up to 900 MW of electricity generating capacity, the Project will aid in the transition of the NEM towards cleaner, more reliable and affordable electricity. It will also provide up to twelve hours of dispatchable energy at full generation to be stored and made available to the NEM through the New England REZ. The expected operational lifespan of the Project is in excess of 100 years.

The Project will utilise the highly favourable natural terrain of the site on which it sits to allow electrical energy from the main grid to be stored by pumping water from the lower reservoir to the upper reservoir. Energy can then be generated when needed by allowing water to flow back down to the lower reservoir via the hydro-electric power station, effectively enabling the Project to act as a large battery.

1.2 The proponent

OMPS (ABN 22 160 259 174) is developing the Project and is located in Kempsey at 2/28 Clyde Street, Kempsey NSW 2440.

1.3 Purpose and components of this report

This geomorphology assessment report is an appendix to the Project's Surface Water Assessment (EMM, 2022a), which is a component of the environmental impact statement (EIS), and should be read in conjunction with it. The Secretary's environmental assessment requirements (SEARs) issued for the Project did not specifically include a requirement to investigate geomorphology, channel, watercourse, stream, sediment or other term usually associated with geomorphology. However, the SEARs included requirements to assess potential impacts on aquatic biodiversity, which is dependent on geomorphic and hydrologic character of streams, and water. Of relevance to geomorphic assessment is "*key water features on site, including potential impacts on riparian land*" and "*where the project involves works within 40 metres 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)…*" (NSW Office of Water 2012a; Natural Resources Access Regulator (NRAR), 2018). The WM Act (NSW Government, 2022) defines waterfront land as the bed and bank of any river, lake or estuary and all land within 40 metres of the highest bank of the river. The Project has been declared by the NSW Government to be CSSI under the EP&A Act. A controlled activity approval to undertake work on waterfront land is not required for projects that are defined as CSSI. Hence, a controlled activity approval is not required for the Project. Notwithstanding, the guidelines for controlled activities have been considered for any proposed works on waterfront land.

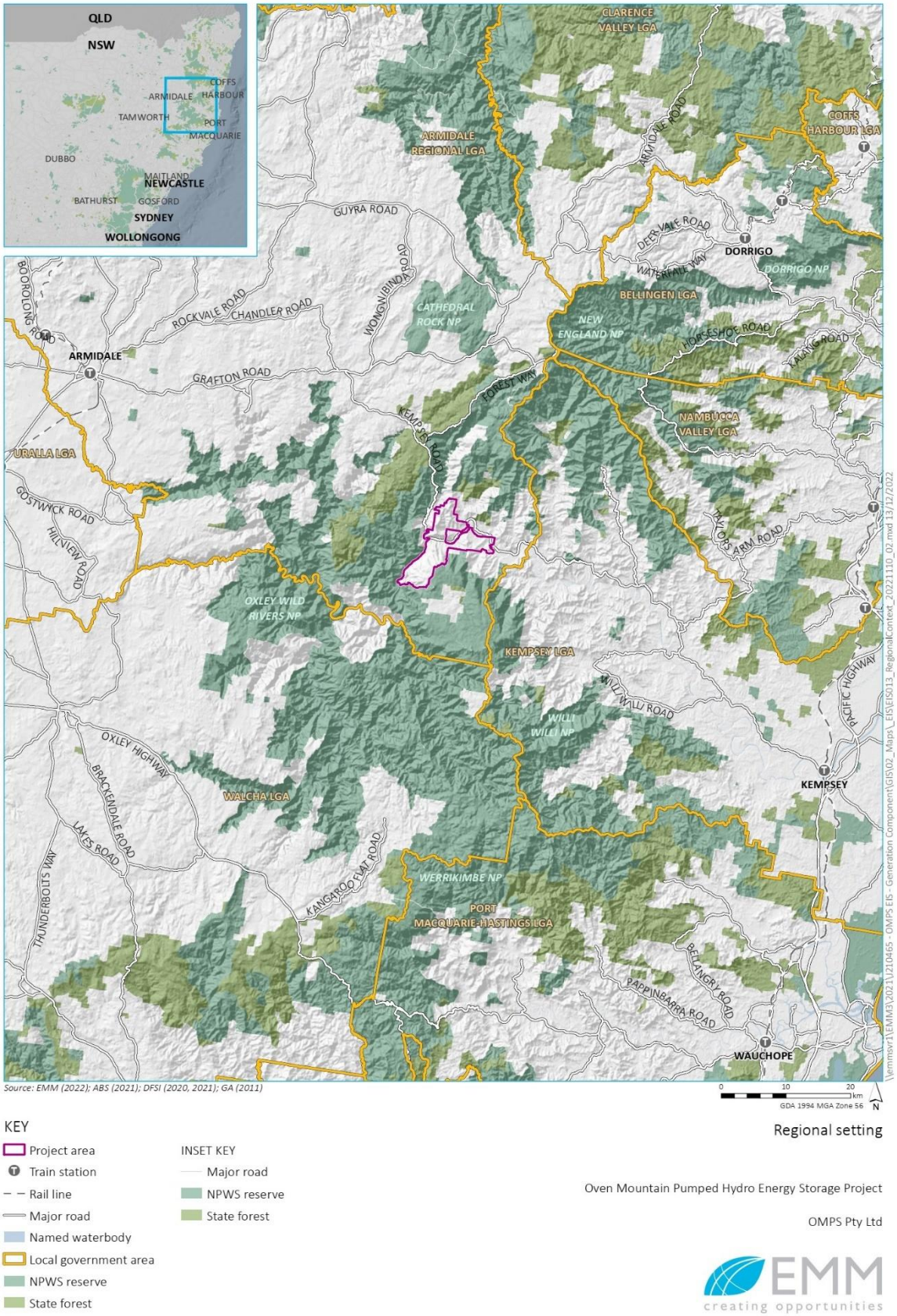

Figure 1. Regional setting of the Project. Source: EMM.

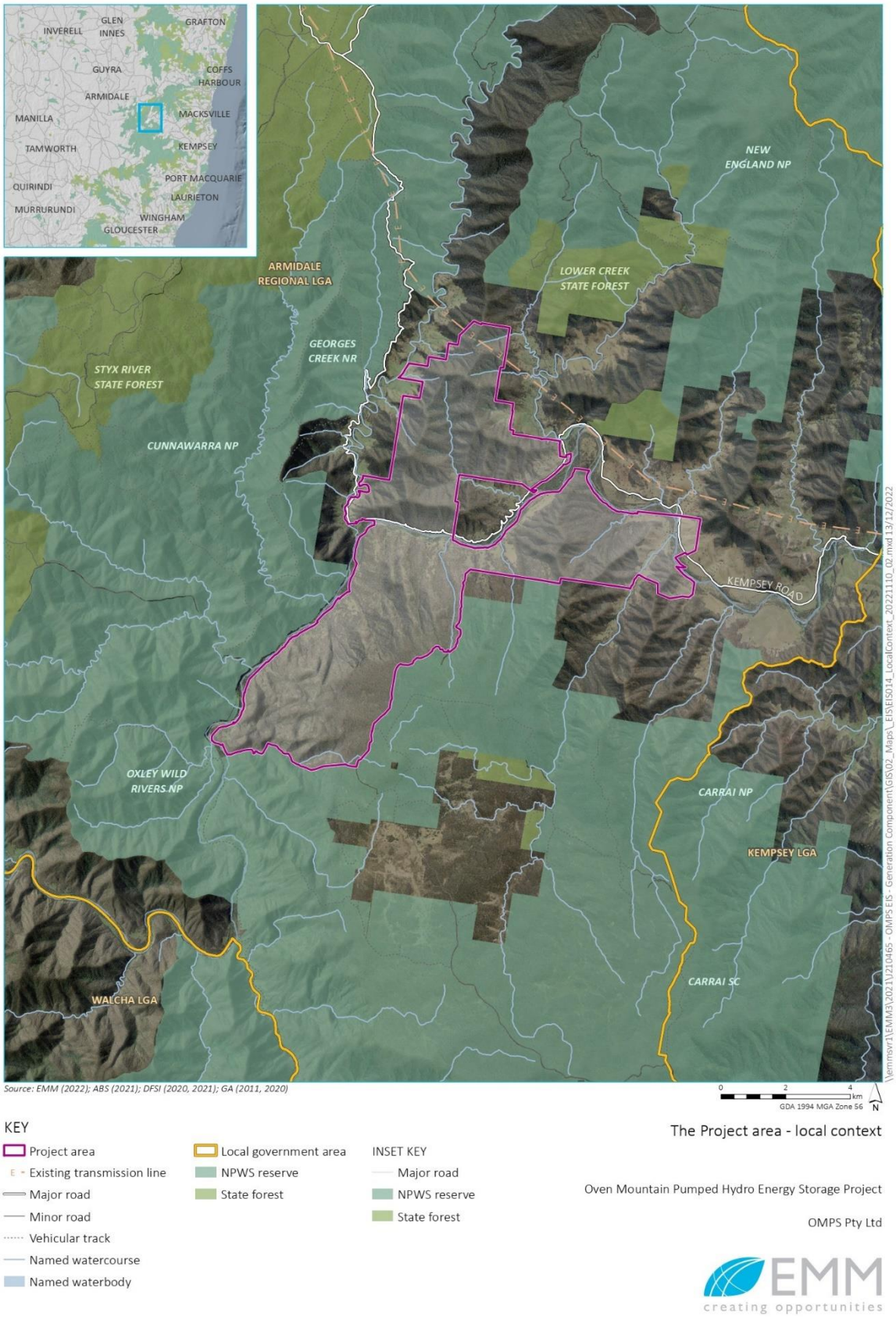

Figure 2. Local context of the Project. Source: EMM.

1.4 The Project description

1.4.1 Project overview

The Project involves building two 'off river' water containment structures to create an upper and a lower reservoir (referred to as 'the upper dam and reservoir' and 'the lower dam and reservoir'), on an ephemeral tributary of the Macleay River. An underground hydro-electric station power complex will be connected to the reservoirs by infrastructure including a power waterway and tunnels. During operation, the water will enable the generation of electricity as it passes through the underground power station while moving from the upper to the lower reservoir, from where it is pumped back up via the same waterway in a 'closed-loop circuit'. The pumped hydro system will be connected to the existing transmission network via new overhead high voltage transmission lines.

A detailed Project description and strategic context of the Project is provided in the EIS which should be read in conjunction with this report.

An overview of the key components and elements are provided below.

1.4.2 Key Project design elements

The Project has three key components:

- pumped hydro-electric and generation works (PHGW) – including:
    - new upper and lower water storage dams and reservoirs;
    - a new underground pumped hydro-electric power station;
    - water and access tunnels;
    - surge tank; and
    - intake and outlet structures;
- transmission connection works – including:
    - new electricity transmission lines to connect the PHGW to the existing electricity transmission network (Line 965);
    - new electricity transmission infrastructure; and
    - a new substation;
- ancillary development – including but not limited to:
    - access roads;
    - on-site quarries and related infrastructure;
    - utilities and communications infrastructure;
    - construction pads containing assets such as workshops, concrete batching plants (CBPs), and offices;
    - construction accommodation;
    - pumping infrastructure; and
    - construction power supply.

Further details of the Project's key elements are described in the Surface Water Report (EMM, 2022a).

1.4.3 Aspects of construction and operation that impact hydrological regimes

Modification of the hydrological regimes of Fingerboard Crossing Creek and Macleay River would be the drivers of impacts to fluvial geomorphic forms and processes within these watercourses. Operation of the Project has

the potential to result in the following impacts to streamflow, which were extracted directly from the Surface Water Assessment (EMM, 2022a):

- changes to the frequency and volume of local inflows to Fingerboard Crossing Creek and the Macleay River due to the upper and lower dams and reservoirs;
- increased streamflow resulting from permanent changes in land use and discharges from the operational stormwater management system;
- increased streamflow due to overflows from the lower dam spillway during energy generation;
- increased streamflow due to discharge from the lower dam during emergency dewatering;
- reduced streamflow resulting from water extraction to supply operational activities (i.e., top-up); and
- changes to the streamflow response in Watercourse 1 and Watercourse 2 as a result of altering the landscape to facilitate spoil emplacements.

Construction activities will require a steady source of water at relatively low rates. The proposed extraction rate of up to 1 ML/day (in the order of 10–20 L/s varying over the course of 24 hours) is expected to be of similar magnitude to extraction rates used for irrigation purposes in the downstream Macleay Valley Water Source and across the broader Macleay River catchment. Hence, it is proposed to apply the access rules outlined in the Macleay WSP for the relevant water sources to water extracted (at low pump rates) from the Macleay River for construction purposes.

Greater extraction rates are required for the initial one-off storage fill (6,500 ML) compared to the rates required for general construction activities (365 ML/year). To minimise potential impacts to downstream users and environmental receptors, extraction for initial fill purposes will only occur during periods of high flow. It is proposed to maintain the 50th percentile streamflow by extracting only flows in the Macleay River in excess of 597 ML/day, up to a maximum extraction rate of 86.4 ML/day. The full 86.4 ML/day will not be taken until the flows in the river reach 683.4 ML/day. The proposed extraction rate represents the upper limit on pumping from the Macleay River. Lower extraction rates may be identified as preferable during future Project design.

The minimum time to achieve the initial storage fill would be three months. The median fill time from December to March is four months while the median fill time for the remainder of the year ranges from 5–6 months. The chance of extracting less than the full initial storage fill volume within a 12-month period occurs in 8–11 years over the entire streamflow record of 53 years depending on the month in which extraction commences. Extracting less than the full initial storage fill volume would generally be associated with periods (years) of below average streamflow or droughts when the full volume could not be achieved regardless of which month extraction commenced. Overall, there would be an 82% probability of achieving the initial fill volume within a 12-month period based on the historical streamflow record and the proposed extraction conditions. The initial fill volume could generally be achieved in a shorter period if extraction commenced immediately prior to or during summer.

Water will be required to top-up the Project reservoirs following extend dry periods. It is proposed to source this water using the initial storage fill pump infrastructure described above, and in accordance with the extraction conditions described above.

The upper dam and reservoir will impound approximately 12% of the Fingerboard Crossing Creek catchment. Streamflow immediately downstream of the dam wall will cease during operations. The relative impact to streamflow will decrease moving downstream along the creek as additional catchment area contributes flow. There is likely to be increased baseflow resulting from maintaining water in the upper reservoir. The impact of increased baseflow would be relatively minor compared to the portion of flow that occurs from runoff during and following rainfall.

During extended wet periods or significant rainfall events, overflows from the lower dam and reservoir spillway are predicted to occur at similar rates to existing conditions. Streamflow in the Macleay River is expected to also be elevated under such circumstances and any inflows from Fingerboard Crossing Creek would be rapidly incorporated into the river flow.

The Project will be operated in a way that allows excess inflow to the reservoirs to overflow via the lower dam spillway. The following processes are expected to occur during and following a rainfall event:

- When the lower reservoir storage level is below the full supply level (FSL), direct rainfall onto the reservoir surface and inflows from the Fingerboard Crossing Creek catchment will be captured in the reservoir and no overflows will occur to the downstream environment.
- When the lower reservoir storage level is at the FSL, direct rainfall onto the reservoir surface and inflows from the Fingerboard Crossing Creek catchment will overflow (via the spillway) to the downstream environment.

The water balance results indicate overflows from the lower dam will occur in only 45% of years, typically during higher than average rainfall years. This is primarily a result of the assumption that the reservoirs will be allowed to draw down to approximately 100 ML below full supply before top-up occurs. This drawdown is the residual of the substantial evaporation and leakage losses partially offset by interception of rainfall and runoff from the local catchment. Thus, the section of Fingerboard Crossing Creek downstream of the lower dam to the Macleay River junction will probably dry out or be at very low flow in most years, only receiving runoff from the catchment downstream of the dam, which is very small, combined with minor baseflow emanating from seepage within the reservoir.

Once the lower reservoir storage level reaches the FSL, overflow volumes are expected to be similar to those experienced from the existing Fingerboard Crossing Creek catchment (i.e., inflows equal outflows). Attenuation of flows within the lower reservoir is predicted to result in decreased peak flow rates compared to existing conditions. The peak flow rate during the 1% AEP event is predicted to reduce from 57 m^3/s to 10 m^3/s while the peak flow in the probable maximum flood (PMF) event is predicted to reduce from 361 m^3/s to 149 m^3/s.

During energy generation, water will be transferred from the upper reservoir to the lower reservoir at a rate of about 120 m^3/s. In the absence of inflows from the local catchment, water that is transferred during energy generation will be captured entirely within the lower reservoir. Inflows from the local catchment that occur during the pumping and generation cycle will be displaced by inflows from the power waterway (i.e., during generation) at a later time, causing overflows via the lower dam spillway at a rate of up to 120 m^3/s. The rate at which water overflows the lower dam spillway will be a function of the volume of local catchment runoff intercepted. The volume of water intercepted by the Project reservoirs is expected to be less than 20 ML/day for approximately 99% of the time. Overflows under these conditions and the resulting impact to the Macleay River streamflow are anticipated to be negligible.

1.5 Key geomorphic forms and processes likely to be impacted by operation of the Project

The following key potential impacts of the Project on watercourse geomorphic forms and processes were identified for investigation in this report:

Initial reservoir filling

- Reduction of storm event magnitudes in the Macleay River by up to 86.4 ML/d for flows exceeding 597 ML/d (EMM, 2022a). The geomorphic impact of this hydrological change could be reduced frequency of mobilisation of coarse bed material as well as reduced flow depth and thus reduced area of hydraulic habitat.

Long term operation

- Physical loss of two reaches of channel of Fingerboard Crossing Creek, as well as minor tributaries, within the dam wall and reservoir inundation footprints of the upper and lower dams.

- Loss of the contributing catchment upstream of the upper dam, reducing the source area for runoff, bed material and suspended sediment to Fingerboard Crossing Creek. This would essentially shift the

head of the creek to downstream of the upper dam wall, reducing the magnitude and duration of storm event flows and associated sediment loads in the creek downstream to the point where the creek meets the upper extent of the area inundated by the lower dam reservoir. The geomorphic impact of this hydrological change could be reduced frequency of mobilisation of coarse bed material within the creek channel, as well as reduced flow depth, and thus reduced area of hydraulic habitat.

- The flow regime of the 400 m long reach of creek downstream of the lower dam to the Macleay River would be impacted by reduced magnitude and duration of storm event flows. Flow would spill downstream of the lower dam only when it was at FSL and was receiving inflows from the catchment, and the peak of those flow hydrographs would be attenuated by the reservoir storage (EMM, 2022a). The geomorphic impact of this hydrological change could be reduced frequency of mobilisation of coarse bed material within the creek channel, as well as reduced flow depth, and thus reduced area of hydraulic habitat. In addition, the lower dam would act as a barrier to the natural transfer of coarse bed material from the catchment to this reach.

- The upper and lower reservoirs would retain all coarse bed material generated within Fingerboard Crossing Creek, denying this natural contribution of bedload to the reaches downstream of the reservoirs, and from Fingerboard Crossing Creek to the Macleay River. If a dam reduces sediment supply but maintains a river's hydraulic and hydrologic capacity to transport sediment, the river could widen and/or incise; conversely, if a dam reduces a river's hydraulic and hydrologic capacity to transport sediment and check the growth of instream vegetation, the river could aggrade (Gippel, 2002). In both cases, the quality of instream hydraulic habitat would change. Riverine and estuarine ecosystems that rely on the supply of sediment and associated nutrients from upstream for normal functioning could be impacted by this geomorphic impact.

- Operation of the upper and lower reservoirs would involve frequent and rapid variation of water levels between FSL and minimum operating level (MOL), a process that would likely progressively strip the soil A and B horizon material from the side slopes within the reservoirs, leaving a surface of bedrock or resistant weathered regolith. The eroded coarse fraction of the soil would settle in the base of the reservoirs, potentially raising the MOLs. Most of the suspended fine silt and clay material released to the upper reservoir would be transferred downstream to the lower reservoir via the power waterway (tunnel). A proportion of the fine sediment sourced from reservoir erosion suspended within the lower reservoir would settle to the base of the reservoir, some would remain in circulation between the lower and upper reservoirs, and the rest would eventually be flushed downstream to the Macleay River during times of spill. The above-described process would cease when all of the inundated soil A and B horizon material was stripped from the reservoir side slopes.

2 Methodology

2.1 Variables of interest

In consideration of the potential impacts of the Project on watercourse geomorphic forms and processes, the variables of interest for geomorphic characterisation and impact assessment were, for Fingerboard Crossing Creek catchment:

Digital spatial data, primary and derived:

- Elevation and topography,
- Drainage network,
- Strahler Stream Order,
- Intactness of native vegetation,
- Tree canopy cover,
- Land cover and land use,
- Bushfire history and extent,
- Channel morphology (slope and bed elevation variability),
- River Styles classification, condition, fragility and recovery potential (also informed by field observations),
- Geology,
- Soil type, and
- Soil depth within the proposed reservoir areas.

Field observation:

- Calibre of the bed material
- Confirmation of River Styles

Modelled:

- Stream hydrology, and
- Stream hydraulics.

2.2 Digital spatial data, primary and derived

2.2.1 Gridded elevation

Two sets of Light Detection and Ranging (LiDAR) derived elevation data were available for the Project area. The Project area was flown between 3 February and 19 March 2020, with the data provided by OMPS in the form of a 1 m grid classified as ground strike. The second set of LiDAR derived elevation data were the Carrai 2 km × 2 km 2-metre Resolution Digital Elevation Model, flown 14 – 21 May 2018. The gridded data tiles were

downloaded from NSW Spatial Services, Department of Finance, Services and Innovation, ELVIS - Elevation and Depth - Foundation Spatial Data, Version 0.1.1.0 (http://elevation.fsdf.org.au/). The data used to create this digital elevation model (DEM) had a stated accuracy of 0.3 m (95% Confidence Interval) in the vertical and 0.8 m (95% Confidence Interval) in the horizontal.

Comparison of the 2020 and 2018 LiDAR-derived DEMs revealed significant differences in elevation between the two data sets. The 2018 elevation data were up to 28 m lower and up to 56 m higher than the 2020 data, with the differences following a systematic pattern across the area surveyed in 2020. An evaluation of these data (Appendix 1. Evaluation of available LiDAR data) found that for this geomorphic analysis, the 2020 DEM was preferred over the 2018 DEM on the grounds that the 2020 LiDAR data were acquired more recently than the 2018 data, and the 2020 DEM was provided at a finer resolution than the 2018 DEM (1 m versus 2 m), suggesting that the 2020 LiDAR survey achieved a higher density of laser pulse ground strikes.

2.2.2 Mapped HydroLine (blue line) network

The blue line drainage network was represented by National Surface Hydrology Lines (Regional) downloaded from Australian Government (https://data.gov.au). The dataset is a collaborative effort by Geoscience Australia (GA) and state governments. GA manages a data aggregation from multiple jurisdictional sources. The scale of the data ranges from 1:25,000 to 1: 250,000 across the continent. GA aggregates the data into a National Model and forms the surface water components of the Foundation Spatial Data Framework. In the area covered by the Project, these lines correspond to the HydroLines ('blue lines') on the NSW 1:25,000 topographic map sheets or digital versions (e.g., Six Maps). In the study area, the GA HydroLine layer is the same as the NSW HydroLine layer provided in WMS form on the NSW Government Spatial Collaboration Portal (https://portal.spatial.nsw.gov.au/portal/apps/sites/#/homepage).

Most of the blue lines on topographic maps, and thus HydroLines, would have been originally drawn in the 1970s mainly on the basis of whether a channel was visible on the aerial photographs available at the time of production, perhaps also guided by vegetation structure. Some important factors impact how well the mapped blue lines represent the existing channel network:

- The blue lines represent the channel network visible or assumed from aerial photographs; the resolution and quality of the photographs limits the scale of mapping.
- Distortion inherent in the original aerial photographs makes precise transfer of the locations of the stream lines to a undistorted map difficult.
- The blue lines are typically depicted as a smoothed representation of the actual stream lines.
- Channels can change in size and position over time.

Given these factors, the HydroLines were not expected to accurately represent the existing drainage lines. Nevertheless, the HydroLine network is the conventional standard used in impact assessments to identify watercourses of interest, and to classify watercourses by size using Strahler Stream Order. In this report, the HydroLines were used to classify watercourses by Stream Order, and also to guide a Geographic Information System (GIS) terrain analysis procedure that generated a more accurate representation of the existing watercourse positions. The GIS used for the spatial analysis in this report was Global Mapper™ Pro V24.0.0 (b101822) (99) (64-bit), build time 18 October 2022.

2.2.3 Automatic watercourse delineation

Given the inadequacies of the HydroLine network, a revised drainage network was automatically generated using GIS. The new drainage networks and catchment areas were generated by flow accumulation using the standard 8-direction pour point algorithm (D-8) (Jenson and Domingue, 1988). The drainage network was evaluated at 1 m DEM resolution. Depressions in the topography were filled prior to flow accumulation. Catchment area was automatically delineated as an outcome of the flow accumulation procedure.

The result produced by the GIS procedure of automatic determination of drainage networks and catchment areas is conditioned by the quality and resolution of the DEM, the chosen resolution to undertake the analysis (which can be coarser than the resolution of the DEM), the chosen minimum ground area the flow must accumulate from for a cell to be considered part of a stream, and the minimum length of stream starts (First Order streams) to be depicted. The purpose of automatic generation of the drainage network was emulation of the HydroLine network, but with streamlines that more accurately followed the LiDAR-defined topography.

2.2.4 Strahler Stream Order

The online NSW Government and downloadable GA HydroLine layers do not include Stream Order as an attribute, although NSW HydroLines with designated Stream Order can be viewed from ArcGIS Online (https://www.arcgis.com/index.html). In this report, Stream Order was assigned to watercourses according to the Strahler system, whereby a headwater stream is Order 1, and the Order increases by 1 when a stream of a given Order meets one of the same Order. Stream Order is specific to the scale and method used to define the drainage network. The Stream Order of a watercourse will be higher the larger the map scale (i.e., the more detailed the map), as more headwater streams will be counted.

In NSW, the convention of measuring Stream Order from 1:25,000 Department of Lands topographic sheets has been replaced by measurement from the equivalent digital HydroLines.

2.2.5 Intactness of native vegetation

Native vegetation intactness was assessed using the Department of Planning and Environment (DPE) NSW Native Vegetation Extent 5 m Raster v1.2 (https://researchdata.edu.au/nsw-native-vegetation-raster-v12/1408659). The purpose of this layer is to help discriminate native tree cover and woodlands from other land cover elements. The layer was developed under the State Vegetation Type Map program (SVTM) and presents a single surface raster that combines the best available information on native vegetation extent for NSW. The layer classifies the data into six classes: differentiating tree cover from candidate native grasslands, water, forestry plantations and a woodland matrix from non-native areas (Table 1). The surface is built on the 2011 5 m NSW Woody Vegetation Extent, with updates up to 2018, with the addition of candidate native grasslands, woodlands and wetlands from the visual interpretation of high-resolution imagery.

2.2.6 Tree canopy cover

The cohesive strength of riparian tree roots has been shown to stabilise river banks (Abernethy and Rutherfurd, 2000). Beeson and Doyle (1995) assessed 748 stream bends for stream erosion after large floods and found that the vegetated banks showed much less erosion than those with semi- or un-vegetated banks. Vegetation on the banks also reduces the velocity of water flowing through it, encouraging sediment accumulation (Lewis and Williams, 1984). Abernethy and Rutherfurd (1996) and Abernethy and Rutherfurd (1998) proposed that the stabilising effect of bank vegetation varied throughout the stream network, generally decreasing downstream. There is considerable debate in the literature regarding whether channels are more stable under tree or grass bank cover (Montgomery, 1997; Hession et al., 2008). However, in addition to geomorphic stability, riparian forests provide significant ecological benefits relative to the limited habitat variability and ecological diversity typically associated with banks that are grassed, or developed for agricultural or urban land use (Healey et al., 2012; Jayawardana et al., 2017; NSW EPA, 2021). In River Styles geomorphic condition assessment, cover of riparian forest is a major determinant of the assigned class.

Globally, water quality, ecological integrity and overall river health have been negatively associated with loss of catchment forest cover and level of human disturbance (e.g., Healey et al., 2012; Jayawardana et al., 2017; DPIPWE, 2020; NSW EPA, 2021; Munoth and Goyal, 2020; Mamun et al., 2022), although in this regard, the state of riparian forest cover could be more important than the state of catchment forest cover (Sheldon et al., 2012). Catchment land cover and land use has been specifically associated with the state of geomorphic processes in rivers (e.g., Fitzpatrick, 2001; James and Lecce, 2013; Goudie and Viles, 2016; Zeiger and Hubbart, 2019; Aher and Yadav, 2021). For these reasons, from an environmental management perspective, intact

natural forest cover is generally considered superior to other land cover types for riparian zones, and also the catchment.

Table 1. Description of the lineage codes and their relationship to the final values in the NSW Native Vegetation Extent 5m Raster v1.0. Source: NSW Native Vegetation Extent 5m Raster v1.2: Metadata (https://datasets.seed.nsw.gov.au/dataset/nsw-native-vegetation-extent-5m-raster-v1-0).

Pixel Value Code: Lineage Surface	Description: Lineage Surface	Pixel Value Code: NSW Native Vegetation Extent 5m Raster v1.0	Description (Type): NSW Native Vegetation Extent 5m Raster v1.0
1	Native woody from NSW Woody v1.2 only (input layer 1)	1	Tree Cover
7	Native vegetation from State Vegetation Type Map only (input layer 2)	5	Native Tree Cover Matrix
8	Native vegetation where NSW Woody v1.2 and State Vegetation Type Map agree (input layers 1 & 2)	1	Tree Cover
2	Candidate Native grasslands from State Vegetation Type Map (woody absent from input layers 1 or 2)	2	Candidate Native Grasslands
6	Plantations override (input layer 3)	3	Plantations Forestry
3	Water Pixel overrides (input layer 5)	4	Water
4	Water mask overrides from Hydro Area (input layer 4 - 'Water Courses' only)	4	Water
5	Water mask overrides from Hydro Area (input layer 4 'Water Bodies' only, woody preserved)	4	Water
0	Not Native (from any input layer)	0	Not Native

The Global Land Analysis and Discovery (GLAD) laboratory in the Department of Geographical Sciences at the University of Maryland investigates methods, causes and impacts of global land surface change. Earth observation imagery are the primary data source and land cover extent and change the primary topic of interest.

The Global Forest Change (GFC) project of Hansen et al. (2013) provides a relative indicator of spatiotemporal trends in forest loss dynamics globally. It provides data on tree cover (tree height >5 m) in the reference year 2000, as well as data on the removal of trees in subsequent years to 2021, if the canopy cover of a 25 × 25 m land unit (one LANDSAT pixel) falls below 30%. Annually updated GFC data are provided by the Global Land Analysis and Discovery (GLAD) laboratory at the University of Maryland, in partnership with Global Forest Watch (GFW). It was noted on the Global Forest Change 2000–2021 Data Download (Version 1.9) site (https://storage.googleapis.com/earthenginepartners-hansen/GFC-2021-v1.9/download.html) that while the data provide a relative indicator of trends, due to unquantified uncertainties, care must be taken when comparing change across any interval. It was suggested that the product not be used for definitive area estimation using pixel counts from the forest loss layers.

The GFC products include the following layers, all at approximately 27 - 28 m pixels in the study area:

- Tree canopy cover for year 2000 (treecover2000)

  Tree cover in the year 2000, defined as canopy closure for all vegetation taller than 5 m in height. Encoded as a percentage per output grid cell, in the range 0 – 100.

- Global forest cover gain 2000 – 2012 (gain)

  Forest gain during the period 2000 – 2012, defined as the inverse of loss, or a non-forest to forest change entirely within the study period. Encoded as either 1 (gain) or 0 (no gain).

- Year of gross forest cover loss event (lossyear)

  Forest loss during the period 2000 – 2020, defined as a stand-replacement disturbance, or a change from a forest to non-forest state. Encoded as either 0 (no loss) or else a value in the range 1 – 20, representing loss detected primarily in the year 2001 – 2021, respectively.

- Data mask (datamask)

  Three values representing areas of no data (0), mapped land surface (1), and permanent water bodies (2).

The GFC data were used to map tree canopy cover in the year 2000.

2.2.7 Land cover and land use

GLAD provides a number of products, in addition to GFC, that are related to land cover, land use, and land cover change, including Global Land Cover and Land Use 2019 (GLCLU 2019) (Hansen et al., 2022). Two versions of the data are available at approximately 27 - 28 m pixels in the study area: continuous measures of bare ground and tree height inside and outside of wetlands as well as of built-up area and binary labels of water, ice, cropland, and recent tree cover loss; and land cover and land use simplified from the full map into 19 classes that were used for stratification (Table 2).

2.2.8 Bushfire history, extent, and severity

The impact of fire on geomorphological forms and processes has long been recognised. Fire alters vegetation and soil properties which can change the way soil and sediment is transferred through catchments. The geomorphic consequences of fire are determined by (a) characteristics of the fire regime, mainly frequency and intensity; and (b) geomorphic sensitivity or erodibility of the landscape (Swanson, 1981; Nyman and Sheridan, 2014). Fire usually reduces soil aggregate stability and can induce, enhance or destroy soil water repellency; changes which have implications for infiltration, overland flow and rainsplash detachment (Shakesby and Doerr, 2006). Research has shown elevated, sometimes extremely large post-fire soil losses before geomorphological stability is re-established (Shakesby and Doerr, 2006; Lourenço et al., 2012). Biswas et al. (2021) found that, in the headwaters of the River Murray, sediment loads increased as a consequence of storm activity and rainfall following the 2019–2020 Australian bushfire season. Peak turbidity in the Murray River reached values of up to 4200 nephelometric turbidity units (NTU). Model simulations suggested that, compared to the pre-fire condition, the sediment load could increase by five times in the first year following a bushfire. It was estimated that Lake Hume would receive up to 600,000 metric tonnes of sediment per month in the period immediately following the bushfire. A review by Nyman and Sheridan (2014) reported that the magnitude of the increase in sediment load relative to the unburned state is highly variable, ranging from 10 – 1000 times the background levels. Bixby et al. (2015) identified a number of research gaps in the understanding of the impacts of fire effects on aquatic ecosystems.

Table 2. The 19 unique land use classes used for stratification in Global Land Cover and Land Use 2019 (Hansen et al., 2022).

Number	Strata	Physiognomic/structural thresholds
	Non-wetland strata	
1	True desert	≥90% bare ground
2	Semi-arid land	≥25% to <90% bare ground
3	Dense short vegetation	0% to <25% bare ground
4	Open tree cover	≥3 and (<10 m or <70% tree cover)
5	Dense tree cover	≥10 m and ≥70% tree cover
6	Recent tree cover gain	≥3 m and ≥10% tree cover
7	Non-fire loss no trees, no cropland, no built-up	
	Wetland strata	
8	Salt pan	≥90% bare ground
9	Semi-arid	≥25% to <90% bare ground
10	Dense short vegetation	0% to <25% bare ground
11	Open tree cover	≥3 and (<10 m or <70% tree cover)
12	Dense tree cover	≥10 m and ≥70% tree cover
13	Recent tree cover gain	≥3 m and ≥10% tree cover
14	Non-fire loss, no trees, no cropland, no built-up	
	Superseding strata	
15	Ice	Permanent ice
16	Water	Permanent surface water
17	Cropland	Cropland land use
18	Built-up	Human-built surfaces and structures
19	Ocean	Ocean

Fryirs et al. (2022) investigated the impact of the 7-month long 2019–2020 'Black Summer' Australian fires on riparian systems in coastal catchments of NSW. Nearly every catchment in coastal NSW was impacted, with fires starting on the North Coast of NSW (which contains the Macleay River catchment) in early September 2019. Over 30% of the Clarence, Macleay and Hastings catchments were burned, with between 9 and 15% at high or extreme severity. On the North Coast, 28% of total stream length was burned, with the Clarence, Macleay and Hastings catchments suffering the highest percentage of total stream length burned at 33, 34 and 34%, respectively. The most heavily impacted rivers were in confined, bedrock valley settings. Fryirs et al. (2022) suggested that climate change could lead to a future increase in the frequency and severity of fires, possibly creating novel ecosystems that burn with greater severity, with some of these perhaps benefitting from some managed burning to reduce the fuel load. A study included in the review of Nyman and Sheridan (2014) found that planned fires can have significant impacts on erosion, but that these are usually modest compared to the impacts of bushfire. Prescribed and cultural burning could lower fire severity on moister riparian zones. Fryirs et al. (2022) suggested managed fires could be used to mitigate against inevitable future catastrophic wildfire events and prevent further loss of riverine and riparian ecosystems.

The GLAD GFC product Year of gross forest cover loss event (lossyear) (Hansen et al 2013) could be useful for evaluating the impact of fires on loss of forest, but the loss data are not classified, so some loss could be due to other causes.

GLAD also produce the Global Forest Loss due to Fire 2001 – 2021 (GFLDF 2001 – 2021) at approximately 27 - 28 m pixels in the study area, with data disaggregated into forest loss due to fire versus other disturbance

drivers (Tyukavina et al., 2022). Each value of forest loss has an associated estimate of the certainty of the forest loss being due to fire, expressed as either high, medium or low certainty. In the Study area, fire forest loss due to fire was high certainty.

The GLAD dataset Global Land Cover and Land Use Change 2000 – 2020 (GLCLUC 2000-2020) (Potapov et al., 2022) quantifies changes in forest extent and height, cropland, built-up lands, surface water, and perennial snow and ice extent from the year 2000 to 2020 at approximately 27 - 28 m pixels in the study area. Forest was defined as wildland, managed, and planted tree cover, including agroforestry and orchards. The forest height was mapped globally for woody vegetation of ≥3 m. The global Landsat-based forest height model calibrated for the year 2019 using GEDI observations was employed. The same model was applied to estimate forest height for the years 2000 and 2020. To reduce errors and noise in the model outputs extensive filtering of the output products was implemented. A set of global products were derived from the year 2000 and 2020 forest height maps:

- Net forest height increase and decrease.

  Net forest height was considered to have increased only if a pixel (i) demonstrated net forest extent gain, or (ii) has net forest height increase from the year 2000 to 2020 by ≥100%. Similarly, the net forest height loss was calculated only for forest loss pixels or in case the net height reduction was by ≥50% of the year 2000 value.

- Forest extent and change

  Year 2000 and 2020 forest extent maps by attributing pixels with ≥5 m forest height as the “forest” land cover class, to ensure consistency with the FAO FRA forest definition. The forest extent change (net forest extent loss and gain) was derived directly from the year 2000 and 2020 map comparison.

- Forest disturbance

  Forests that have tree height ≥5 m in both years 2000 and 2020 and experienced significant or stand-replacement disturbance during the tile interval were assigned to “disturbed forest” class.

Forest extent and change between 2000 and 2020 was mapped to indicate areas that had suffered stand replacement disturbance due to bushfires. Areas lacking forest in 2020 compared to 2000 would suggest catastrophic loss of the canopy, or failure of the canopy to partially recover, from bushfire damage, most likely the 2019/20 fires.

The Fire Extent and Severity Mapping (FESM) products (https://datasets.seed.nsw.gov.au/dataset/fire-extent-and-severity-mapping-fesm) were developed by NSW Department of Planning and Environment Remote Sensing and Regulatory Mapping in collaboration with the NSW Rural Fire Service. The FESM used a semi-automated approach to mapping fire extent and severity, a metric of the loss of biomass caused by fire, through a machine learning framework to map fire extent and intensity for the years 2016 to 2022. The 2016/17 modelling was based on Landsat 8 satellite imagery, which is available at a resolution of 30 m pixels, while datasets for later years was based on Sentinel 2 satellite imagery, which is available at a resolution of 10 m pixels. The FESM dataset includes all wildfires with a fire start date between July and June that covered an area >100 ha for 2016/17, 2017/18, and >10 ha for 2018/19, 2019/20, 2020/21 and 2021/22. Fire severity was assigned to one of 5 classes: unburnt, low severity (burnt understory, unburnt canopy), moderate severity (partial canopy scorch), high severity (complete canopy scorch, partial canopy consumption), extreme (full canopy consumption).

The FESM utilises both Landsat (2016/17) and Sentinel 2 (2017/18 onwards) imagery, while the GFLDF 2001 – 2021 dataset utiises Landsat imagery for all years 2000 to 2021. White and Gibson (2022) compared FESM outputs from Sentinel 2 and Landsat 8 sensors across 27 case study fires. They compared the mapped areas of fire severity classes between outputs and assessed the classification agreement at random sampling points. They found very similar levels of accuracy for both sensor algorithms and substantial agreement between the

outputs from the two sensors. They attributed differences partly to differences in sensor resolution (10 m and 30 m pixel sizes for Sentinel 2 and Landsat 8, respectively) and suggested that the differences may be influenced by landscape complexity, such as terrain roughness and foliage cover. While this study found that applying the same algorithm to Landsat and Sentinel 2 imagery produced comparable results, no comparison has been made of FESM and GFLDF 2001 – 2021 fire extent distributions for the common years 2016/17 to 2020/21. These products are essentially mapping the same variable.

2.2.9 Channel morphology

Channel morphology of Fingerboard Crossing Creek was characterised by downstream slope, smoothed by calculating slope over a 10 m distance, and distribution of pool depth. The main purpose of characterising pool depth variation was to establish the presence or otherwise of variability in bed morphology that would provide a range of hydraulic habitat.

Pool depth was measured by filling sinks in the DEM along the channel to create a new DEM that represented the condition of low flow, with all pools full to the level set by the downstream hydraulic control. Sinks were filled using the method of Planchon and Darboux (2001). Subtraction of the original DEM from the sink-filled DEM produced a DEM of pool depth. The downstream distribution of maximum pool depth was mapped at 1 m intervals by extracting the maximum value of the pool depth grid cells intersected by 1 metre-spaced transects aligned perpendicular to the thalweg and passing through the width of the channel.

The pool depth measured by the method employed here would underestimate the range of pool depth variation along the length of the creek due to limitations of the LiDAR data used to derive the DEM. Any water present in the channels at the time of the survey would have prevented the LiDAR laser pulses striking the creek bed in those locations. However, the LiDAR was flown at the peak of the 2019/20 drought when Fingerboard Crossing Creek would almost certainly have been dry. Even under dry conditions, at a 1 m spatial resolution, the DEM could not have characterised the true maximum local range in downstream bed morphological variation, the detail of which is controlled by the distribution of mostly sub-metre sized bed material.

2.2.10 River Style classification of watercourses

River Styles is a system for classifying stream geomorphic type based on valley setting, level of floodplain development, bed materials and reach-scale physical features within the stream (Brierley et al., 2011). The potential for physical recovery after disturbance depends on stream geomorphic condition, whereby streams in good condition (undisturbed and close to natural state) are more likely to be resilient and recover faster than those that are already degraded (Outhet and Cook, 2004; Brierley et al., 2011).

Classification requires collection of data concerning valley setting, stream slope, channel dimensions and shape, slope, bed material type, sinuosity, and stream energy. While most of the mapping can be done on the basis of spatial data sets and aerial imagery, it is usual practice to undertake field work. Also, River Styles has an emphasis on larger alluvial streams, and assessments are usually limited to streams of Order Three and higher. Whilst in principle the classification system could be extended to smaller streams, some of the expected attributes are scale-dependent and might not be found on small streams. In most cases, Order One and Two streams with small catchments would be classified as Headwater Style, even if they are found in lowland areas and lack the steep, rocky character normally associated with headwater streams.

Geomorphic condition is strongly linked to the degree of naturalness and extent of cover of riparian vegetation (Outhet and Cook, 2004; Outhet and Young, 2004a). Fragility is the ease of adjustment of bed material, channel geometry, and channel planform when subjected to degradation or certain threatening activities, and resilience is the property of having low fragility (Cook and Schneider, 2006; Brierley et al., 2011). The determination of stream fragility is based on the adjustment potential of three main characteristics of each geomorphic category. These include the adjustment potential of each category's channel attributes (geometry, size and connection to floodplain), planform (lateral stability, number of channels and sinuosity) and bed character (bedform and bed materials) (Cook and Schneider, 2006). Different stream types have characteristic levels of

fragility (Outhet and Young, 2004b; Healy et al., 2012). Stream types with “low fragility” are resilient or “unbreakable”, those with “medium fragility” have local adjustment potential, and those with “high fragility” have significant adjustment potential (Cook and Schneider, 2006). Following on from this, the conservation and rehabilitation priority of stream reaches can be determined on the basis of geomorphic fragility and condition. Stream reaches with high fragility and poor condition are rated low priority, while reaches with low fragility that are in good geomorphic condition are rated the highest priority for protection.

Conservation recovery potential means the watercourse has not been recently disturbed or has fully recovered from past disturbances and the most appropriate action is to protect the watercourse from human disturbance. Strategic recovery potential means specific locations of rapid change from good geomorphic condition to moderate or poor condition with the effects usually detrimentally affecting upstream and/or downstream reaches. Situations include a headcut or bend cutoff present or imminent, recent bed material extraction, vegetation clearing or large woody debris removal, accelerated bank erosion or a gully that is supplying excess sediment to downstream reaches, or poorly represented riparian vegetation community. The appropriate action is to control the disturbance agent. Rapid recovery potential means recovery is presently occurring quickly due to a connection with upstream reaches in good condition. The appropriate action is to stop further human disturbance. High recovery potential means recovery is presently occurring at a moderate rate, with these reaches usually downstream of a conservation or rapid recovery reach. Moderate recovery potential means there is potential to recover at a slow to moderate rate if existing pressures are removed. Low recovery potential means no or very little recovery occurring, and degradation still possibly occurring. Actions would involve extensive rehabilitation of a long length of upstream reaches and this reach.

NSW Department of Planning, Industry and Environment and Macquarie University together developed the River Styles Spatial Layer for New South Wales (NSW Office of Water, 2012b). The database provides River Style, fragility, sensitivity to disturbance, condition, rarity and recovery potential for all third and higher order rivers in NSW. The data were derived from a number of sources depending on the Catchment Management Authority area.

The River Styles survey methodology is normally limited to Third Order and higher watercourses, but all Third Order and higher watercourses are not necessarily included in a River Styles survey. The River Styles Spatial Layer for New South Wales (NSW Office of Water, 2012b) did not include Fingerboard Crossing Creek. The River Styles type, condition, fragility, and recovery potential of Fingerboard Crossing Creek were characterised using standard Rivers Styles methodology, informed by comparison with the characteristics that were assigned to nearby classified stream reaches, such as Peach Tree Creek. Condition was based primarily on relative riparian tree canopy cover and intactness of native vegetation; fragility was assigned according to geomorphic type, following Cook and Schneider (2006, pp. 60-61); and recovery potential was assigned following Cook and Schneider (2006, pp. 62-64). Note that River Styles classification involves a degree of subjectivity and other practitioners could produce different sets of results.

2.2.11Geology

The Geological Survey of New South Wales (GSNSW) Seamless Geology Database is a compilation of the state’s best available geological mapping data in an internally consistent format (https://search.geoscience.nsw.gov.au/product/9232) (Colquhoun et al., 2021). The data has been organised into a series of layers, or time slices, representing the major lithotectonic units of NSW.

Three lithological units were found within Fingerboard Crossing Creek catchment and the near vicinity (Table 3).

Table 3. Descriptions of lithological units found within Fingerboard Crossing Creek catchment and the near vicinity.

Unit Name	Age (medial)	Age (range)	Description
Carrai Granodiorite	Late Triassic	237.00 Ma to 201.30 Ma	Medium-grained, porphyritic and equigranular, hornblende-biotite granodiorite and mafic to leucocratic monzogranite, crosscut by porphyritic and aplitic dykes.
Parabel beds	Permian	298.90 Ma to 251.90 Ma	Paraconglomerate, conglomerate (rounded clasts of silicic volcanic rocks, siltstone and rare granite); diamictite, lithic sandstone, mudstone, limestone, metabasalt and minor vitric tuff.
Pee Dee beds	Permian	323.20Ma to 251.90Ma	Slaty siltstone, lithic sandstone, minor diamictite.

2.2.12Soil type

Australian Soil Classification (ASC) data were obtained from the ASC Soil Type map of NSW (Office of Environment and Heritage, 2017) (https://data.gov.au/dataset/ds-nsw-22b3123a-f119-4f2d-9e84-849f03e2d976/details?q) which provides soil types across NSW using the ASC at Order level (Isbell et al., 1997; Jacquier et al., 2001; Isbell and the National Committee on Soil and Terrain, 2020). It uses the best available soils natural resource mapping coverage developed for the Land and Soil Capability (LSC) dataset. It was derived from a lookup table system linking a Great Soil Group classification soil type to a most appropriate ASC class for each mapping unit. Four ASC units were found within Fingerboard Crossing Creek catchment and the near vicinity (Table 4).

Table 4. Australian Soil Classification (ASC) class general descriptions for soils found within Fingerboard Crossing Creek catchment and the near vicinity. Source: Isbell et al. (1997) and Yield Gap Australia (2022).

ASC Soil Type	Description
Rudosols (Alluvial)	Soil with negligible (rudimentary) pedologic organisation; on Macleay River, gravel that consists dominantly of mostly rounded materials that have been transported by the river.
Rudosols and Tenosols	Rudosols have little, if any, pedologic organisation. They are usually young soils in the sense that soil forming factors have had little time to pedologically modify parent rocks or sediments. Tenosols generally have only weak pedologic organisation apart from the A horizons. They differ from Rudosols by virtue of having either a more than weakly developed A1 horizon, an A2, or a weakly developed B horizon.
Kurosols	Soils with strong texture contrast between A horizons and strongly acid B horizons.
Kandosols	Soils which lack strong texture contrast, have massive or only weakly structured B horizons, and are not calcareous throughout.

2.2.13Soil depth

Soil Depth (3" resolution) - Release 2, published 28 October 2022 (Malone and Searle, 2020), is a product of the Soil and Landscape Grid of Australia (Grundy et al., 2015) (https://www.clw.csiro.au/aclep/soilandlandscapegrid/index.html). This product provides a modelled estimate of the spatial distribution of soil depth (A and B horizons) in soils across Australia. Three separate models were

used, one to predict the occurrence of rock outcrops, one to predict the thickness of soils in the 0 – 2 m range, and one to predict the occurrence of deep soils (soils greater than 2 m thick).

Depth of regolith (3" resolution) - Release 2, published 16 March 2018 (Wilford et al, 2015), is a product of the Soil and Landscape Grid of Australia (Grundy et al., 2015) (https://www.clw.csiro.au/aclep/soilandlandscapegrid/index.html). The methodology consisted of the following steps: (i) drillhole data preparation, (ii) compilation and selection of the environmental covariate raster layers and (iii) model implementation and evaluation.

The 5% and 95% confidence intervals were estimated for each grid cell (pixel) in both prediction datasets, but only the medians were presented in this report. The data are provided in raster format at a resolution of 3 arc sec (approx. 79 x 79 m pixels in the Project area).

2.3 Field assessment

Twenty sites within Fingerboard Crossing Creek were inspected in the field on 12, 13 and 14 July 2022, with each site identified by a unique waypoint (WP) number (Figure 3). The objective of the field inspection was to determine the geomorphic character of the creek, with a focus on bed material calibre, and River Styles. The field inspection covered the length of Fingerboard Crossing Creek from its headwaters at the FSL of the upper reservoir to the Macleay River junction. The channel of the 750 m long steepest reach of the creek (from waypoints 6 to 8) could not be safely walked, and was avoided by following an adjacent course along the valley wall. The bed of this reach of the creek was sheer, smooth bedrock.

The field assessment included:

- Photograph the site in the downstream and upstream directions (Appendix 2. Selected photographs from field sites)
- Estimate present and dominant bed material calibre class using a simplified Wentworth classification (Table 5), that also included exposed bedrock
- Note any signs of accelerated geomorphic processes
- Confirm River Style classification

2.4 Hydrology of Fingerboard Crossing Creek

A water balance model for the operational phase of the Project was developed for the Surface Water Assessment using GoldSim (version 14) (EMM, 2022a). Surface runoff from rainfall was estimated over Fingerboard Crossing Creek at a daily time-step from 1/01/1890 to 31/12/2021 using the Australian Water Balance Model (AWBM). The catchment was divided into six sub-catchments (Figure 3). The output from the model was reported at the outflows from sub-catchments CA06, CA05, CA04, CA03 and CA01 for the existing scenario, and from sub-catchments CA05, CA04, CA03 and CA01 for the with Project scenario.

Annual maximum flood frequency analysis was undertaken on the existing mean daily flow series to determine the magnitude of the relatively frequent 63.2%AEP event. This event frequency, when estimated using the annual maximum series of peak instantaneous flow, is commonly used as an index to represent flows that maintain channel geomorphological processes and forms, although more frequent and less frequent events, and variability of event magnitude, can also play important roles in maintaining geomorphic processes (Gippel, 2002; Gordon et al., 2004). It was assumed that the instantaneous peak of the 63.2%AEP event would be an order of magnitude, or more, higher than the mean daily flow peak, but that, over a long time-series, event instantaneous peak would be highly correlated with event mean daily flow peak. Spells analysis was undertaken to determine the frequency, duration and interval characteristics of the 63.2%AEP mean daily flow event. Spells were considered independent if greater than 7 days apart. The spells analysis was done for both the existing and with Project scenarios, at all model reporting points.

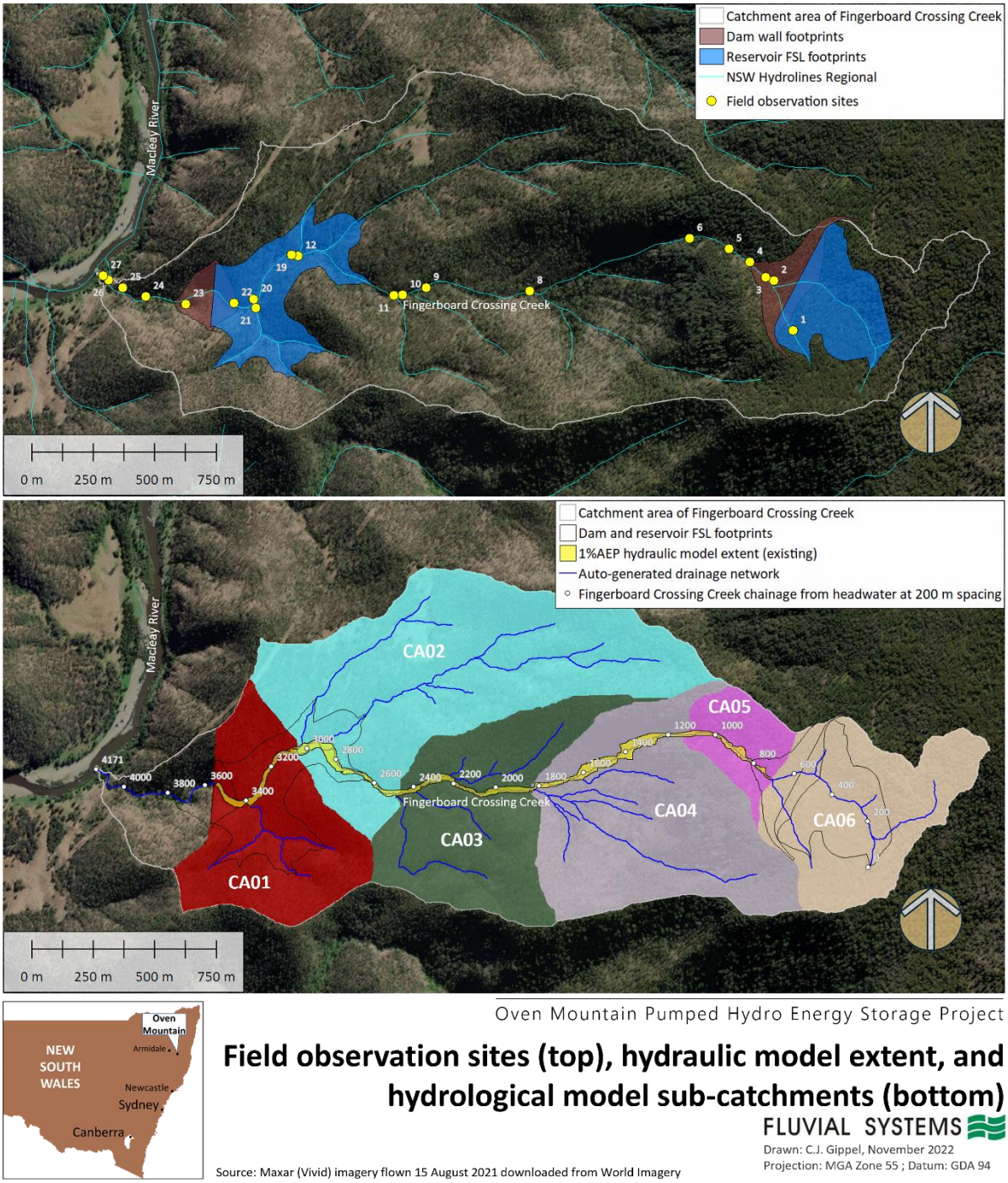

Figure 3. Fingerboard Crossing Creek field observation sites (top), and hydrological model sub-catchments and hydraulic model extent (bottom). Field sites were identified by a unique waypoint (WP) number. For the with Project scenario the hydraulic model extent was clipped to exclude the lower reservoir area.

Table 5. Wentworth sediment particle size classification and simplified Wentworth classification.

Wentworth classification		**Simplified Wentworth classification**	
Diameter range	**Name**	**Diameter range**	**Name**
>256 mm	Boulder	>256 mm	Boulder
64–256 mm	Cobble	64–256 mm	Cobble
32–64 mm	Very coarse gravel	2 - 64 mm	Gravel
16–32 mm	Coarse gravel		
8–16 mm	Medium gravel		
4–8 mm	Fine gravel		
2–4 mm	Very fine gravel		
1–2 mm	Very coarse sand	62.5 µm - 2 mm	Sand
0.5–1 mm	Coarse sand		
0.25–0.5 mm	Medium sand		
125–250 µm	Fine sand		
62.5–125 µm	Very fine sand		
3.9–62.5 µm	Silt	0.95 µm - 62.5 µm	Mud
0.98–3.9 µm	Clay		
0.95–977 µm	Colloid		

2.5 Hydraulics of Fingerboard Crossing Creek

As part of the Surface Water Assessment (EMM, 2022a) a hydraulic assessment was undertaken to estimate the changes to flood characteristics within Fingerboard Crossing Creek due to operation of the Project (EMM, 2022b). The methodology employed was to apply peak flow estimates from an XP-RAFTS rainfall-runoff-routing model (SMEC, 2022) to a purpose-built 1 m grid TUFLOW hydraulic model. The peak flows for 63.2%, 50%, 20%, 5%, 1% and 0.2% AEP storm events (Table 6) were each applied as a constant (steady-state) flow. The hydraulic model was developed for the section of Fingerboard Crossing Creek between the proposed upper and lower reservoirs, extending from approximately 500 m upstream of the confluence with the Macleay River to the embankment of the upper dam and reservoir (Figure 3). The flows were proportionally adjusted along the modelled length of the creek as a function of contributing catchment area, thereby simulating the change in hydraulic behaviour downstream. The hydraulic model generated output of the hydraulic variables water surface elevation, water depth, mean velocity and mean bed shear stress (BSS) at each grid cell. BSS was the main variable of interest to this geomorphology assessment as BSS can be related to bed material mobilisation.

Periodic mobilisation of coarse bed material in association with a balanced sediment supply from upstream often has a positive association with river health, whereas infrequent bed sediment mobilisation can have a negative association with river health due to clogging of the substrate with fines, and very frequent mobilisation of coarse bed material without adequate supply of sediment from upstream can result in channel incision.

The approach taken in this report to characterise coarse bed material movement was to determine the threshold of mobilisation of coarse material in the creek bed, based on its size distribution, and use this together with the output of the hydraulic and hydrological models of the river to determine the hydrological conditions under which bed material is likely to be mobilised.

Table 6. Reservoir peak inflows predicted by XP-RAFTS model. Source (EMM, 2022b).

Storm event (AEP%)	Upper reservoir inflow (CA06)		Lower reservoir inflow (CA01)	
	Critical duration (min)	Peak flow (m^3/s)	Critical duration (min)	Peak flow (m^3/s)
63.2	60	2.0	60	13.5
50	60	2.5	45	16.4
20	45	4.2	45	26.8
5	60	6.6	45	39.6
1	45	10.0	45	57.2
0.2	30	13.7	45	76.5

The initiation of particle movement on the bed depends on the hydraulics of the near bed region. As determination of velocity near the bed is difficult, bed shear stress is a commonly used method of determining incipient motion. In one-dimensional (cross-sectional) space, mean bed shear stress (N/m^2) (τ_b) is conventionally calculated as (Gordon et al., 2004, p. 163):

$$\tau_b = \rho g R S \quad (1)$$

where,

R = hydraulic radius of the channel, equal to A/P where A is the cross-sectional area of the flow, and P is the length of the wetted perimeter; in a spatial flood model R of a cell can be represented by water depth at the cell y (m).

S = the energy slope of the water; in a spatial flood model S can be approximated by the water surface slope at the cell (m/m).

ρ = the density of the water (usually assumed to be 1,000 kg/m^3)

g = the acceleration due to gravity (9.8 m/s^2)

In Fingerboard Crossing Creek, a natural cobble and gravel bed streams with a range of particle sizes present, the theory of equal mobility predicts that most of the grain sizes would begin moving at nearly the same discharge. This does not imply that the entire bed surface would move at the one time, but that, at any instant, the bed load may consist of a range of particle sizes, and the bed would selectively unravel from different locations as discharge increased (Gordon et al., 2004, p. 190). The critical shear stress (N/m^2) (τ_c) is the shear stress required to set the bed particles in motion, represented by the Shields equation:

$$\tau_c = \theta_c g d(\rho_s - \rho) \quad (2)$$

where,

θ_c = dimensionless critical Shields stress

g = acceleration due to gravity (9.8 m/s^2)

d = representative particle size (m)

ρ_s = particle density (2,650 kg/m^3)

ρ = water density (1,000 kg/m^3)

For particles to move, the actual shear stress (τ_b) must exceed the critical shear stress (τ_c). Lorang and Hauer (2003) defined the mobility ratio, or stream stability index (ξ):

$$\xi = \tau_b / \tau_c \quad (3)$$

whereby threshold entrainment for the full range of particle sizes composing the bed material is achieved when $\xi \geq 1$.

There is considerable debate in the literature concerning the appropriate values of θ_c and d to use in the Shields equation (Gordon et al., 2004, p. 194). Shields (1936) found that in gravel bed channels of homogeneous sediment sizes and turbulent flow an appropriate value of θ_c was 0.06. For sand sized particles the value of θ_c was 0.032. Buffington and Montgomery (1997) compiled 8 decades of flow-competence work and found that θ_c values ranged from 0.03 to 0.07. Reviews by Miller et al. (1977) and Yalin and Karahan (1979) both reported that θ_c approaches a constant value of 0.045 for coarse particles (diameter > 10 mm). The median diameter (D_{50}) is often used as the representative diameter.

For $\theta_c = 0.06$, and $\rho_s = 2650\ kg/m^3$, $\tau_c = \ 0.97d$, for d in millimetres. Thus, as a 'rule of thumb', the critical bed shear stress in N/m^2 required to move a coarse particle is approximately the same as the particle diameter in millimetres (Gordon et al., 2004, p.194). This rule of thumb was adopted for this report, with τ_b assumed equivalent to modelled BSS, and D_{50} estimated in the field using the Wentworth classification adopted as the particle size index d.

3 Existing catchment environment

3.1 Elevation and topography

The elevation of the Fingerboard Crossing Creek catchment varied from 138 m to 978 m AHD, with slope varying up to 90° on cliff lines (Figure 4). The catchment has a steep, rugged topography with deep valleys. At approximately 1070 m chainage, Fingerboard Crossing Creek meets a cliff line that runs directly south. The topography of the valley slope downstream of this cliff line is steep, at around 30°, which is similar to the angle of repose of broken stone. As would be expected, this slope is rough, with multiple drainage channels draining over thin soils, exposed rock and patchy vegetation. This slope, located downstream of the upper dam, is likely to be a major long-term source of coarse bed material to Fingerboard Crossing Creek.

3.2 Drainage network delineation

3.2.1 Official mapped HydroLine drainage network

The mapped HydroLines within the Fingerboard Crossing Creek catchment were generally a poor fit to the detailed topography defined by the DEM (Figure 5). These HydroLines are useful for characterising Stream Order and as a general representation of the drainage network, but they are not an accurate representation of the actual drainage lines found on the ground.

3.2.2 Auto-generated drainage network

An auto-generated drainage network of the Fingerboard Crossing Creek catchment was derived to emulate the HydroLine network (Figure 5). This emulated HydroLine network differed in detail to the mapped Hydroline network, but it retained a similar distribution of streams. Field inspection confirmed that the auto-generated stream lines followed the channel thalwegs.

3.2.3 Stream Order

The HydroLine and auto-generated networks had the same distribution of Stream Order, with Fingerboard Crossing Creek being First Order over the first 100 m of chainage, Second Order from 100 m to 1800 m chainage, and Third Order from 1800 m to 4171 m chainage at the junction with the Macleay River (Figure 5).

3.3 Vegetation

3.3.1 Intactness of native vegetation

Native vegetation, classified as tree cover, was intact over the vast majority of Fingerboard Crossing Creek catchment (Figure 6).

3.3.2 Tree canopy cover

The Global Forest Change (GFC) data indicated that in 2000 the vast majority of Fingerboard Crossing Creek catchment was under tree cover, although the density of canopy cover was variable (Figure 6). The upstream half of the catchment was covered with dense trees, mostly exceeding 70% cover (Figure 7), while the lower half of the catchment was covered with less dense trees, mostly in the range 20 – 70% cover (Figure 6 and Figure 7). The drainage network had high tree canopy cover on both sides of the riparian zones, with the exception being the short reach downstream of the proposed lower dam wall, which had high tree canopy cover on the right (northern) side, but the southern side had dense short vegetation (Figure 6 and Figure 7). The GLAD Forest extent change between 2000 and 2020 demonstrated that there was very little change in forest cover over between these years, despite the occurrence of a large-scale bushfire in 2019 (Figure 7).

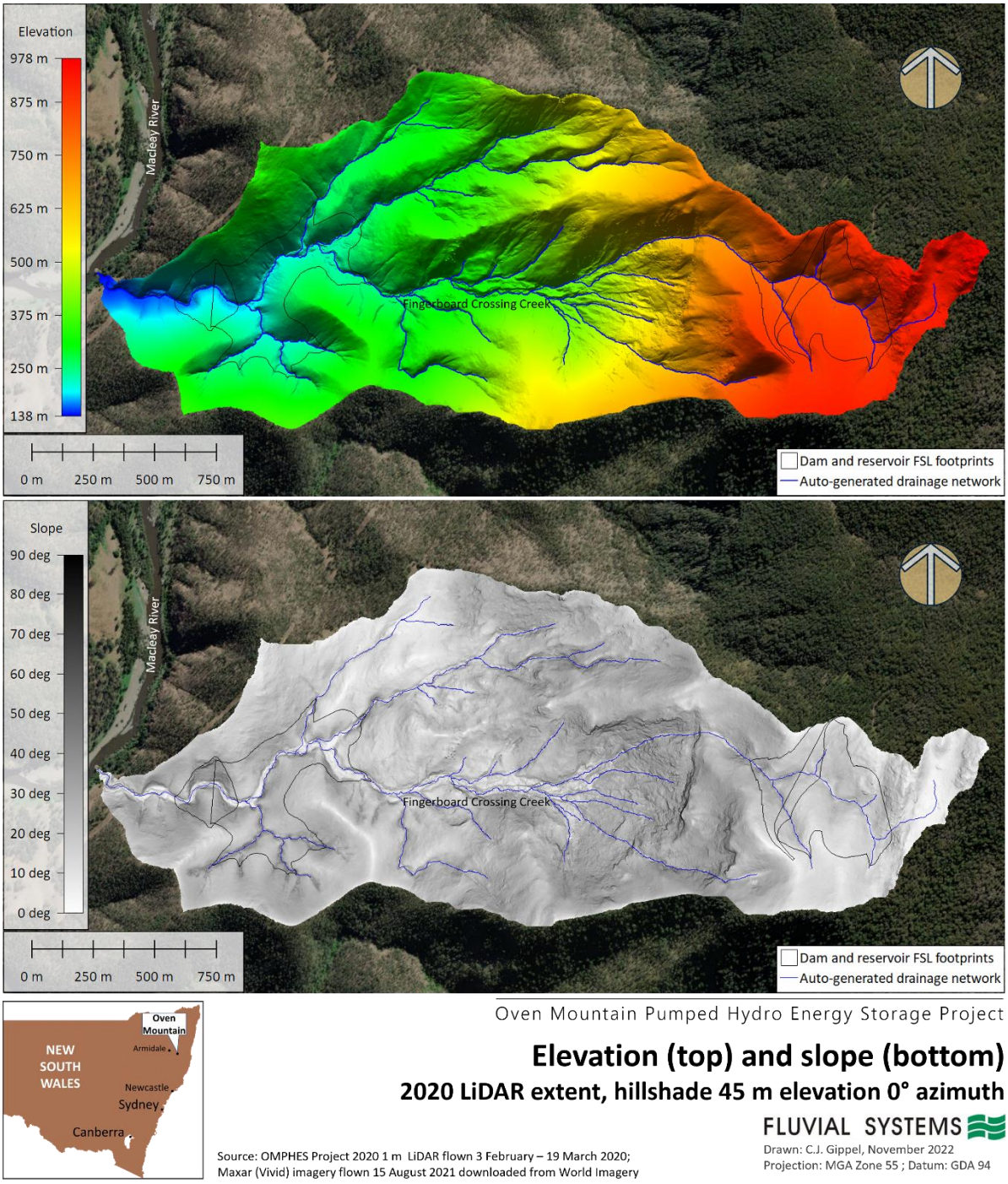

Figure 4. Elevation and slope of Fingerboard Crossing Creek catchment. Elevation rendered with hillshading.

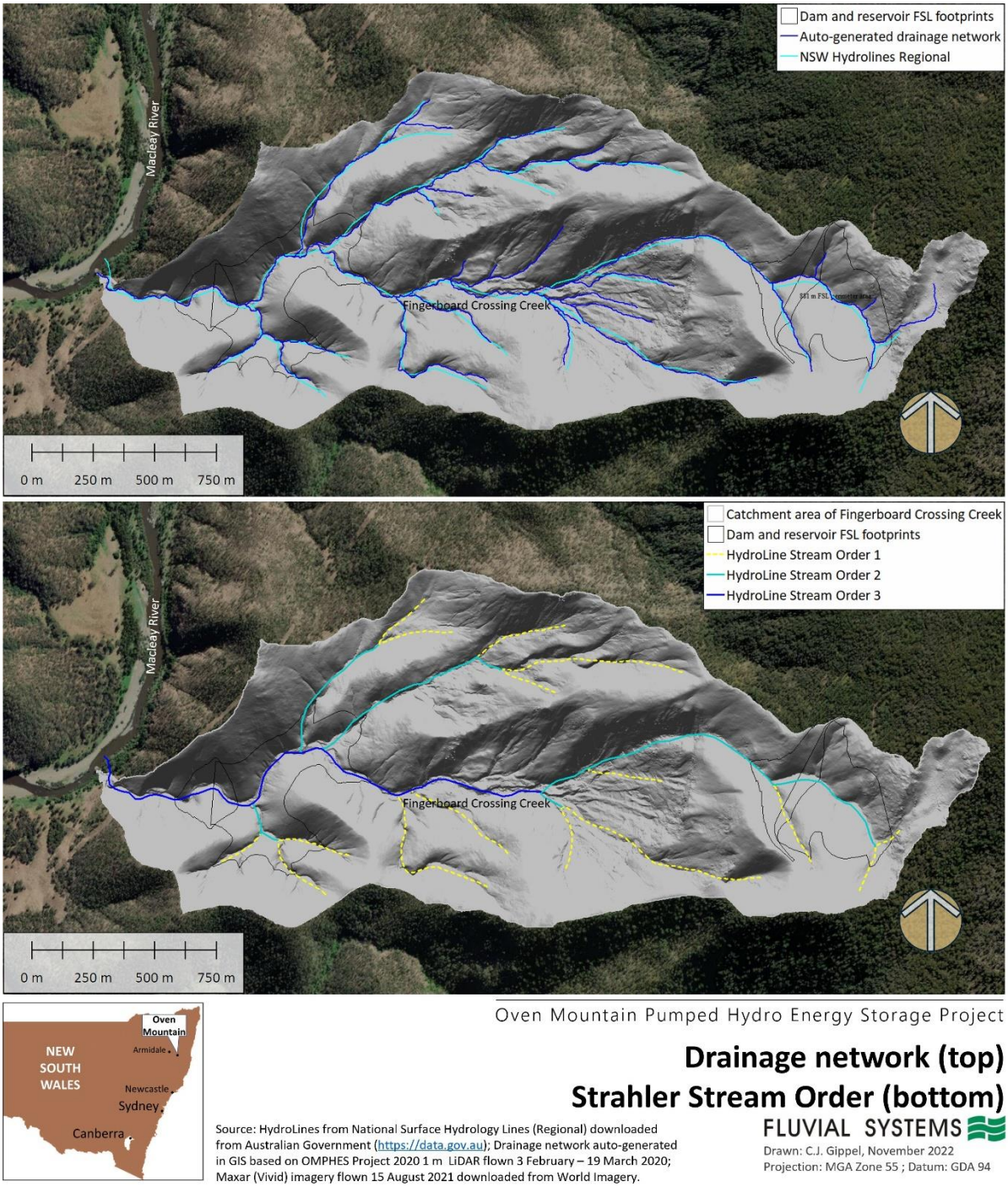

Figure 5. HydroLines and auto-generated drainage networks and Strahler Stream Order of HydroLines of Fingerboard Crossing Creek catchment, rendered with elevation hillshading.

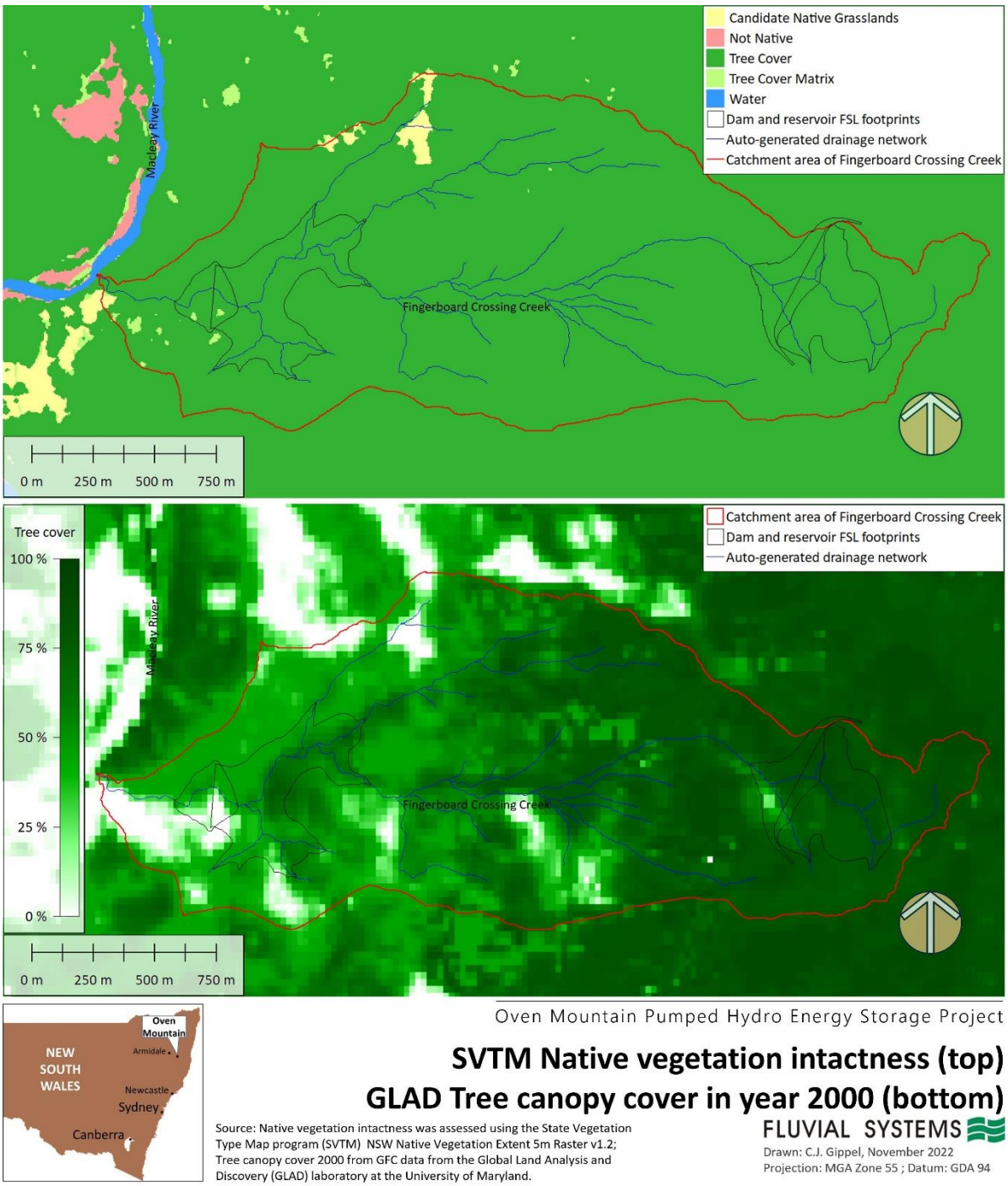

Figure 6. Native vegetation intactness and tree canopy cover in year 2000 of Fingerboard Crossing Creek catchment and surrounds.

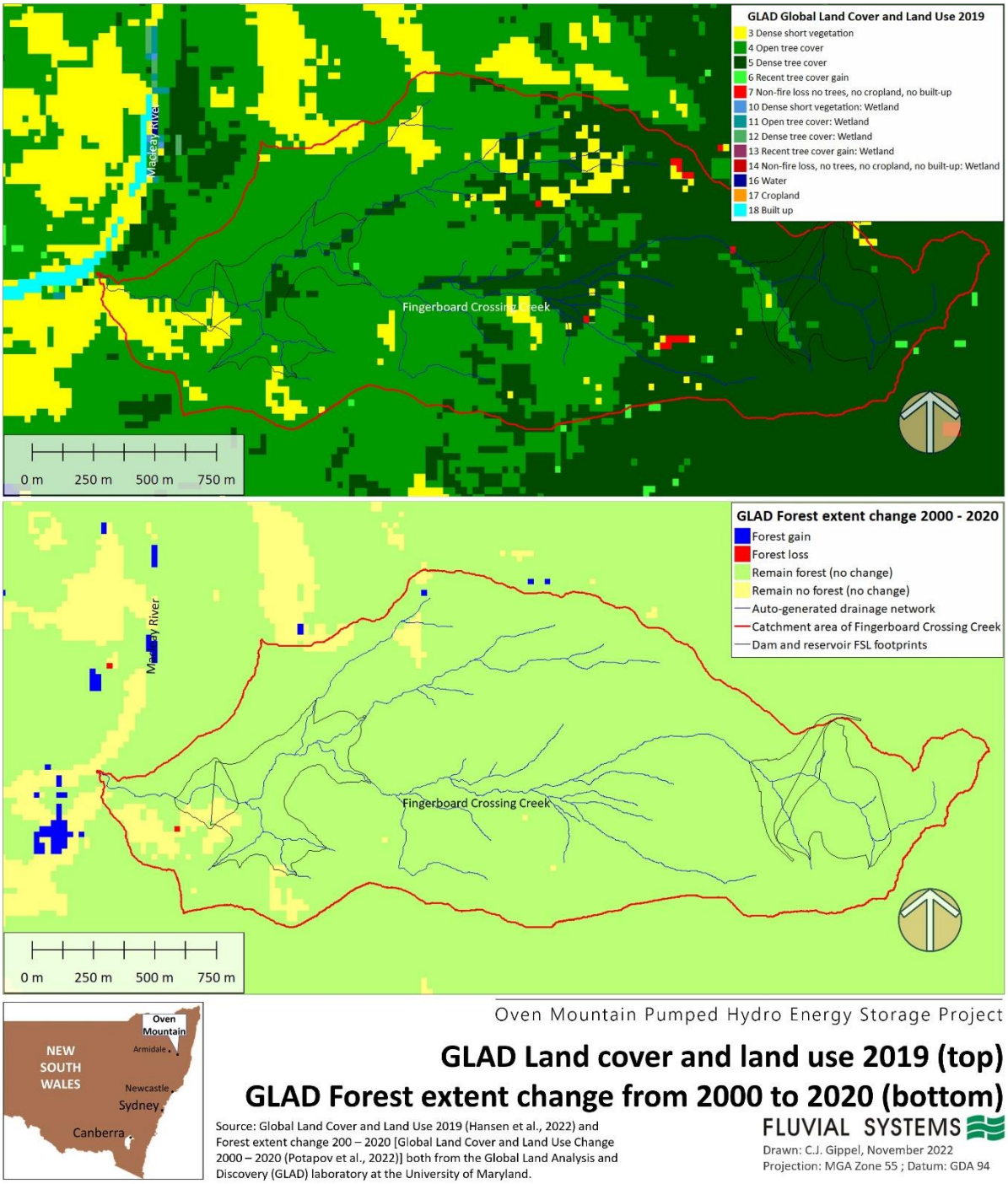

Figure 7. GLAD Land cover and land use 2019, and GLAD Forest extent change between 2000 and 2020, of Fingerboard Crossing Creek catchment and surrounds. Areas of water in the Macleay River were misclassified as Built up.

3.4 Bushfire history, extent and severity

A significant proportion of the Fingerboard Crossing Creek catchment was affected by loss of forest in the bushfires of 2019 (Figure 8). The spatial pattern of fire extent mapped by FESM was very different to that mapped by GLAD forest loss due to fire data (Figure 8). Without independent ground truth data for verification, it is not possible to determine the reliability of the two datasets. The FESM data incorrectly mapped fire extending over part of the water and gravel bars of the Macleay River near the Fingerboard Crossing Creek junction (Figure 9), but inconsistencies in the data over the Project area (compare Figure **31** and Figure **33**) were not investigated in detail. Within Fingerboard Crossing Creek, most of the burned areas were at low and moderate severity. The GLAD forest loss due to fire data indicates minor bushfire impact in in the catchment in 2012, but otherwise 2019 was the only year since 2000 with significant bushfire impact (Figure 9). The FESM data indicated a small area of bushfire within the Project area in 2016/17, but this did not burn within the catchment of Fingerboard Crossing Creek (Table 7).

The area impacted by bushfire was calculated over the Project area (Figure 2) and also the catchment of Fingerboard Crossing Creek, for both the GLAD (Table 7) and FESM data (Table 8). The data indicated that the Project area was sporadically impacted by fires from 2001 to 2018, but these were small areas compared to the extent of the 2019/20 fire (Table 7). Using the GLAD data, the 2019 fire impacted 36% of the Project area and 38% of the catchment of Fingerboard Crossing Creek (Table 7). The FESM data indicated that 27% of the area of Fingerboard Crossing Creek catchment was impacted by the 2019/20 fire, with the majority burned at low severity (Table 8). The FESM data suggested that 55% of the Project area was impacted by the 2019/20 fire, with the majority burned at low and moderate severity (Table 8).

3.5 Geology

Apart from a small section of the lower part of the Fingerboard Crossing Creek catchment in conglomerate lithology, the catchment was in granodiorite (Figure 10), a durable igneous rock composed of relatively hard minerals (quartz and feldspar).

3.6 Soils

3.6.1 Soil type

Given the dominantly granodiorite lithology and steepness of the topography, as expected, the majority of the of Fingerboard Crossing Creek catchment is covered with thin, poorly structured Rudosols and Tenosols soil type (Figure 10). The lower gradient catchment areas, upstream of the proposed upper dam, and just upstream of the proposed lower dam and reservoir, were in somewhat more developed Kandosols soil type (Figure 10).

3.6.2 Soil depth

The depth of the A and B horizons of the soil varied up to 1.2 m over the catchment of Fingerboard Crossing Creek (Figure 11). The A and B horizons of the soils within the proposed reservoirs were mostly less than 0.8 m deep.

The depth of the regolith varied up to 8.9 m over the catchment of Fingerboard Crossing Creek (Figure 11). The regolith within the proposed upper reservoir area was up to approximately 3 m deep, while the depth of the regolith within the proposed lower reservoir area was shallow, in some areas shallower than the modelled depth of the A and B horizons. This is a contradiction, explained by the different models used to predict A and B horizon and total regolith depth.

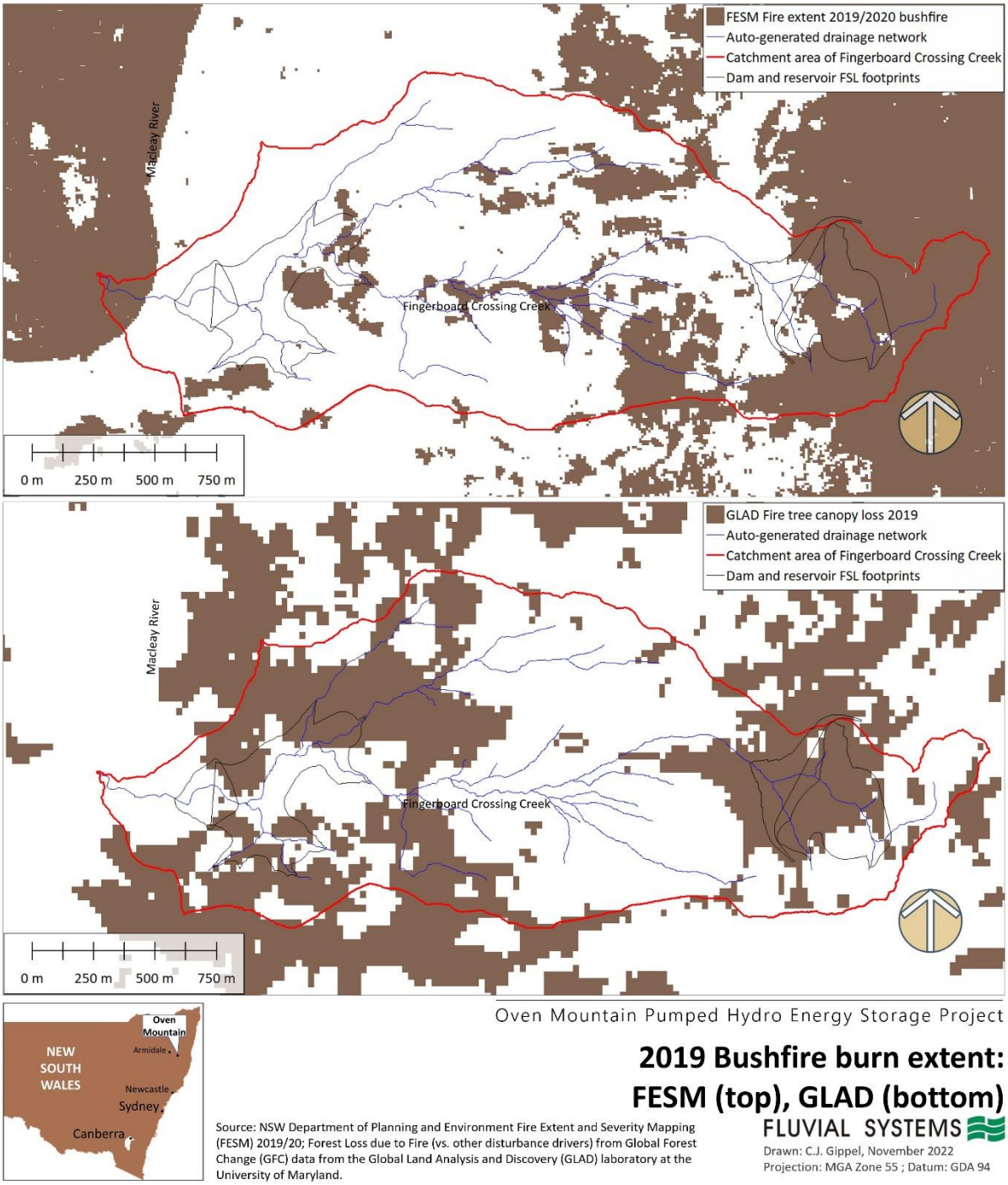

Figure 8. 2019 bushfire extent, mapped using FESM burn severity data and GLAD forest loss due to fire data.

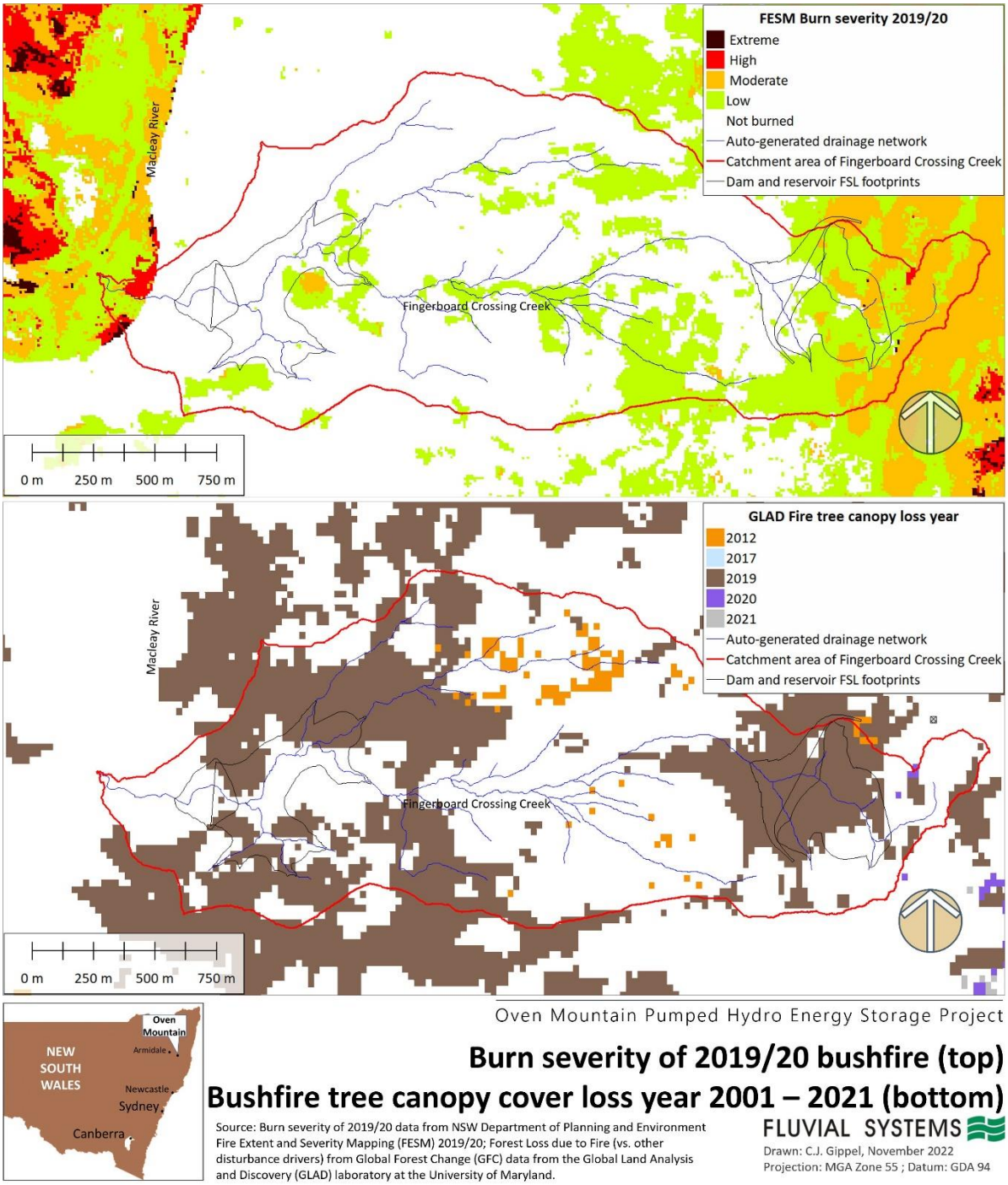

Figure 9. FESM burn severity for the 2019 bushfire in Fingerboard Crossing creek catchment, and the history of fire events in the catchment from 2001 to 2021 using GLAD forest loss due to fire data.

Table 7. Areas of forest loss over time in the Project area and the catchment of Fingerboard Crossing Creek estimated by GLAD forest loss due to fire data 2001 to 2021.

Year	Area of forest cover loss (ha)		Percent of total area impacted (%)	
	Project area	Fingerboard Crossing Creek	Project area	Fingerboard Crossing Creek
2001	0	0	0.0%	0.0%
2002	0	0	0.0%	0.0%
2003	0.07	0	0.0%	0.0%
2004	0.20	0	0.0%	0.0%
2005	0	0	0.0%	0.0%
2006	0	0	0.0%	0.0%
2007	0	0	0.0%	0.0%
2008	0	0	0.0%	0.0%
2009	0.33	0	0.0%	0.0%
2010	0	0	0.0%	0.0%
2011	2.19	0	0.0%	0.0%
2012	32.55	7.03	0.5%	2.2%
2013	0	0	0.0%	0.0%
2014	0.07	0	0.0%	0.0%
2015	0	0	0.0%	0.0%
2016	0.93	0	0.0%	0.0%
2017	0.33	0	0.0%	0.0%
2018	0	0	0.0%	0.0%
2019	2362.35	123.32	35.9%	37.9%
2020	26.26	0.20	0.4%	0.1%
2021	0.93	0	0.0%	0.0%

Table 8. Areas burned by 2016/17 and 2019/20 bushfires within the Project area and catchment of Fingerboard Crossing Creek using FESM data.

Years with fire	Burn severity (ha)				Total area burned (ha)
	Low	Moderate	High	Extreme	
Area burned in Project area					
2016/17	10.0	6.1	0.0	0.0	16.1
2019/20	1944.5	1154.9	405.5	81.1	3585.9
Percent of area burned in Project area					
2016/17	0.2%	0.1%	0.0%	0.0%	0.2%
2019/20	29.6%	17.6%	6.2%	1.2%	54.6%
Area burned in Fingerboard Crossing Creek catchment					
2016/17	0.0	0.0	0.0	0.0	0.0
2019/20	69.9	18.0	1.1	0.2	89.2
Percent of area burned in Fingerboard Crossing Creek catchment					
2016/17	0.0%	0.0%	0.0%	0.0%	0.0%
2019/20	21.5%	5.5%	0.3%	0.1%	27.4%

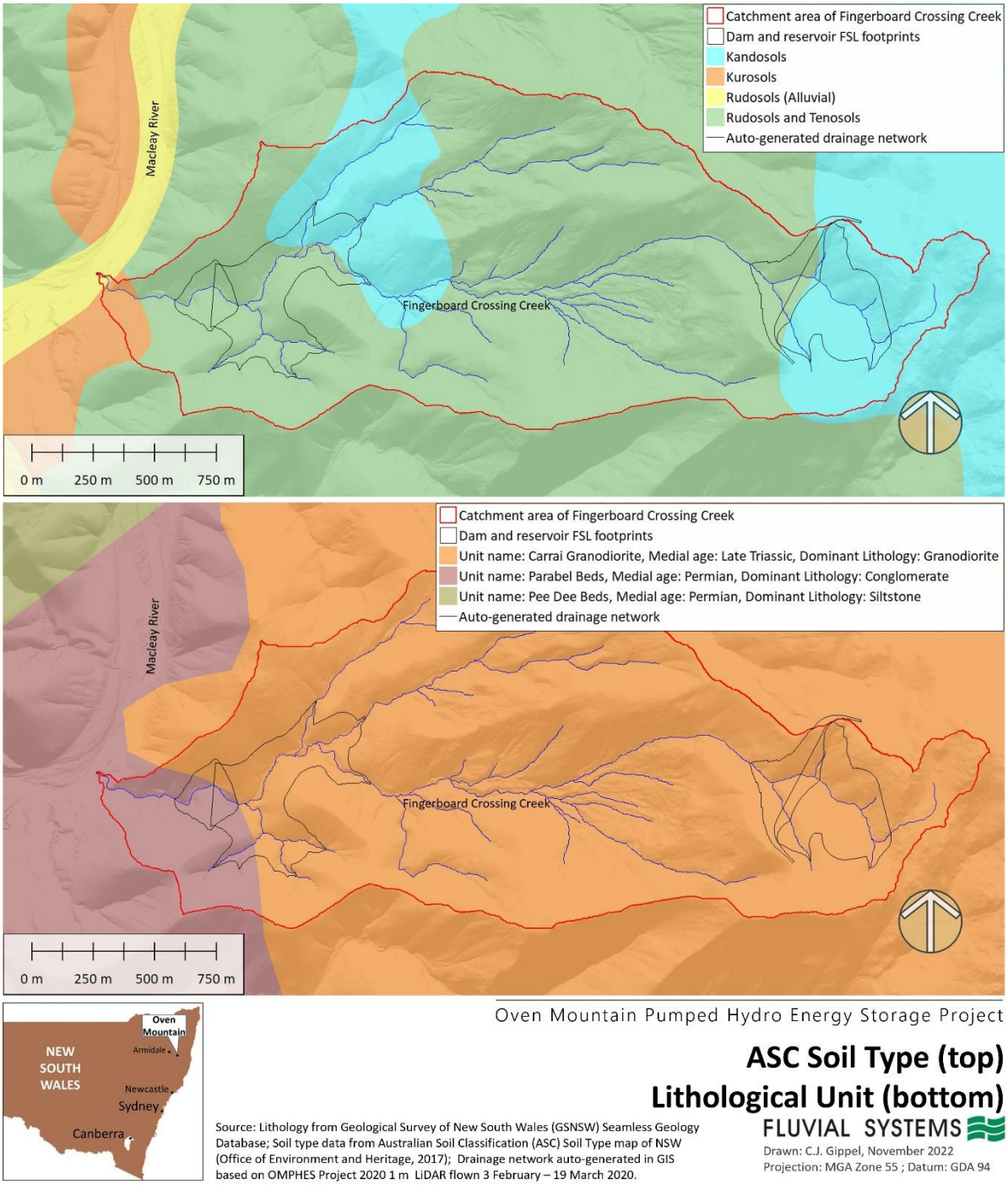

Figure 10. Australian Soil Classification and lithology of Fingerboard Crossing Creek catchment and surrounds, rendered with elevation hillshading.

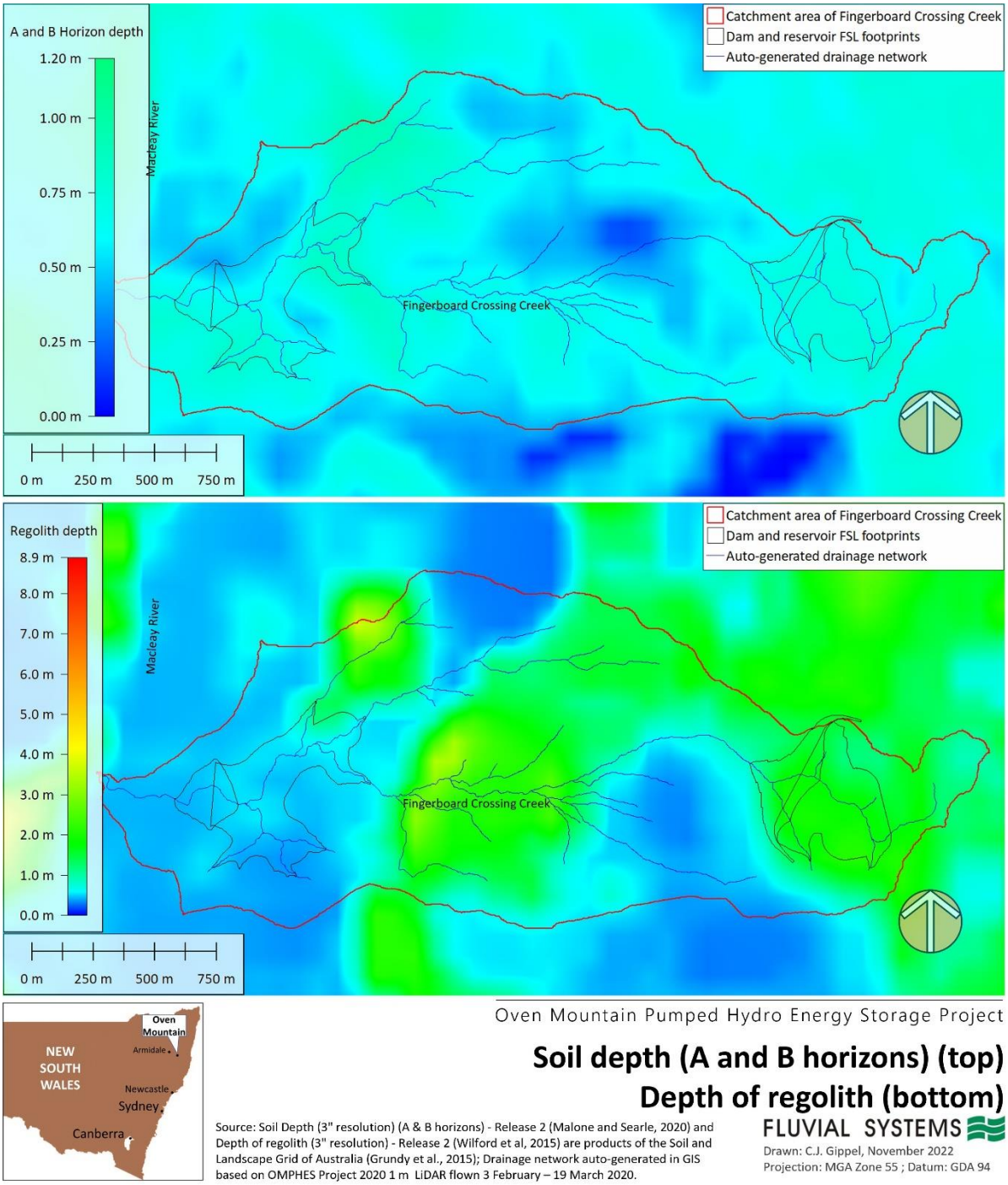

Figure 11. Modelled depth of A and B soil horizons and modelled depth of regolith of Fingerboard Crossing Creek catchment and surrounds. The same shading scale was applied to both variables, although the range differs between them.

3.7 Bed material calibre

A wide range of bed material size was observed at most field sites on Fingerboard Crossing Creek. Mud was uncommon, found only at one site (Figure 12). Sand was also uncommon, found only at two sites, one being at the most downstream site, where the sediment was likely sourced from the Macleay River (Figure 12). Gravel and cobble were present at a majority of sites (Figure 13), as were boulder and bedrock (Figure 14). The general pattern of dominant bed material was bedrock and boulder dominant from the headwaters down to the proposed lower reservoir, while cobble was the dominant bed material in the lower part of the creek (Figure 15). The creek did not show any signs of bushfire impact, such as greater than expected sediment deposition and deposition of fine-grained material.

Photographs of the field sites are provided in Appendix 2. Selected photographs from field sites.

3.8 Channel morphology

Long profiles of thalweg elevation and slope (Figure 16) revealed that Fingerboard Crossing Creek was moderately steep in the headwater area, and very steep downstream of the cliff at 1050 m chainage to approximately 1800 m chainage. From this point to the Macleay River junction, the slope progressively declined. The long profile of estimated maximum pool depth suggested frequent but shallow pools (Figure 16), which generally aligned with the field observations. The maximum pool depth estimated from the DEM likely underestimated actual maximum pool depth. The methodology correctly predicted lack of pools in the steepest reach of the creek, which was observed to have a steeply sloping, smooth bedrock bed (Figure 16). Photographs of the field sites are provided in Appendix 2. Selected photographs from field sites.

3.9 River Styles

The Macleay River in the vicinity of the Project area and for a distance 9.7 km downstream of Fingerboard Crossing Creek junction, has been classified by the River Styles Spatial Layer for New South Wales (NSW Office of Water, 2012b) *PCVS Bedrock controlled gravel*, good condition, moderate fragility and conservation recovery potential. The classification of moderate fragility can be attributed to the corridor of adjustable alluvium in which the channel is formed. Also note that the 'gravel' bed material can comprise sand, gravel and/or cobble-sized material. Bankfull level is typically exceeded every 2 – 5 years unless incised.

Consistent with how other minor tributaries of the Macleay River in the Project area have been classified, and based on the collected data concerning bed material calibre, channel morphology and vegetation, Fingerboard Crossing Creek was assessed to comprise two River Styles:

- The upper creek from its head down to the cliff line at chainage 1070 m, was classified *CVS Headwater,* good condition, low fragility and conservation recovery potential.
- The lower creek, from chainage 1070 m to the junction at Macleay River, the creek was classified *CVS Gorge,* good condition, low fragility and conservation recovery potential.

Headwater and gorge types have no floodplain, so the concept of bankfull refers only to a flood frequency, not a level corresponding with top of bank. The good condition of these types relate to the naturalness of the vegetation, lack of physical disturbance, and lack of flow alteration. The entire Fingerboard Crossing Creek is low fragility as it is formed within resistant bedrock rather than adjustable alluvium. The practical meaning of conservation recovery potential is that construction and operation of the Project should seek to minimise impact to geomorphic processes and forms linked to maintenance of any high conservation ecological values that might be identified. Identification of such values and links was not within the scope of this report.

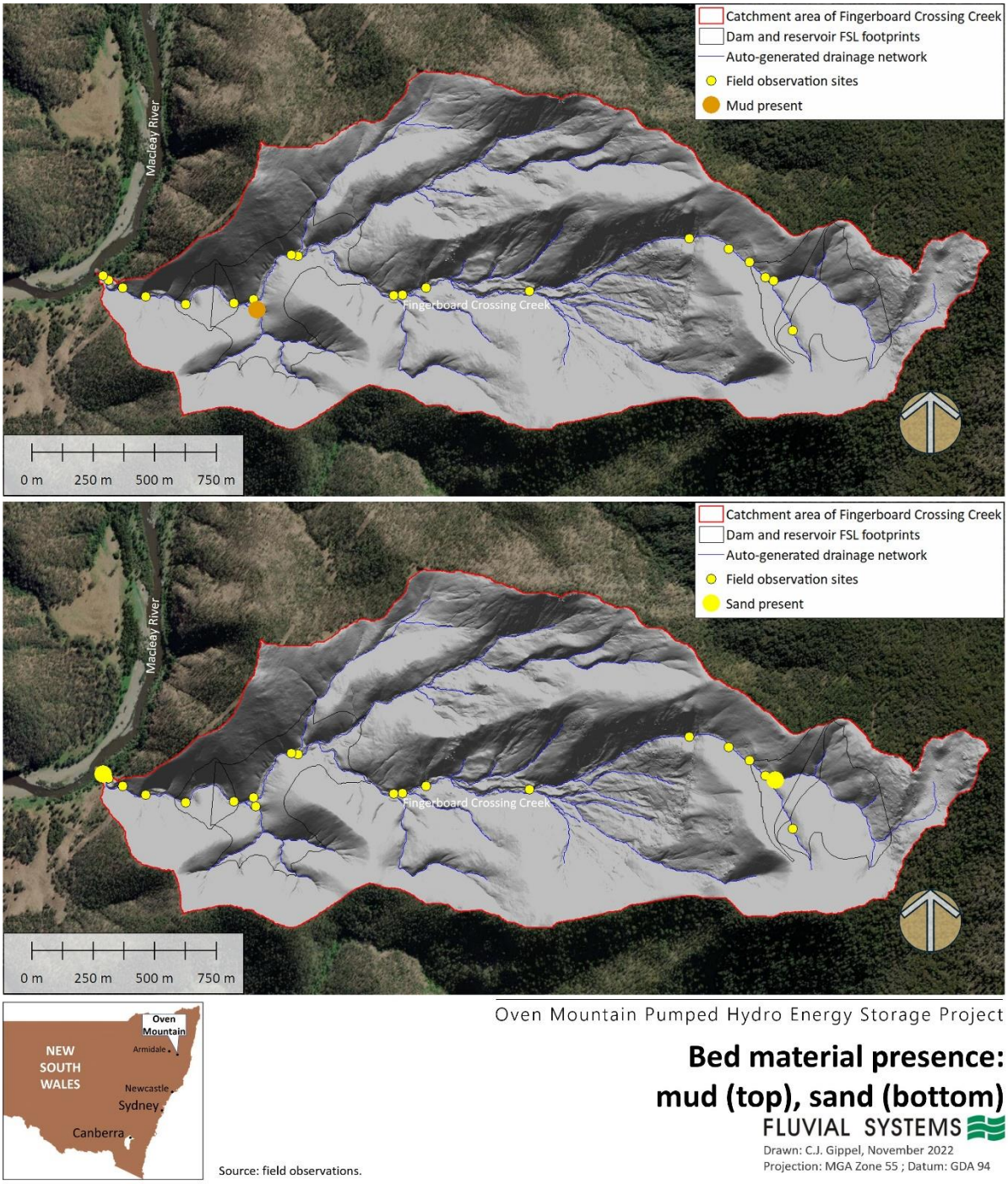

Figure 12. Fingerboard Crossing Creek bed material presence: mud and sand.

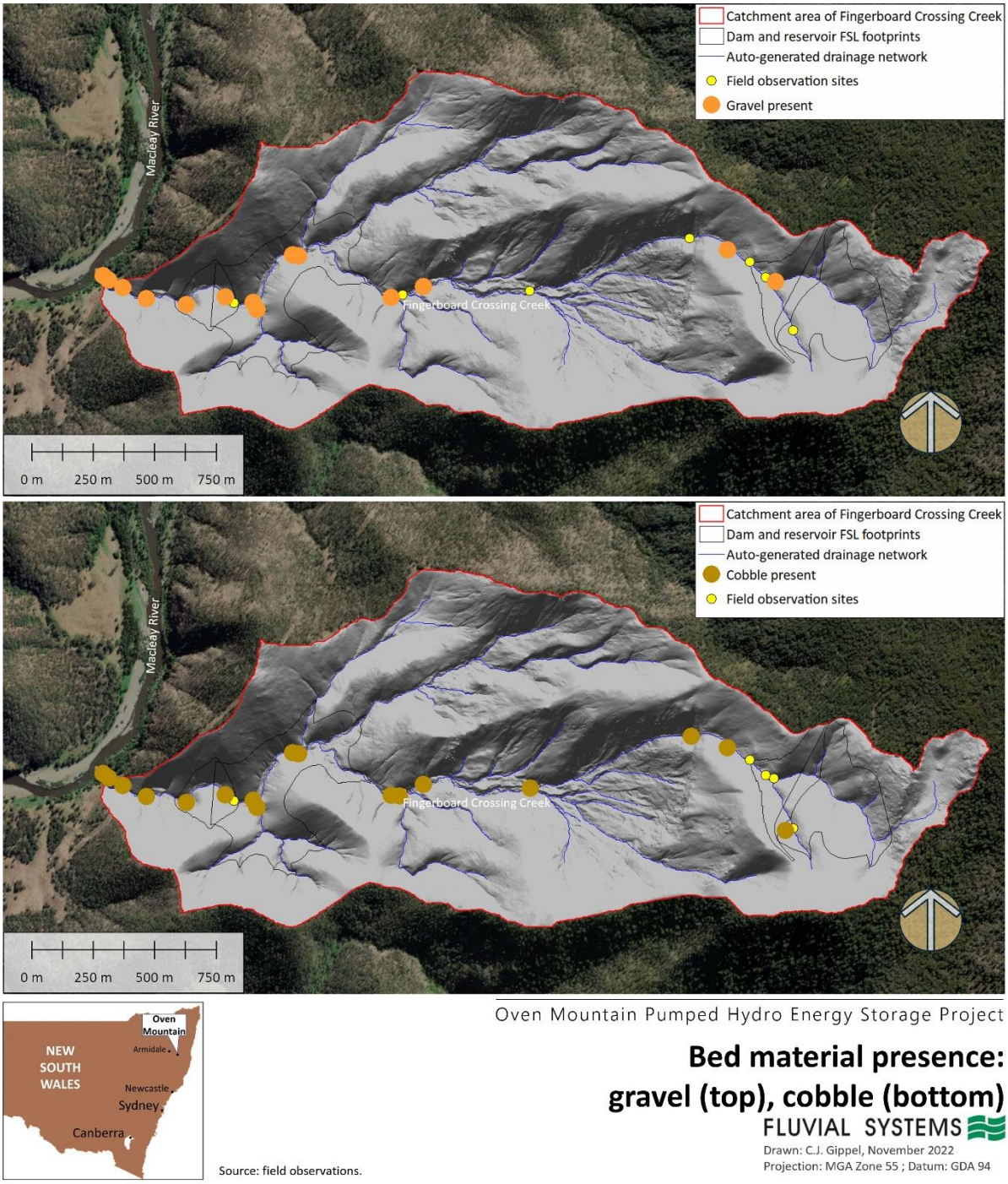

Figure 13. Fingerboard Crossing Creek bed material presence: gravel and cobble.

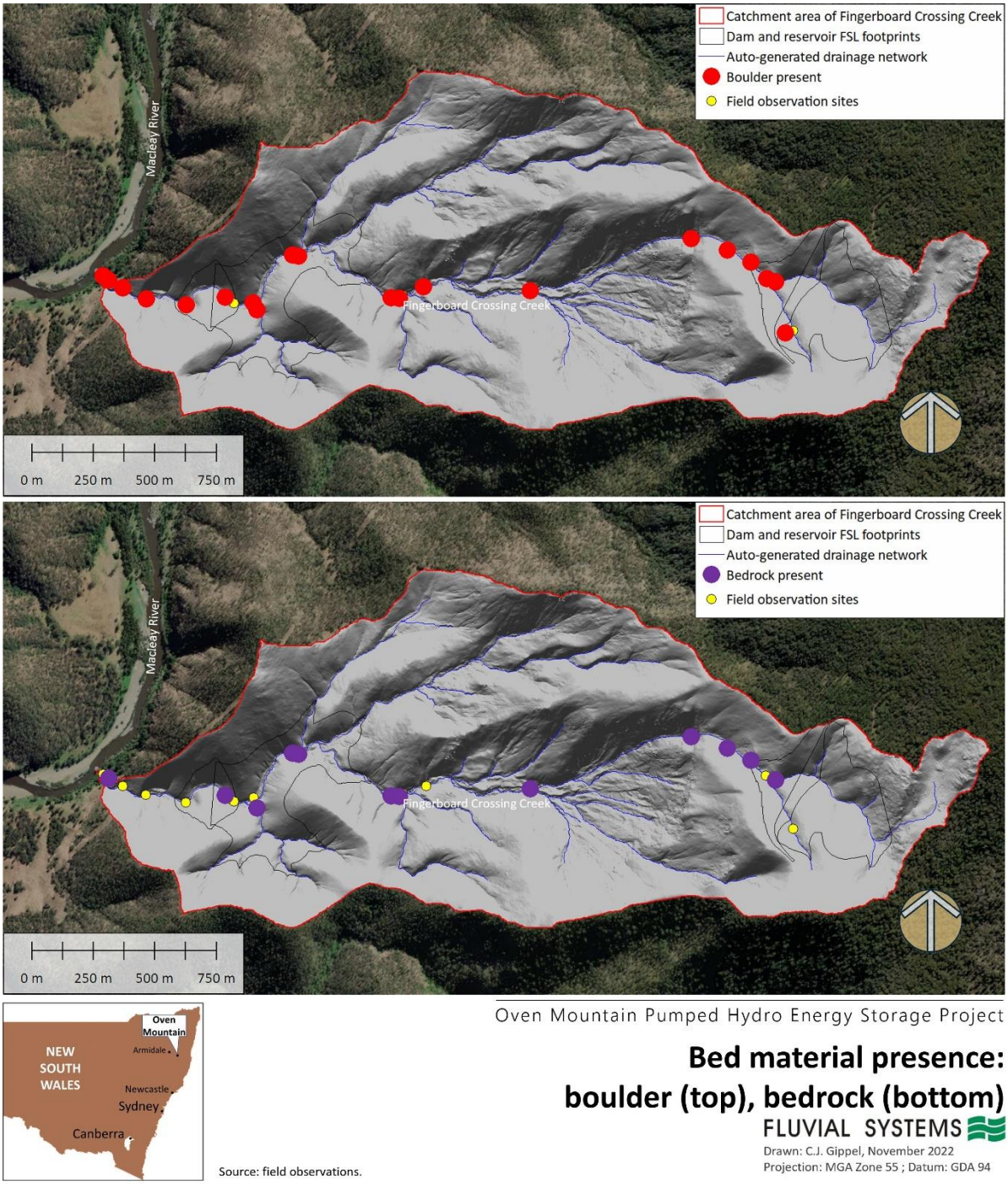

Figure 14. Fingerboard Crossing Creek bed material presence: boulder and bedrock.

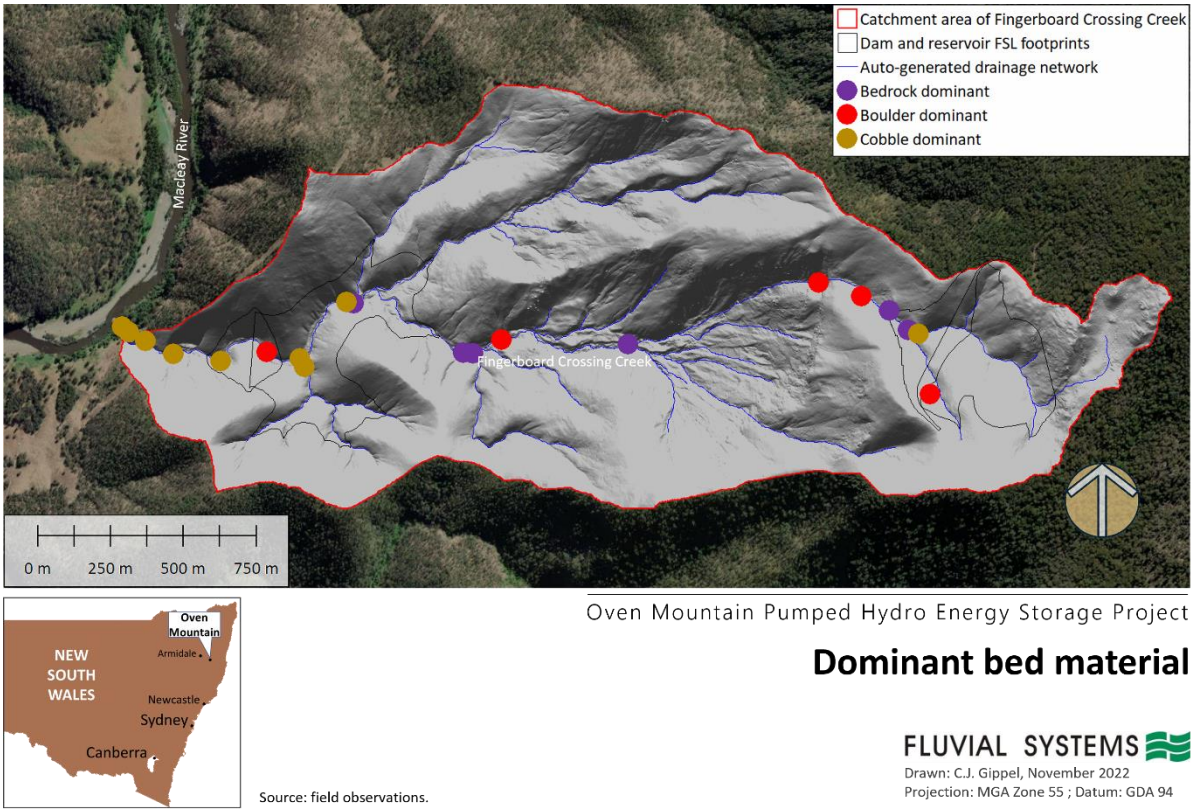

Figure 15. Fingerboard Crossing Creek dominant bed material.

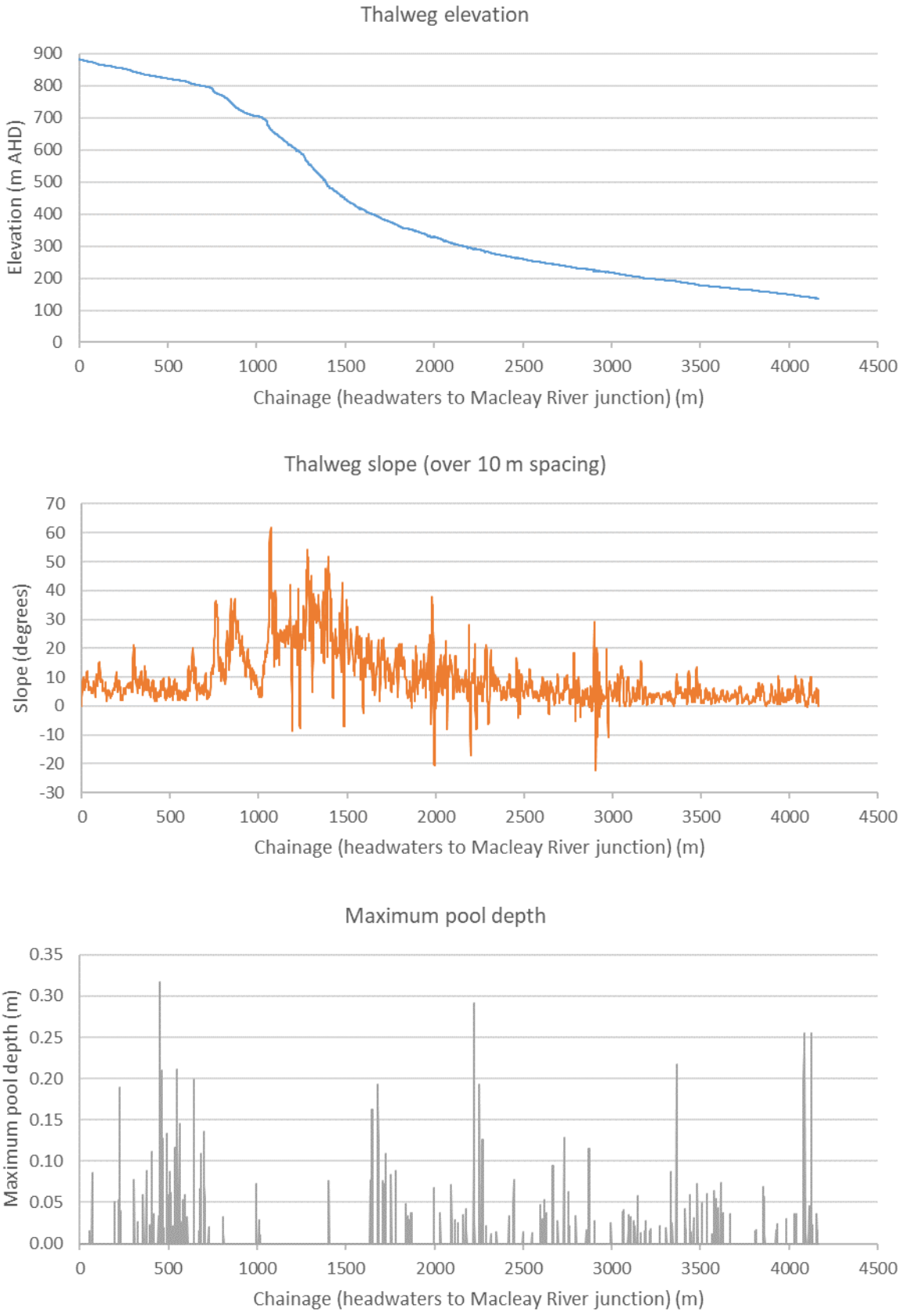

Figure 16. Elevation (top), slope (middle) and maximum pool depth (bottom) of Fingerboard Crossing Creek.

4 Impacts

4.1 Displacement of watercourses by dams and reservoirs

Some drainage lines will be displaced by burial and submergence due to the Project dam walls and reservoirs (Figure 17). The lengths of these displaced drainage lines were classified by upper and lower dam and reservoir, and by mainstem drainage lines of Fingerboard Crossing Creek and tributary drainage lines (Table 9).

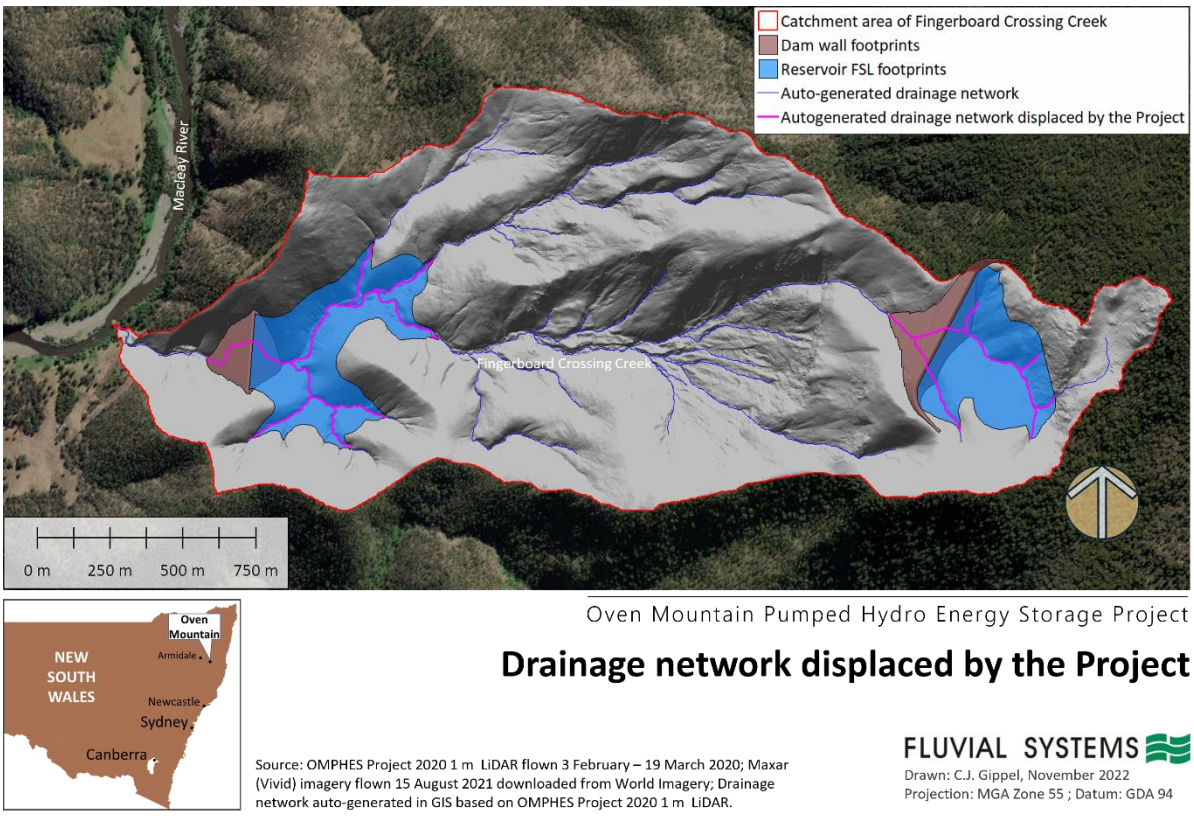

Figure 17. Drainage lines displaced by burial and submergence due to the Project dam walls and reservoirs.

Table 9. Length of watercourses displaced by the Project dam walls and reservoirs.

Area	Length of displaced drainage line (m)	
	Mainstem	Tributary
Upper dam and reservoir	689	664
Lower dam and reservoir	1153	1395
Total	1842	2059

4.2 Erosion of soil within the reservoirs

Erosion of reservoir shorelines and subsequent sedimentation within the reservoir is a recognised problem in pumped storage projects due to fluctuating water levels during operations (Saulsbury, 2020). To achieve

adequate storage volume, the Project will involve excavation of significant quantities of soil and rock within the impounded areas. The excavated rock will be used in dam wall construction. The natural soil surface remaining in the unexcavated parts of the inundated areas could be left the way it is or scraped and removed prior to filling (Figure 18). If the soil is not removed, it will be subject to stripping of the A and B horizons, or potentially greater depths of regolith, depending on the erosion resistance of the lower weathered bedrock. To inform this aspect of the construction method, an estimate was made of the volume of soil that could potentially be stripped by erosion.

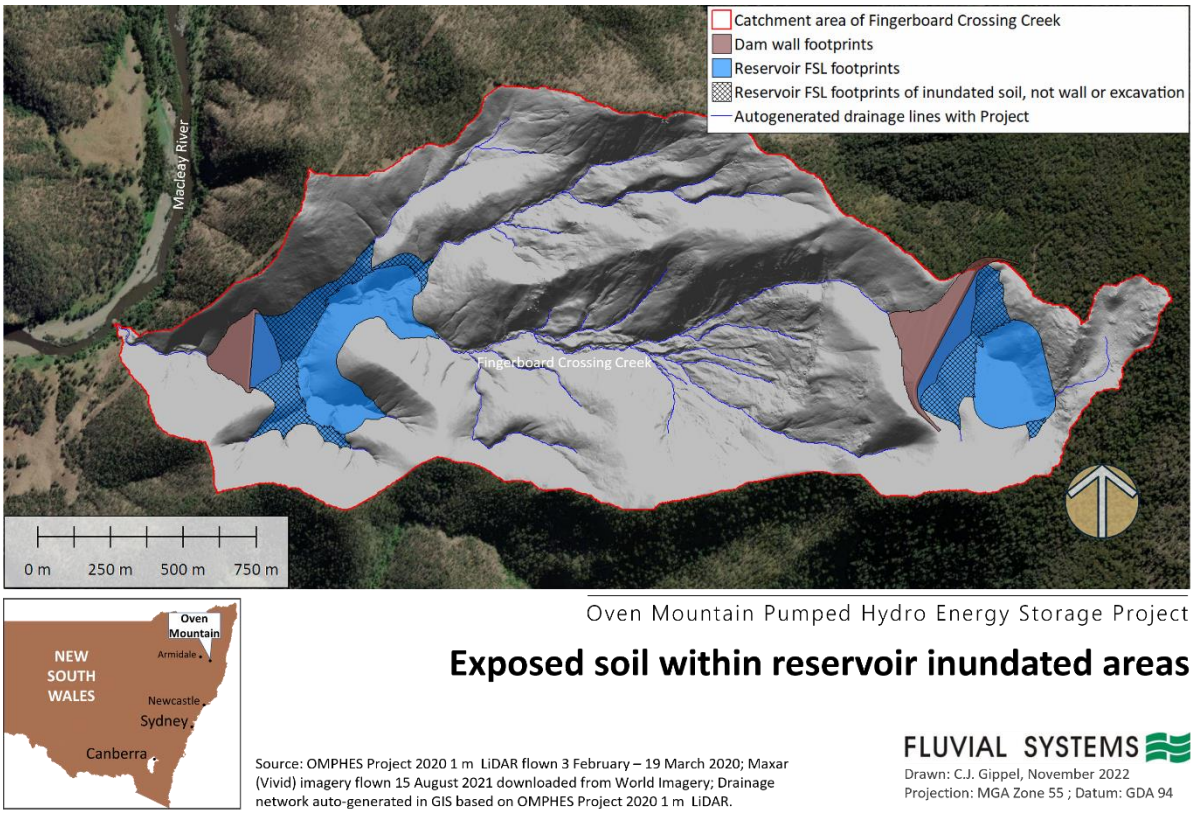

Figure 18. Areas of exposed soil within reservoir inundated areas subject to stripping.

The 3-D areas of exposed soil were calculated to be 5.66 ha (5.42 ha + 0.24 ha areas) for the upper reservoir and 7.66 ha for the lower reservoir. The mean depths of A and B horizons were 0.78 for the large area and 0.71 m for the small area of the upper reservoir, and 0.66 m for the lower reservoir. The estimated volumes of soil that would potentially be eroded from within the reservoirs were 40,514 m^3 for the upper reservoir and 50,725 m^3 for the lower reservoir. These material volumes, if removed, would be equivalent to an additional 40.5 ML and 50.7 ML reservoir capacity respectively. The proposed capacities of the upper and lower reservoirs are 5,100 ML and 6,500 ML respectively (EMM, 2022a), so the additional volumes created by soil erosion represent only 0.8% of reservoir capacity.

The mean depths of regolith were 1.67 for the large area and 2.08 m for the small area of the upper reservoir, and 0.54 m for the lower reservoir. For the lower reservoir, the depth of regolith was less than the depth of the A and B horizons, so this was considered unreliable. Using depth of regolith to estimate potential soil loss from the upper reservoir resulted in a value of 95,321 m^3, a volume which, if eroded, would be equivalent to an additional 95.3 ML reservoir capacity, or 1.9% of reservoir capacity.

If all soil eroded from within the reservoirs settled to the bases of the reservoirs, there would be no net change in capacity at the reservoir FSLs, but the MOLs could be raised by the slightly elevated bases. If all soil eroded from within the reservoirs became suspended in the water columns it would likely find its way downstream, ultimately to the Macleay River, and the reservoir capacities would be increased. The actual impact would likely lie between these two extremes, but regardless, the change in dam capacity or MOL would be minor due to the thin soils and relatively small areas of soil exposed to erosion. Including mechanical removal of all soil from unexcavated areas within the reservoirs as part of the construction method would avoid these potential impacts.

4.3 Trapping of sediment load within the reservoirs

4.3.1 Sediment dynamics of pumped storages

Reservoir sedimentation is a major concern in the operational management of dams for two main reasons: (i) the volume of sediments deposited in reservoirs reduces their storage capacity over time, and (ii) trapping of sediments by dams interrupts the sediment balance of the downstream river, which may result in negative impacts on the aquatic environment and coastal areas (Guillén-Ludeña et al., 2018).

The presence of fine sediments in the vicinity of the dam may result in partial or total blockages of the water release structures, and in turbine abrasion if they are absorbed by the power intakes (Guillén-Ludeña et al., 2018). In the case of reservoirs of pumped-storage schemes, fine sediment can move back and forth from one reservoir to the other during the different operation cycles. Müller et al. (2014) found that the suspended sediment concentration in the two reservoirs of a pumped-storage plant in Switzerland varied considerably over the course of a year, as determined by seasonally variable sediment supply. The short-term pattern of the suspended sediment concentration was found to be correlated to the pumped-storage sequences.

While there is very little literature concerning sediment dynamics of pumped storages, it can be hypothesised that in the case of the Project, excavation within the reservoirs, and initial filling with river water sourced at times of high flow when turbidity is likely to be elevated, means that initial operation is likely to involve circulation of water containing suspended sediment. Storm events are likely to periodically deliver turbid water to the reservoirs, and pumping operations could maintain silts and clays in suspension for extended periods of time.

4.3.2 Impacts to reservoir storage capacity

The upper and lower reservoirs will trap all inflowing bed load, and a high proportion of the inflowing suspended load. For suspended sediment, the commonly applied Brune (1953) equation relates trap efficiency of normally ponded reservoirs to the ratio of reservoir capacity to mean annual flow. Normally ponded reservoirs were distinguished from those that are periodically drawn down to expose sediments. The Project reservoirs will be operated on a cycle of frequent draw down and refill, so the Brune (1953) and other similar trap efficiency equations are not appropriate. Knowledge of the trap efficiency and trapping rate of pumped hydro storages is limited, and no empirical equation is available on which to base a simple estimate. Another limitation of estimating the long-term volume of sediment trapped within the Project reservoirs is the lack of knowledge of the sediment yield from the catchment, both bed material and suspended sediment. Given the small catchment areas of the reservoirs, sediment loads would be small relative to reservoir capacities, so loss of reservoir capacities due to sediment trapping would be a minor impact over the expected operational lifespan of the Project of 100+ years.

4.3.3 Impacts to downstream geomorphic processes

If a dam reduces sediment supply but maintains a river's hydraulic and hydrologic capacity to transport sediment, the river could widen and/or incise; conversely, if a dam reduces a river's hydraulic and hydrologic capacity to transport sediment and check the growth of instream vegetation, the river could aggrade (Gippel, 2002). In both cases, the quality of instream hydraulic habitat would change. Riverine ecosystems that rely on

the supply of sediment and associated nutrients from upstream for normal functioning could be impacted by construction of a dam upstream.

The consequences of a sudden reduction in coarse bed load (gravel, cobble and boulder-sized material) to Fingerboard Crossing Creek downstream of the reservoirs will be scour of the bed material from the bed of the creek downstream, without replacement by sediment delivered from upstream, thereby lowering the bed and removing the most mobile fractions of the bed material. Lowering the bed could lead to more concentration of discharge within the channel, increasing the capacity of the creek to scour bed sediments. Reduced bed load supply but ongoing bed material transport will, over time, lead to incision of the bed down to bedrock outcrops and large boulders, with some gravel and cobble material persisting in sheltered spaces between boulders and bedrock outcrops. The Gorge River Style of Fingerboard Crossing Creek has low geomorphic fragility, which means that the incision process will be limited by the creek's natural resistance to change. Loss of gravels and cobbles from the bed substrate could have implications for biota that utilise this material as an element of habitat.

4.4 Hydraulics of Fingerboard Crossing Creek

The gridded hydraulic model output was converted to long-profiles of BSS and depth along Fingerboard Crossing Creek over the model extent by extracting at 1-metre spacing the peak values of BSS and depth in the perpendicular across the width of the wetted area. This was done for all modelled flood event profiles and for the existing and with Project scenarios (Figure 19, Figure 20, Figure 21, Figure 22 and Figure 23). The model extent was shorter for the with Project scenarios due to the upper reach being displaced by the upper dam and reservoir, and the lower reaches being displaced by the lower dam and reservoir. The flood event magnitudes were lower for the with Project scenario compared to the existing scenario due to the headwater area (sub-catchment CA06 in Figure 3) being effectively excised from the catchment by the upper dam and reservoir. Thus, with the Project operational, compared to existing, for the same event frequency, flow peak magnitude was lower, and therefore BSS and depth were lower along the length of the creek.

The BSS threshold 256 N/m^2 corresponds to mobilisation of all material cobble size and finer. Gravels and cobbles are common on the bed of Fingerboard Crossing Creek. Under the existing scenario, the 256 N/m^2 threshold was exceeded along the entire length of Fingerboard Crossing Creek for the 63.2%AEP, 50%AEP, 20%AEP, 5%AEP and 1%AEP events (Figure 19, Figure 20, Figure 21, Figure 22 and Figure 23). This result suggests that gravels and cobbles would be frequently mobilised in at least some part of the cross-section all the way along the creek. For all modelled flood event profiles, peak BSS was considerably higher than the threshold to mobilise all cobbles and finer material along most of the creek's length, with values commonly exceeding 1000 N/m^2. These very high BSS values do not necessarily mean that large boulders metres in diameter would be mobilised by these flow events. Over most of the creek's length the flow depth would be too shallow to fully submerge large boulders, and large boulders are often wedged in position by bedrock or other boulders.

Under the with Project scenario, the BSS threshold 256 N/m^2 was exceeded along the majority of the length of Fingerboard Crossing Creek for the 63.2%AEP and 50%AEP events (Figure 19 and Figure 20) and along the entire length of Fingerboard Crossing Creek for the 20%AEP, 5%AEP and 1%AEP events (Figure 21, Figure 22 and Figure 23). The hydraulic model results suggest while the Project will reduce BSS and depth along the length of Fingerboard Crossing Creek for all modelled flood event profiles, both the BSS and depth both be frequently high enough to mobilise fines, sands, gravels, cobbles and some boulder-sized material.

The results of hydraulic modelling suggest that with the Project operational, Fingerboard Crossing Creek immediately downstream of the upper dam, lacking flow and sediment supply, will become geomorphologically dormant. Further downstream, natural inflow and sediment supply will maintain fundamental geomorphic processes, but at a reduced intensity. This will lead to contraction of the hydraulically and geomorphologically active channel width and depth.

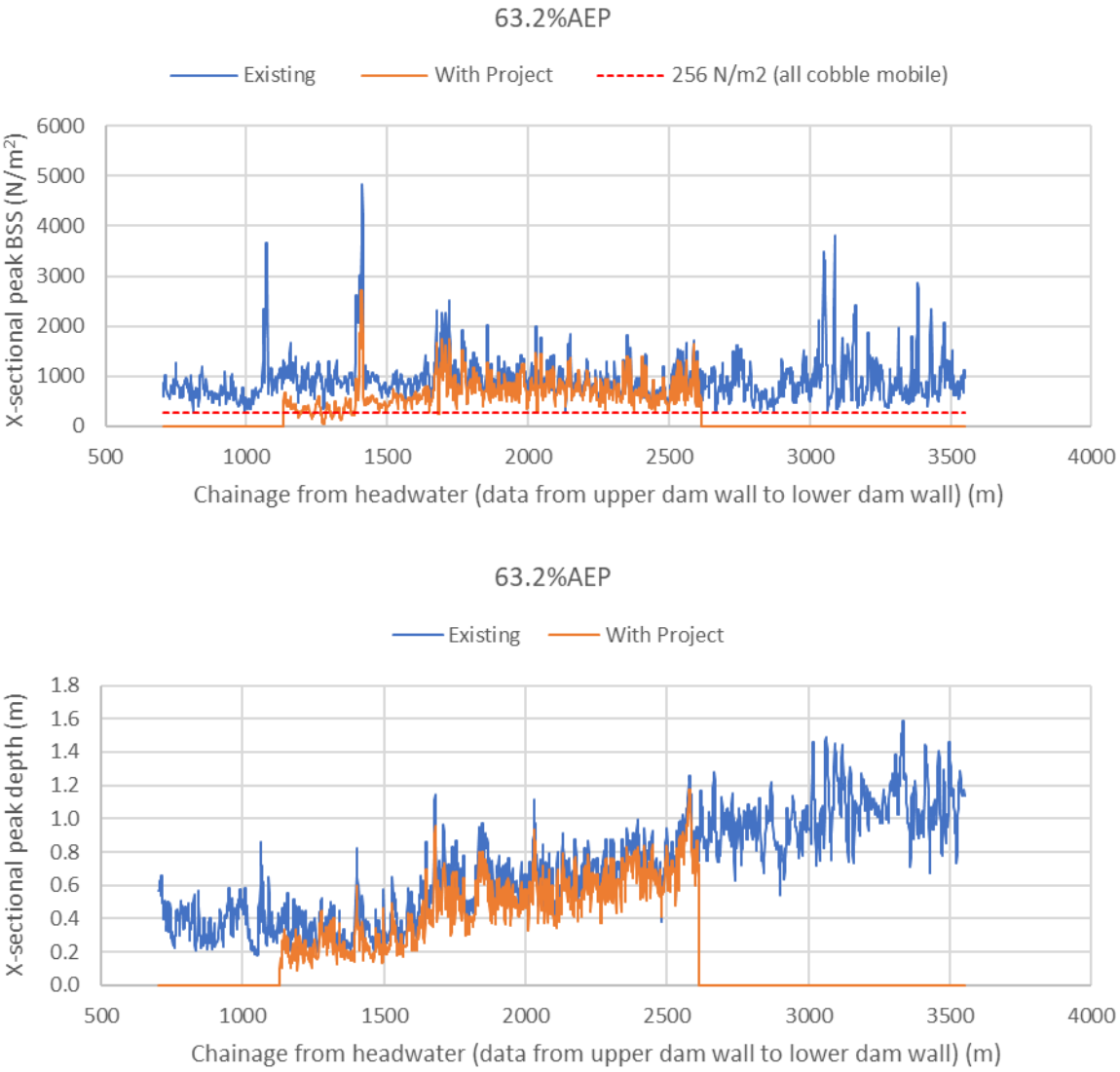

Figure 19. Long profile of cross-sectional peak bed shear stress (BSS) (top) and peak depth (bottom) at 1 metre spacing along the length of the hydraulic model extent for the 63.2%AEP event

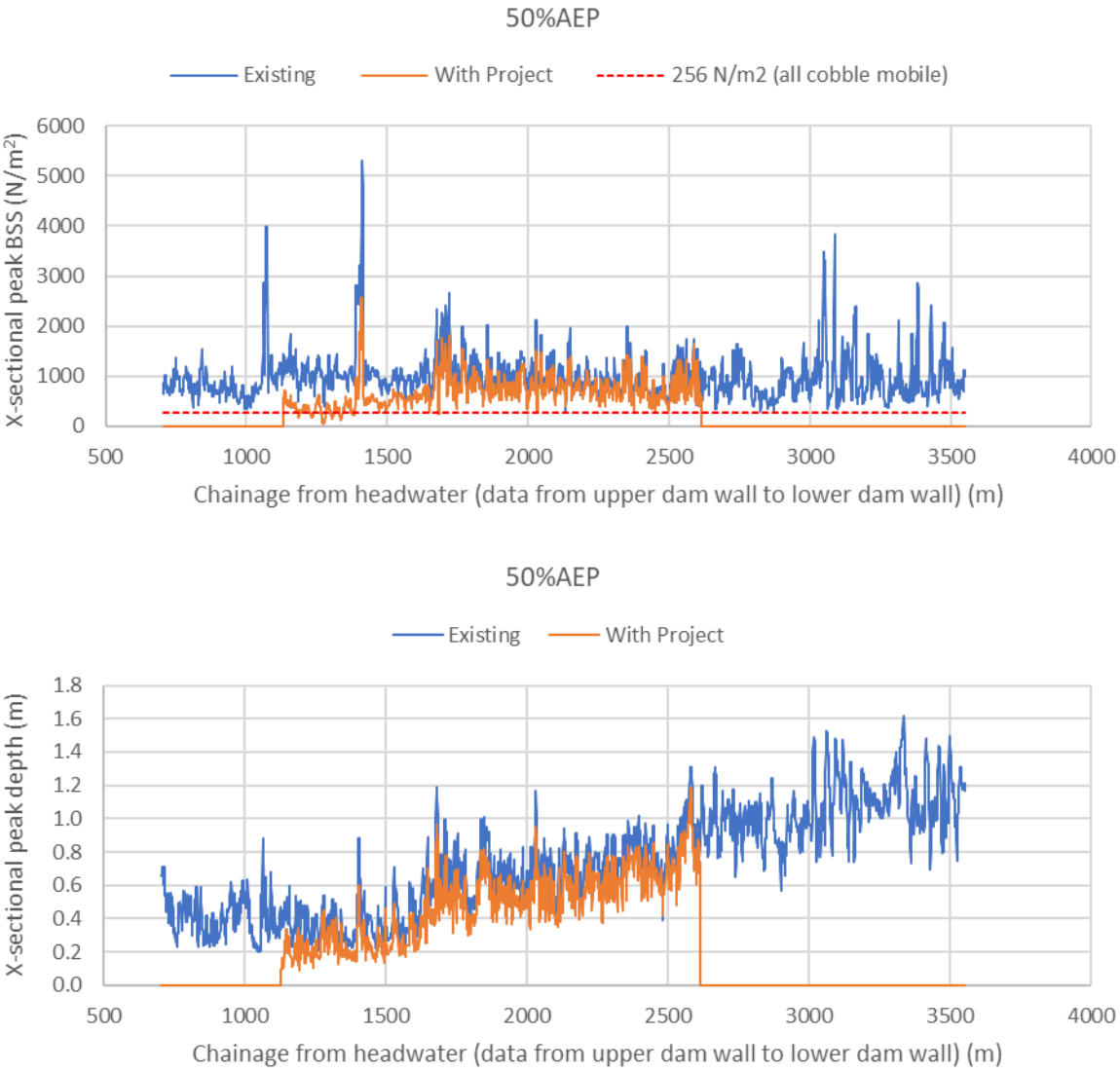

Figure 20. Long profile of cross-sectional peak bed shear stress (BSS) (top) and peak depth (bottom) at 1 metre spacing along the length of the hydraulic model extent for the 50%AEP event

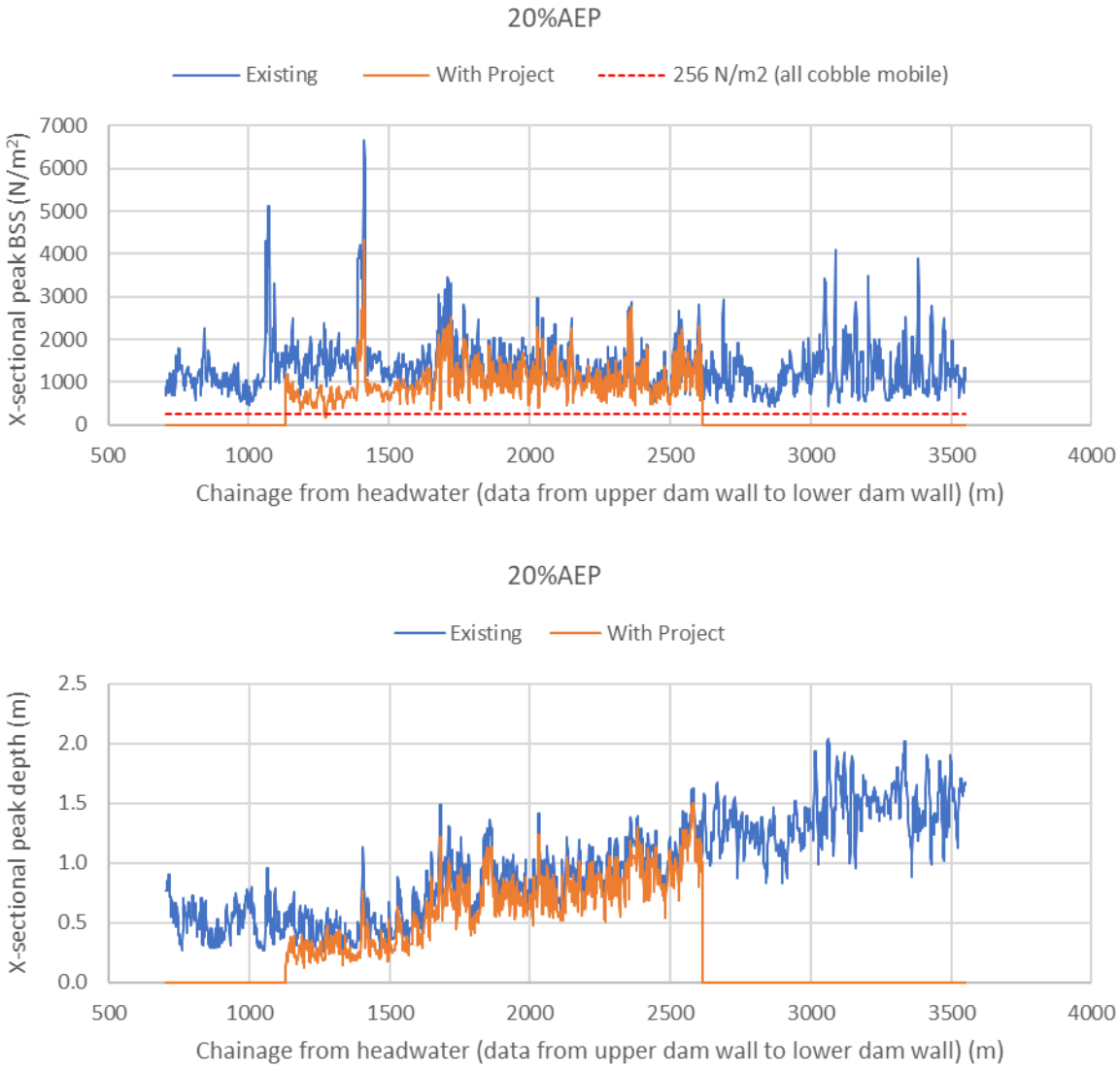

Figure 21. Long profile of cross-sectional peak bed shear stress (BSS) (top) and peak depth (bottom) at 1 metre spacing along the length of the hydraulic model extent for the 20%AEP event

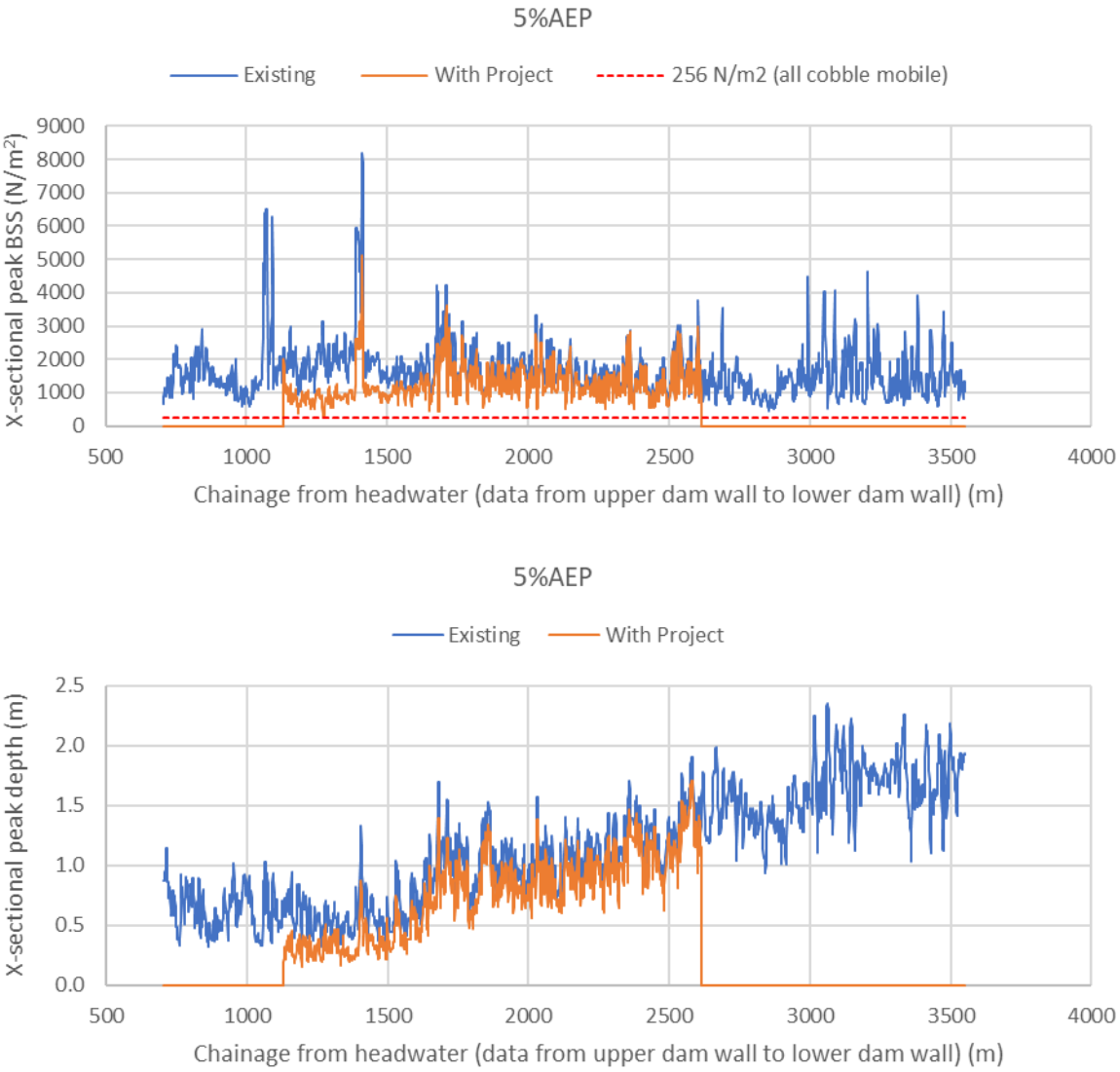

Figure 22. Long profile of cross-sectional peak bed shear stress (BSS) (top) and peak depth (bottom) at 1 metre spacing along the length of the hydraulic model extent for the 5%AEP event

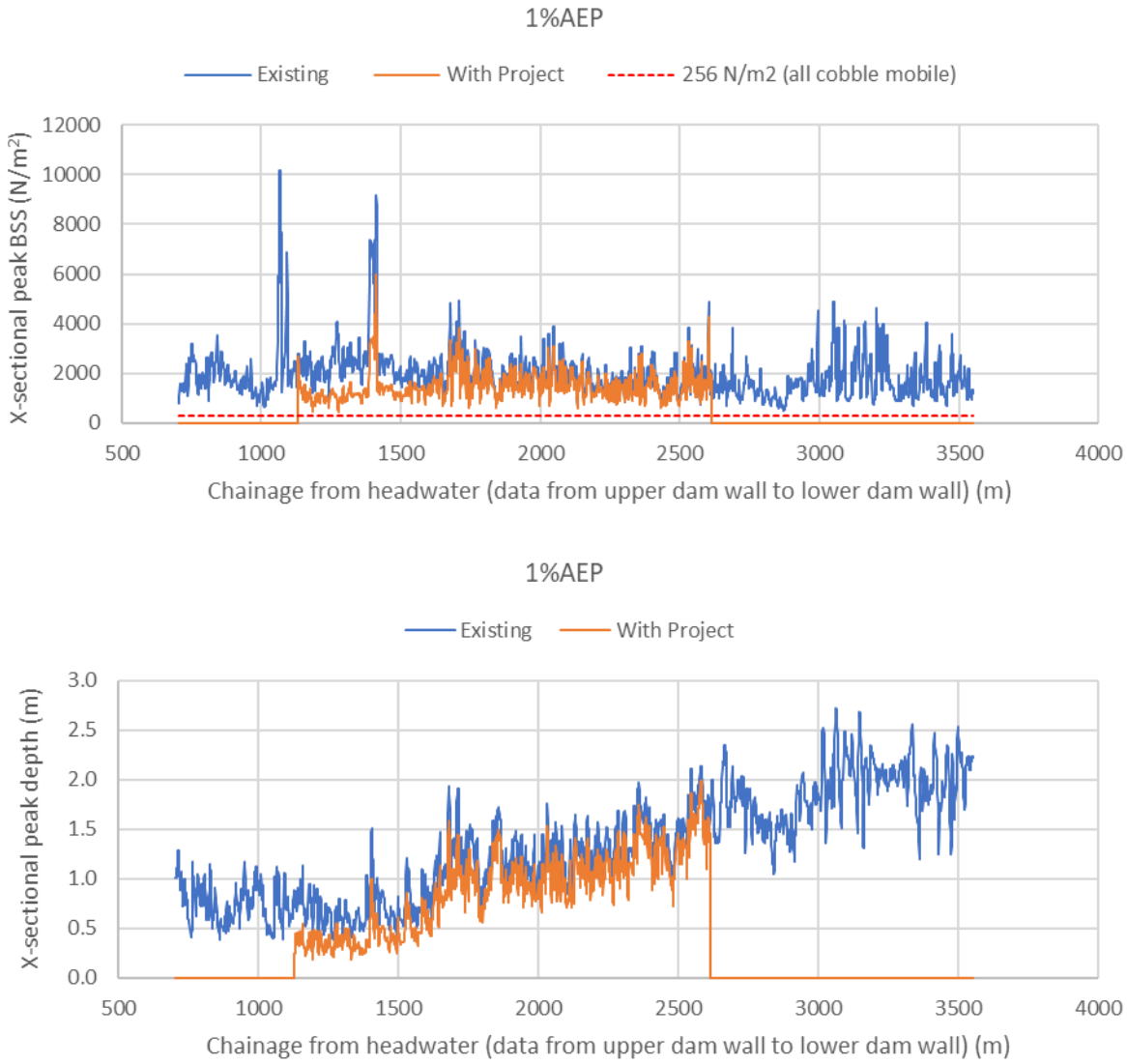

Figure 23. Long profile of cross-sectional peak bed shear stress (BSS) (top) and peak depth (bottom) at 1 metre spacing along the length of the hydraulic model extent for the 1%AEP event

4.5 Hydrology of Fingerboard Crossing Creek

4.5.1 Flood frequency analysis

The hydraulic model established that the BSS and depth conditions generated within the channel of Fingerboard Crossing Creek under the 63.2%AEP event peak were adequate to mobilise fines, sands, gravels, cobbles and some boulder-sized material. It was of interest to characterise the durations and intervals between these events over a long time series.

Flood frequency analysis was undertaken on the 132 year long mean daily time series modelled for the outlets of sub-catchments CA01, CA03, CA04, and CA05. The *annual maximum series* was extracted and fitted to a Log Pearson Type III (LPIII) distribution to estimate the magnitude of the 63.2%, 50%, 39.35%, 20%, 10%, 5%, 2% and 1%AEP events (Figure 24). Smaller floods will occur more frequently than indicated by the *annual*

maximum series, because several peaks in one year may be higher than the highest flood in other years. For this reason, *partial-duration series* is more appropriate for smaller events. The *partial-duration series* and *annual maximum series* often diverge for events smaller than the 10%AEP event (Gordon et al., 2004, p. 214). A special case of the *partial-duration series* is the *annual exceedance series*, where the N highest peaks within the N years of data are chosen, irrespective of when they occur. The *annual exceedance series* was extracted and fitted to a polynomial to estimate the magnitude of the 98.17%, 95.02%, 86.47%, 63.2%, 50%, 39.35%, 20%, 10% and 5% AEP events (Figure 24). The results of the mean daily flow *annual maximum series* and *annual exceedance series* results for CA01 were compared with the peak instantaneous flows modelled by XP-RAFTS (SMEC, 2022), as reported by EMM (2022b) (Table 6) (Figure 24). As expected, for CA01, for the same flood frequency, the instantaneous flood peaks were one or two orders of magnitude higher than the estimate made using the mean daily flow series (Figure 24). Also as expected, for the frequent low magnitude events, the annual exceedance series estimated higher annual exceedance probability than that estimated by the annual maximum series (Figure 24).

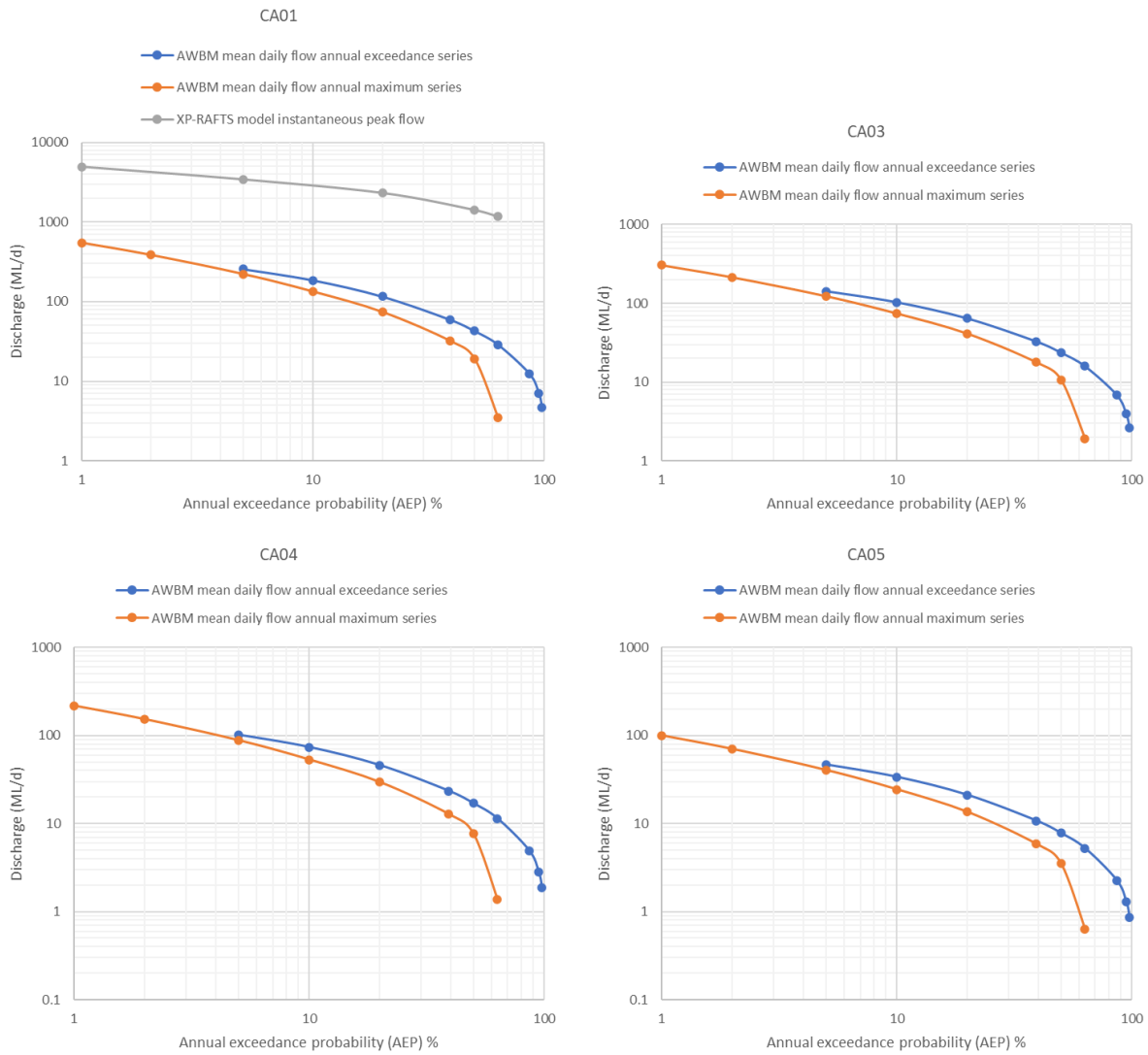

Figure 24. Mean daily flow *annual maximum series* and *annual exceedance series* results for Fingerboard Crossing Creek sub-catchment outlets. For CA01, these results were compared with the peak instantaneous flows modelled by XP-RAFTS (SMEC, 2022).

Consideration of the results of the flood frequency analysis suggested that: (i) the 63.2%AEP event magnitude estimated using the *annual maximum series* extracted from the mean daily flow time series was more than two orders of magnitude lower than the event instantaneous peak magnitude, as modelled by XP-RAFTS, (ii) mean daily event peak was likely correlated with instantaneous event peak, so it would be meaningful to describe the duration and interval characteristics of periods of flow exceeding the 63.2%AEP event magnitude, and (iii) events exceeding the 63.2%AEP event magnitude, estimated from a mean daily flow time series using the *annual maximum series*, would likely occur more frequently than once per year on average. This conclusion also likely applies to the 63.2%AEP event modelled by XP-RAFTS.

4.5.2 Spells analysis

Spells analysis was undertaken for flows exceeding the 63.2%AEP event magnitude, estimated from a mean daily flow time series using the *annual maximum series*. This analysis was undertaken for the 132 year long mean daily time series modelled for the outlets of sub-catchments CA01, CA03, CA04, and CA05, for the existing scenario and with the Project operational. The objective of this analysis was to characterise the relative impact of the Project on the frequency, duration and interval between events that are thought to be associated with geomorphological channel maintenance processes. Under existing conditions, the 63.2%AEP event occurs frequently, and the hydraulic model established that the instantaneous peak magnitude of this event is associated with sufficiently high BSS and depth to mobilise sands, gravels, cobbles and some boulders.

The spells analysis found that the characteristics of the spells for the 63.2%AEP event for 4 locations on Fingerboard Crossing Creek under the existing scenario were identical for each location (Table 10). This is explained by the AWBM model generating a flow series for one location (CA01) and then factoring this series by catchment area to create time series for the other sites. The %AEP thresholds calculated for each location are therefore also related by the same factors. As expected, events exceeding the 63.2%AEP threshold discharge occurred frequently, on average 5.6 times per year under the existing scenario. With the Project operational, frequency was slightly lower for CA01, CA03 and CA04, but substantially lower for CA05 (Table 10). Despite the reduction in frequency, the events remained relatively frequent, at 1.8 times per year on average. The percent of years with no event, less than or equal to one event, or less than or equal to two events, increased with the Project operational. The increase was particularly marked for CA05 (Table 10). Event duration was little impacted by operation of the Project (Table 10). The intervals between spells increased with the Project operational, explained by the reduced frequency of events. The increase in interval between events was small, except for CA05, where the interval increased by a factor of approximately 3 (Table 10).

The results of the spells analysis, undertaken using mean daily time series, provided characterisation of the relative impact of the Project on the frequency, duration and interval of events sufficiently high in frequency and magnitude to play an important role in maintenance of geomorphic processes within Fingerboard Crossing Creek. Given the small, steep nature of catchment, and resultant flashy hydrological response, a time series generated on a shorter time step (e.g., hourly) would provide a more realistic characterisation of the hydrographs.

The results of spells analysis suggested that, with the Project operational, Fingerboard Crossing Creek downstream of the upper dam will experience a decline in the magnitude, frequency and duration of flows that contribute to channel maintenance processes. This could impact ecological processes and communities that depend on maintenance of these processes at their natural rates. Further downstream, natural inflow and sediment supply will maintain fundamental geomorphic processes within Fingerboard Crossing Creek, but with minor reduction in magnitude, frequency and duration.

Table 10. Results of spells analysis.

Hydrological index	CA01		CA03		CA04		CA05	
	Existing	With Project	Existing	With Project	Existing	With Project	Existing	With Project
Threshold magnitude								
63.2AEP% (mean daily ML/d)	3.47	3.47	1.93	1.93	1.38	1.38	0.63	0.63
Frequency of spells								
Mean frequency (events/year)	5.6	5.3	5.6	4.7	5.6	4.3	5.6	1.8
Percent of years with no event	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	20.5%
Percent of years with <= 1 event	3.0%	5.3%	3.0%	5.3%	3.0%	7.6%	3.0%	57.6%
Percent of years with <= 2 events	9.1%	11.4%	9.1%	17.4%	9.1%	22.7%	9.1%	76.5%
Duration of spells								
Mean (days)	4	3	4	3	4	3	4	3
Median (days)	2	2	2	2	2	2	2	2
Standard deviation (days)	6	5	6	4	6	4	6	2
5th percentile (days)	11	10	11	10	11	10	11	8
Interval between spells								
Mean (days)	61	66	61	74	61	82	61	203
Median (days)	36	38	36	41	36	45	36	94
Standard deviation (days)	70	75	70	83	70	89	70	244
5th percentile (days)	212	227	212	261	212	271	212	745

4.6 Impacts to Fingerboard Crossing Creek downstream of the lower dam

The flow regime of Fingerboard Crossing Creek downstream of the lower dam would be impacted by reduced magnitude and duration of storm event flows and increased duration of cease to flow. Flow would spill downstream only when the lower dam was at FSL and was receiving inflows from the catchment, and the peak of those flow hydrographs would be attenuated by the reservoir storage. The geomorphic impact of this hydrological change could be reduced frequency of mobilisation of coarse bed material within the creek channel, as well as reduced flow depth, and thus reduced area of hydraulic habitat. In addition, the lower dam would act as a barrier to the natural transfer of coarse bed material from the catchment to this reach. It is planned to offset losses due to evaporation from the open water surfaces of the reservoirs through periodic top-up by pumping water from the Macleay River. The water balance results indicate overflows from the lower dam will occur in only 45% of years, typically during higher than average rainfall years (EMM, 2022a). This is primarily a result of the assumption that the reservoirs will be allowed to draw down to approximately 100 ML below full supply before top-up occurs. Drawdown results from interception of rainfall and runoff from the local catchment not fully offsetting the substantial evaporation and leakage losses. Thus, the 400 m long section of Fingerboard Crossing Creek downstream of the lower dam to the Macleay River junction will probably dry out or be at very low flow in most years, only receiving runoff from the catchment downstream of the dam, which is very small, combined with minor baseflow emanating from seepage within the reservoir (EMM, 2022a).

The bed of the 400 m reach of Fingerboard Crossing Creek from the lower dam wall to the Macleay River junction was dominated by cobble-sized material (Figure 15). The mean slope of this reach was 3.6°. The lower 223 m of this reach lies within the inundation extent of the 1%AEP flood event on the Macleay River (SMEC, 2022), and a shorter length of approximately 136 m would be inundated by frequent events on the Macleay River that maintain the prominent gravel bars of the river. These frequent Macleay River events would supply gravel and cobble material to the bed of the lower 136 m of Fingerboard Crossing Creek independently of the transport of bedload sourced from the creek catchment. However, the 264 m long reach of Fingerboard Crossing Creek downstream of the lower dam wall will be at risk of scour of sand, gravel and cobble-sized material from the bed, leading to coarsening of the bed material calibre, and a degree of incision. Unlike upstream of the lower dam, where the creek flows through granodiorite lithology, this lower section of creek flows through conglomerate (Figure 10). Scour of the unconsolidated bed material could shift the character of the bed to conglomerate bedrock, but the hard rock should constrain the degree of bed incision.

4.7 Impacts to the Macleay River

4.7.1 Dam-filling phase

The dam-filling phase of the Project will involve reduction of storm event magnitudes in the Macleay River by up to 86.4 ML/d for flows exceeding 597 ML/d. The geomorphic impact of this hydrological change could be reduced frequency of mobilisation of coarse bed material as well as reduced flow depth and thus reduced area of hydraulic habitat.

At the Macleay River at Downstream of Georges River Junction gauge, the available rating curve data suggests that extraction of water during the dam filling phase would cause a maximum reduction in depth of 0.05 m, which represents a 5% change in depth from a streamflow rate of 683.4 ML/day (0.95 m depth) to a streamflow rate of 597 ML/day (0.90 m depth) (EMM, 2022a). Most of the time that water was extracted the river would be at higher discharges, so the percentage change would be smaller than 5%. The reduction in water depth due to extraction of water would be associated with a similar, relatively small, reduction in bed shear stress. This implies a reduction in the likelihood, spatial extent, or particle size range of bed sediment mobilisation at times of water extraction from the river. The overall impact of water extraction on sediment transport processes in the Macleay River would be to create conditions that emulated a slightly drier period with lower flood peaks. This would have a minor short-term impact, and a negligible long-term impact, on sediment transport processes.

4.7.2 Operational phase

The Surface Water Assessment noted that Fingerboard Crossing Creek catchment makes up 0.03% of the overall Macleay River catchment, and it was anticipated to contribute a proportionate volume of streamflow (EMM, 2022a). The creek is also likely to contribute a slightly higher than proportional load of coarse sediment and slightly lower than proportional load of suspended sediment (due to variation in topographic and land use characteristics that control sediment delivery over the Macleay River catchment).

Due to the substantial difference in catchment size between Fingerboard Crossing Creek and the Macleay River, impacts (whether reduced or increased flow combined with reduced coarse and suspended sediment load) to the Macleay River as a result of impounding Fingerboard Crossing Creek are considered negligible at the catchment scale and minor at the local scale of the vicinity of the junction of Fingerboard Crossing Creek with the Macleay River.

The 15 August 2021 aerial imagery (taken at somewhat elevated flow), November 2020 CNES/Airbus imagery available on Google Earth (taken at low river flow), and 3 February – 19 March 2020 LiDAR data (taken at somewhat elevated flow), all show the presence of a small (300 m^2) alluvial fan emerging from the mouth of Fingerboard Crossing Creek and protruding around 18 m into the bed of the Macleay River. This is a minor local feature compared with the scale of the massive gravel/cobble bars on the Macleay River. The sediment fan is not a permanent feature of the river, as it is not visible on the 1 December 2013 Maxar Technologies imagery available on Google Earth (taken at very low river flow), 11 November 2010 Maxar Technologies imagery

available on Google Earth (possibly obscured by elevated river flow), 1 September 2010 Six Maps aerial imagery from NSW imagery (possibly obscured by elevated river flow), and 30 January 2003 Maxar Technologies imagery available on Google Earth (taken at very low river flow).

The alluvial fan visible on the 2020 – 2021 imagery is likely deposited at times of storm flow events in Fingerboard Crossing Creek but hydraulic conditions in the Macleay River insufficient to mobilise the coarse sediment. The fan would persist until such time that a flood event occurred in the Macleay River that had sufficiently high bed shear stress to mobilise the sediment in the fan and incorporate it into the Macleay River bedload. With the Project operational, the fan will cease to form.

5 Mitigation and Monitoring

5.1 Mitigation

Physical loss of two reaches of channel of Fingerboard Crossing Creek, as well as minor tributaries, within the dam wall and reservoir inundation footprints of the upper and lower dams cannot be mitigated.

Reduced delivery of bedload to Fingerboard Crossing Creek downstream of the dams and to the Macleay River cannot be mitigated.

Deposition of fine and coarse sediment within the reservoirs, delivered to the reservoirs from the catchment at natural rates, cannot be mitigated.

With the Project operational, creek flows will be lower in magnitude than natural, but will retain sufficient depth and bed shear stress to mobilise bed material. The creek will likely adjust by scouring of bed material, and incision. These impacts cannot be mitigated.

Scour of soils within the reservoir due to repeated cycles of drawdown and refilling, and subsequent deposition of the coarse fraction within the reservoir and suspension of the fine fraction within the water column, is inevitable. Mitigation of this would be impractical, so it is recommended to allow areas covered with soil to erode to hard rock, after which time this impact will cease.

Mitigation of the potential geomorphic impacts of the Project would be impractical. The recommended alternative is to allow geomorphic adjustments to the altered flow and sediment regimes to proceed. The watercourses are formed in bedrock, the resistance of which limits the extent of geomorphic adjustment that can take place. Bushfires can cause temporary acceleration of sediment release from catchments, and this risk should be minimised using an appropriate management plan.

5.2 Monitoring

It is not practical to directly measure coarse bed material transport. Accelerated scour of coarse bed material from the channel of Fingerboard Crossing Creek could be monitored by repeated LiDAR surveys but this would not serve a critical purpose, as mitigation of this process would not be practical. Water quality monitoring is proposed for the Project dams and reservoirs during operations to monitor and respond to unforeseen water quality risks (EMM, 2022a). This monitoring will include suspended sediment. Data from downstream of the lower dam, if measured with adequate frequency to capture data from reservoir spills, will monitor residual suspended sediment not deposited within the Project reservoirs, and released to the Macleay River.

Monitoring of dam sedimentation will effectively monitor the capture by the Project of fine and coarse sediment released within the catchment. The rate of sedimentation is expected to be low, so a sounding survey every 10 years will be adequate.

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7 Appendix 1. Evaluation of available LiDAR data

7.1 Available LiDAR data

Two sets of Light Detection and Ranging (LiDAR) derived elevation data were available for the Project area. The Project area was flown between 3 February and 19 March 2020, with the data provided by OMPS in the form of a 1 m grid classified as ground strike. The second set of LiDAR derived elevation data were the Carrai 2 km × 2 km 2-metre Resolution Digital Elevation Model, flown 14 – 21 May 2018. The gridded data tiles were downloaded from NSW Spatial Services, Department of Finance, Services and Innovation, ELVIS - Elevation and Depth - Foundation Spatial Data. The data used to create this DEM had a stated accuracy of 0.3 m (95% Confidence Interval) in the vertical and 0.8 m (95% Confidence Interval) in the horizontal.

Comparison of the 2020 and 2018 LiDAR-derived DEMs revealed significant differences in elevation between the two data sets. The 2018 elevation data were up to 28 m lower and up to 56 m higher than the 2020 data, with the differences following a systematic pattern across the area surveyed in 2020 (Figure 25). No independent ground-surveyed elevation data were available to determine which of the two DEMs was the more accurate.

7.2 Factors that impact accuracy of LiDAR-derived DEMs

Accuracy of LiDAR-derived DEMs is known to vary across terrain and land cover types. Deems et al. (2013) noted that the potentially substantial errors induced due to scanner/terrain geometry combinations are not commonly assessed or quantified and therefore are usually not included in error estimates. Peng and Shih (2006) found that the accuracy of elevation was correlated with five factors: terrain slope, vegetation angle, vegetation canopy cover, local roughness of point clouds, and point spacing of laser pulse ground strikes. High vegetation angle and low point spacing produced higher error. Low vegetation angle of canopy indicates good openness to the sky. For similar tree heights, higher vegetation angles indicate a dense canopy. Similarly, for similar canopy densities, higher elevation angles indicate taller canopies returns. Peng and Shih (2006) also found that aspect had a significant effect on error when single flight lines were used, but this was eliminated when cross-flight data were available.

Goulden et al (2016) found elevation uncertainty and slope uncertainty in LiDAR data were correlated with the incidence angle between the laser pulse and the terrain. Over inclined terrain, vertical error can be induced by horizontal errors and also by laser spot spread (Deems et al., 2013). The number of successful ground hits, and therefore the final surveyed point density, decreases inversely with vegetation canopy cover density (Deems et al., 2013). Terrain geometry, such as slope magnitude and aspect relative to the flight-line, interacts with the laser scan angle to affect the laser angle of incidence at a given ground surface location (Deems et al., 2013). Scan locations that produce predominately downslope (high incidence angle) laser geometries will have greater errors than those that achieve incidence angles closer to slope normal. A study by Aryal eta l. (2013) confirmed that LiDAR-derived DEM accuracy was related to laser pulse density, slope, aspect, and tree type.

7.3 Investigation of source of error in Oven Mountain DEMs

The possible sources of error in the LiDAR-derived DEMs was explored by examining terrain elevation (Figure 26), terrain slope (Figure 27) and terrain aspect (Figure 28). In addition, other factors examined were land cover (Figure 29), tree canopy cover in year 2000 (Figure 30), tree canopy cover loss due to fire from 2001 to 202**1** (Figure 31), with changes between the dates of the 2018 and 2020 LiDAR flights being of particular interest, Forest extent change from 2000 to 2020 (Figure 32), and burn severity of 2019/20 bushfire (Figure 33).

It was apparent that the areas where the 2020 DEM was higher than the 2018 DEM (red shading in Figure 25), corresponded well with the shadowed areas (south-facing slopes) of the hillshaded topography (Figure 26), and this was confirmed by the spatial distribution of aspect (Figure 28). The spatial distribution of terrain slope (Figure 27) was not systematically related to the spatial distribution of differences in elevation of the two

DEMs. Land cover was variable (Figure 29), and visually appeared to be unrelated to the spatial distribution of differences in elevation of the two DEMs. Tree canopy cover in year 2000 (Figure 30), which quantified the distribution of land cover, was not strongly related to the spatial distribution of differences in elevation of the two DEMs. Tree canopy cover loss due to fire (Figure 31) indicated small areas of loss from 2001 to 2018, and a large area of loss due to the major bushfire in 2019. The FESM mapping of burn intensity indicated an even greater area of forest burned (Figure 33). The 2019 bushfire occurred between the two LiDAR flights. This was investigated as a possible cause of the difference in the LiDAR elevations. However, bushfire appeared unlikely to be the cause of the DEM elevation difference due to the pattern of tree canopy cover loss being unrelated to the spatial distribution of differences in elevation of the two DEMs. Also, the map of Forest extent change from 2000 to 2020 suggested that by 2020 most of the Project area remained classified as forest, apart from some areas within the northern extent of the Project area (Figure 32). These areas that were classified as areas of forest lost in 2020 compared to 2000 were coincident with those areas classified as suffering extreme burn severity in the 2019/20 bushfire (Figure 33).

The difference in elevation of the two DEMs was investigated at the scale of individual grid cells, resampled at 20 m resolution, by correlating elevation difference against the attributes aspect, slope and tree canopy cover (Figure 34). At 20 m grid resolution, the surveyed area comprised 444,728 grid cells, with each cell represented by a central point assigned the mean value for the cell. The scattergrams revealed that the difference in elevation between the two DEMs tended to increase with increasing slope and tree canopy cover, but the variability was equally distributed between positive and negative differences. On the other hand, the difference in elevation between the two DEMs was systematically related to aspect, with positive differences associated with southern to western aspect (Figure 34).

The relationship between aspect and other potential explanatory attributes was explored by grouping the 20 m resolution grid data by the eight aspect classes centred on the cardinal and intercardinal directions, then within these classes calculating mean difference in elevation between the 2020 and 2018 DEMs, mean slope, mean tree canopy cover in year 2000 and area of forest burned at high or extreme severity or lost in 2019/20 bushfire, estimated by FESM and GLAD data (Figure 35). This descriptive statistical procedure removed scatter, which highlighted the relationships between the central tendency of aspect and the other selected spatially distributed attributes. S and SW aspect was strongly associated with positive mean difference in elevation of the two DEMs, while N and NE aspect was strongly associated with negative mean difference in elevation of the two DEMs (Figure 35). Mean slope also systematically varied with aspect, with S and SW facing slopes being marginally steeper than N and NW facing slopes (Figure 35). Mean tree canopy cover in year 2000 was highest on moister SW and W facing slopes and lowest on drier N, NE and E facing slopes. Tree area burned at high or extreme severity or lost in 2019 was lowest on S and SW facing slopes for both FESM and GLAD data, but otherwise was not systematically related to aspect (Figure 35). The distribution of forest burned or lost by slope was virtually the same as the distribution of aspect over the entire area, which means that the bushfire burned slopes of different aspect equally.

7.4 Likely source of error in Oven Mountain DEMs

Whilst the differences in elevation between the 2020 and 2018 DEMs could be extreme for individual grid cells, the mean differences by aspect class were within ±0.65 m, and there was an approximately equal distribution of positive and negative differences over the surveyed area (Figure 25 and Figure 35). The differences in elevation between the 2020 and 2018 DEMs were most clearly correlated with aspect. Aspect displayed mild association with slope and tree canopy cover. The 2019 bushfires burned over a wide area that was not strongly associated with aspect, so it appears that the resultant sudden change in tree canopy cover does not provide a simple explanation for the differences in elevation between the 2020 and 2018 DEMs. The strength of the association between differences in elevation and aspect suggests that the differences in elevation most likely related to laser shot geometries as determined by scan angle and steep terrain interactions. Differences in density of laser pulse ground strikes could also have been relevant. Details of these aspects of the LiDAR surveys were not available, so it was not possible to evaluate which of the 2018 or 2020 surveys was the most accurate.

7.5 Preferred DEM

For this geomorphic analysis, the 2020 DEM was preferred over the 2018 DEM on the grounds that the 2020 LiDAR data were acquired more recently than the 2018 data, and the 2020 DEM was provided at a finer resolution than the 2018 DEM (1 m versus 2 m), suggesting that the 2020 LiDAR survey achieved a higher density of laser pulse ground strikes.

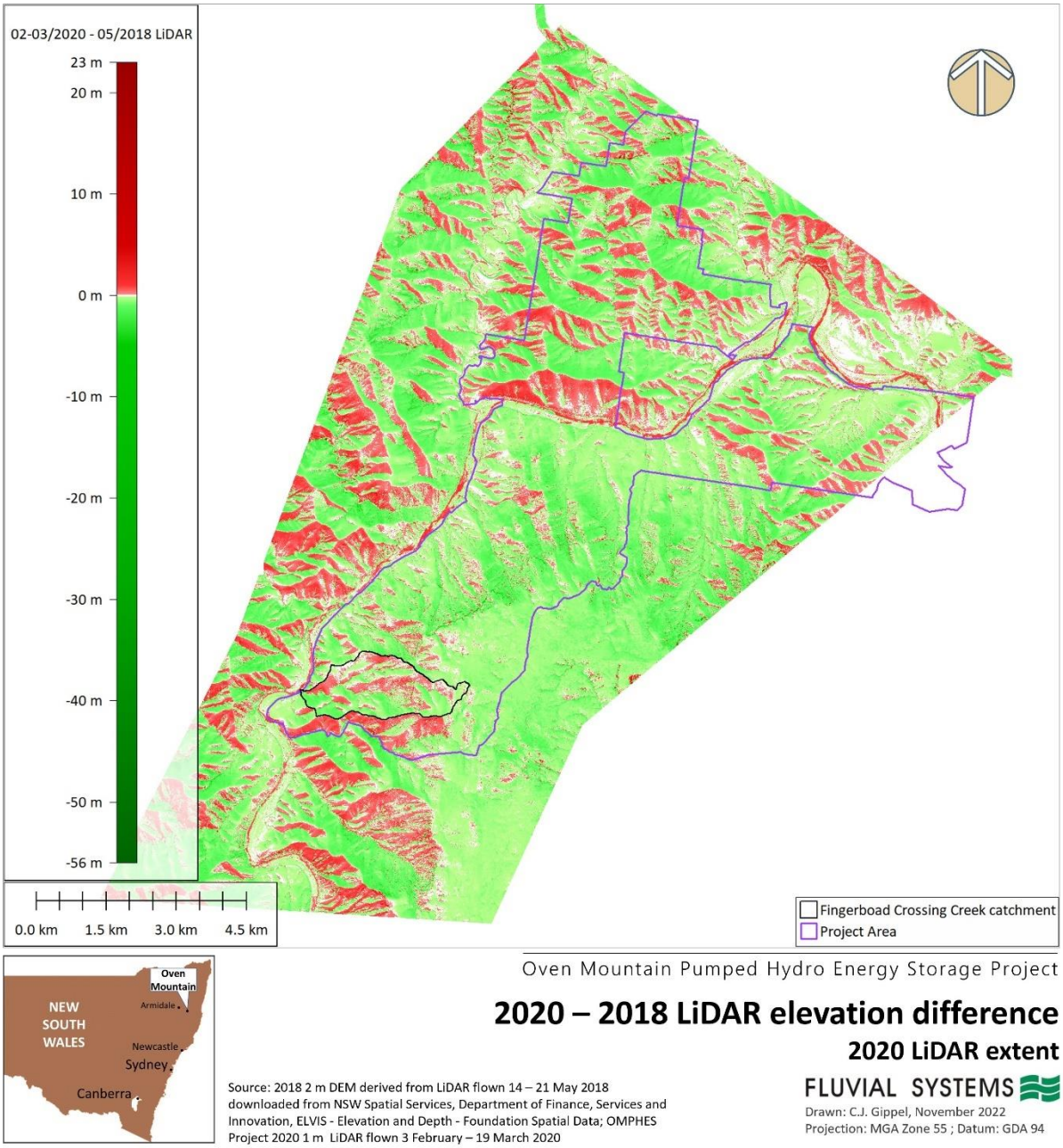

Figure 25. Elevation difference between 2020 and 2018 LiDAR. Positive values are 2020 elevations higher than 2018 elevations. Mapped at 2 m grid, corresponding to the 2018 data resolution. White shading covers small elevation differences ±0.1 m.

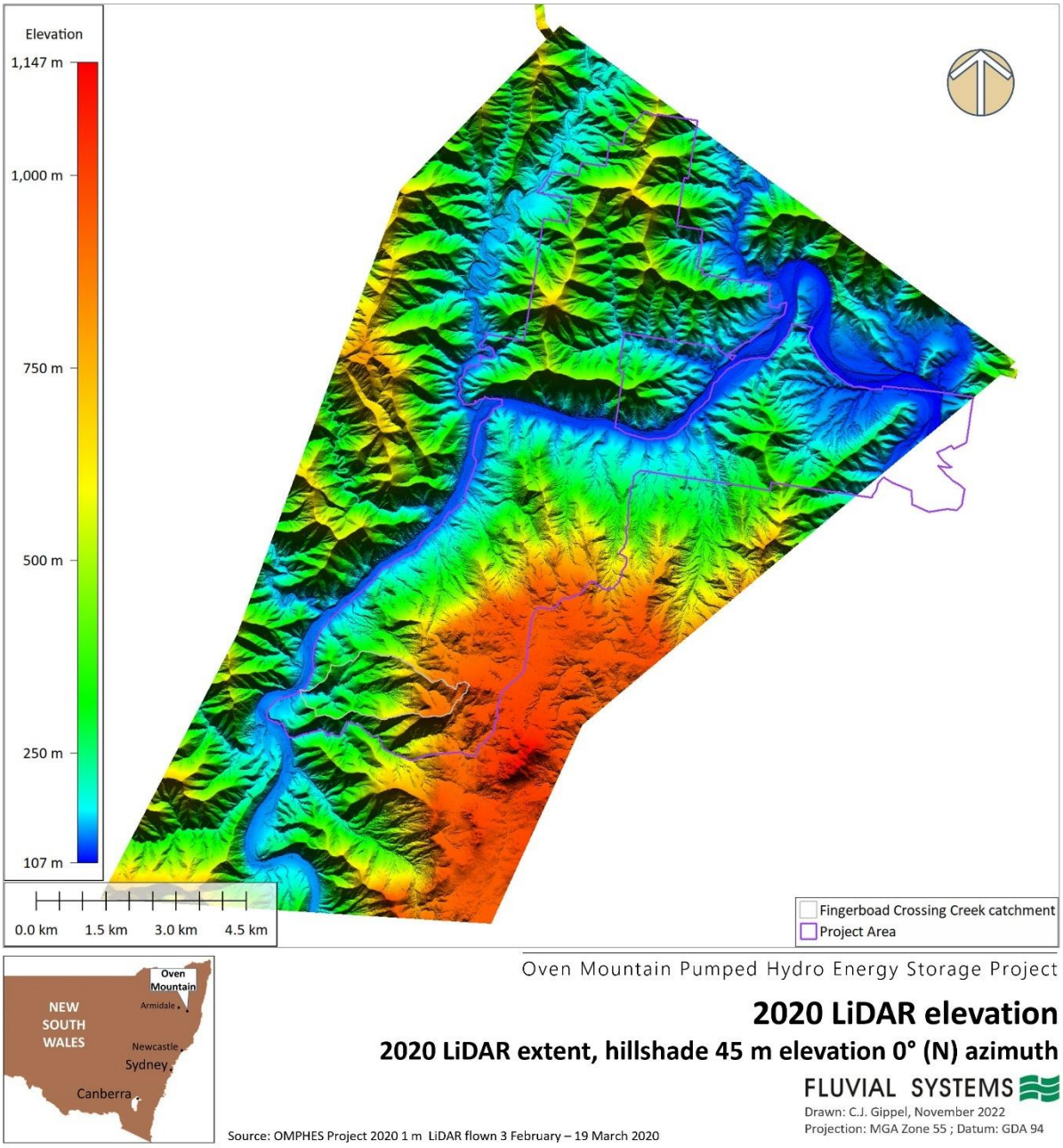

Figure 26. Elevation of 2020 LiDAR-derived DEM, rendered with hillshading cast by light sourced from 45 m elevation and 0° (N) azimuth.

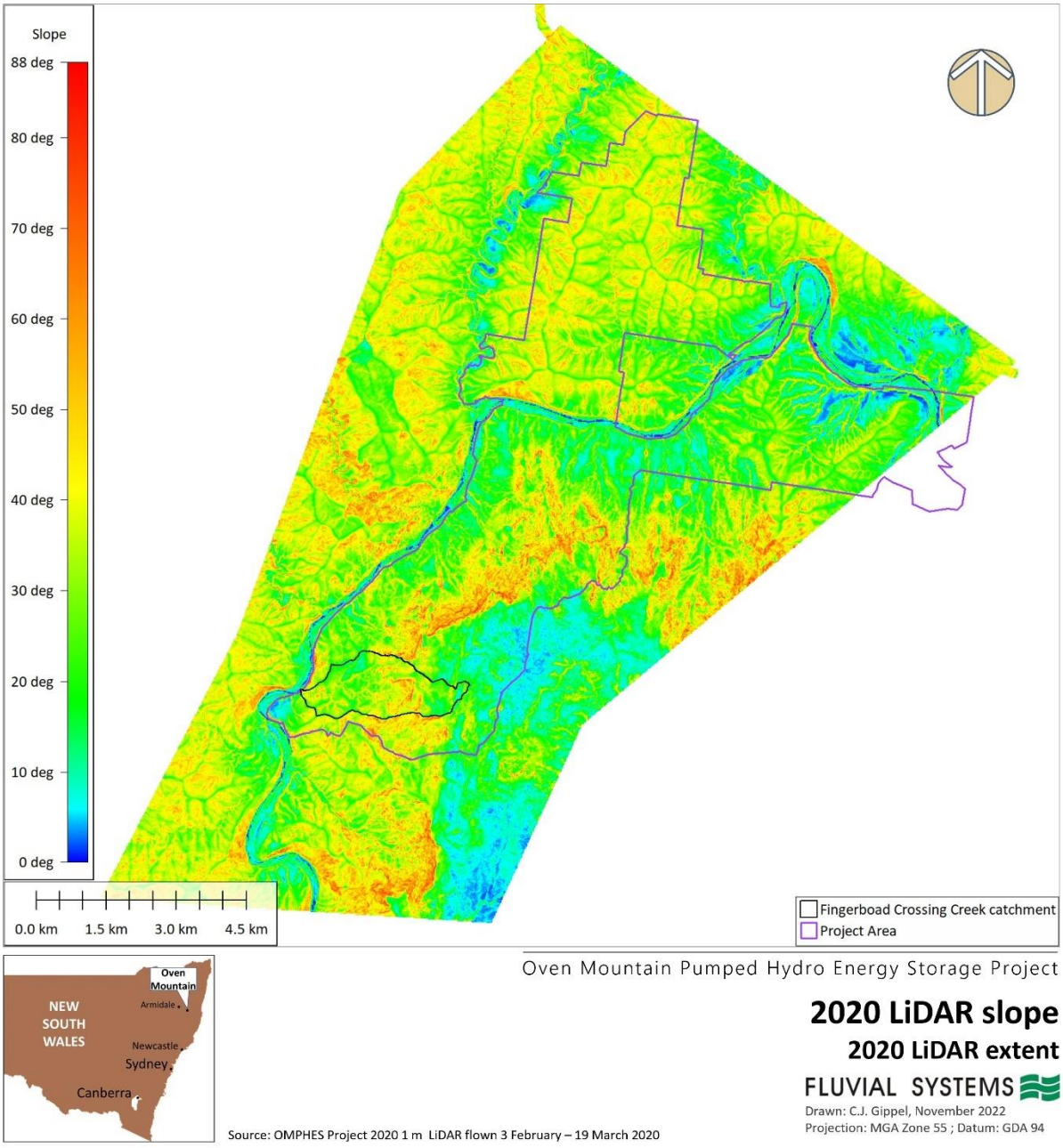

Figure 27. Slope of 2020 LiDAR-derived DEM.

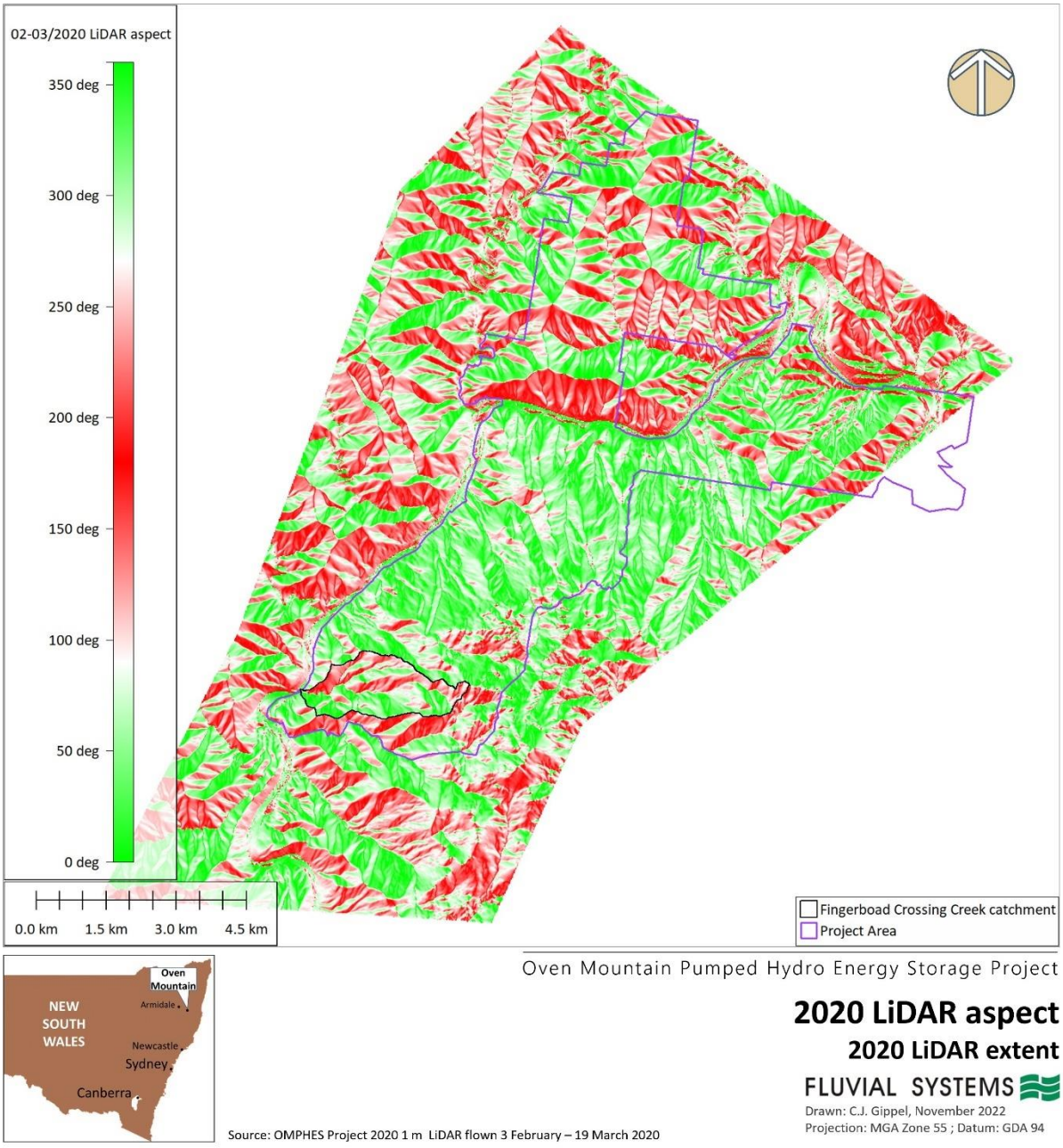

Figure 28. Aspect of 2020 LiDAR-derived DEM.

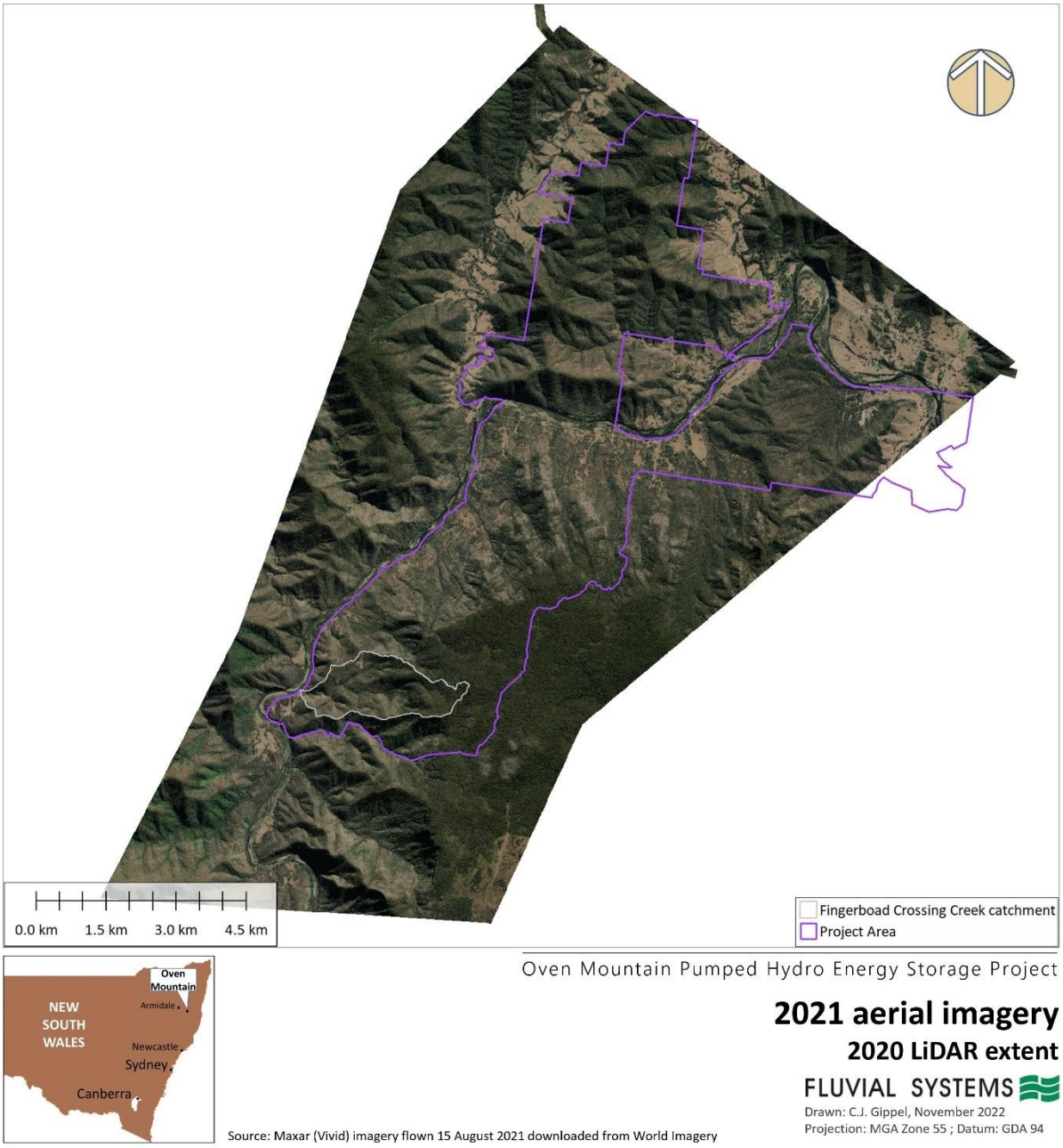

Figure 29. Land cover at August 2021.

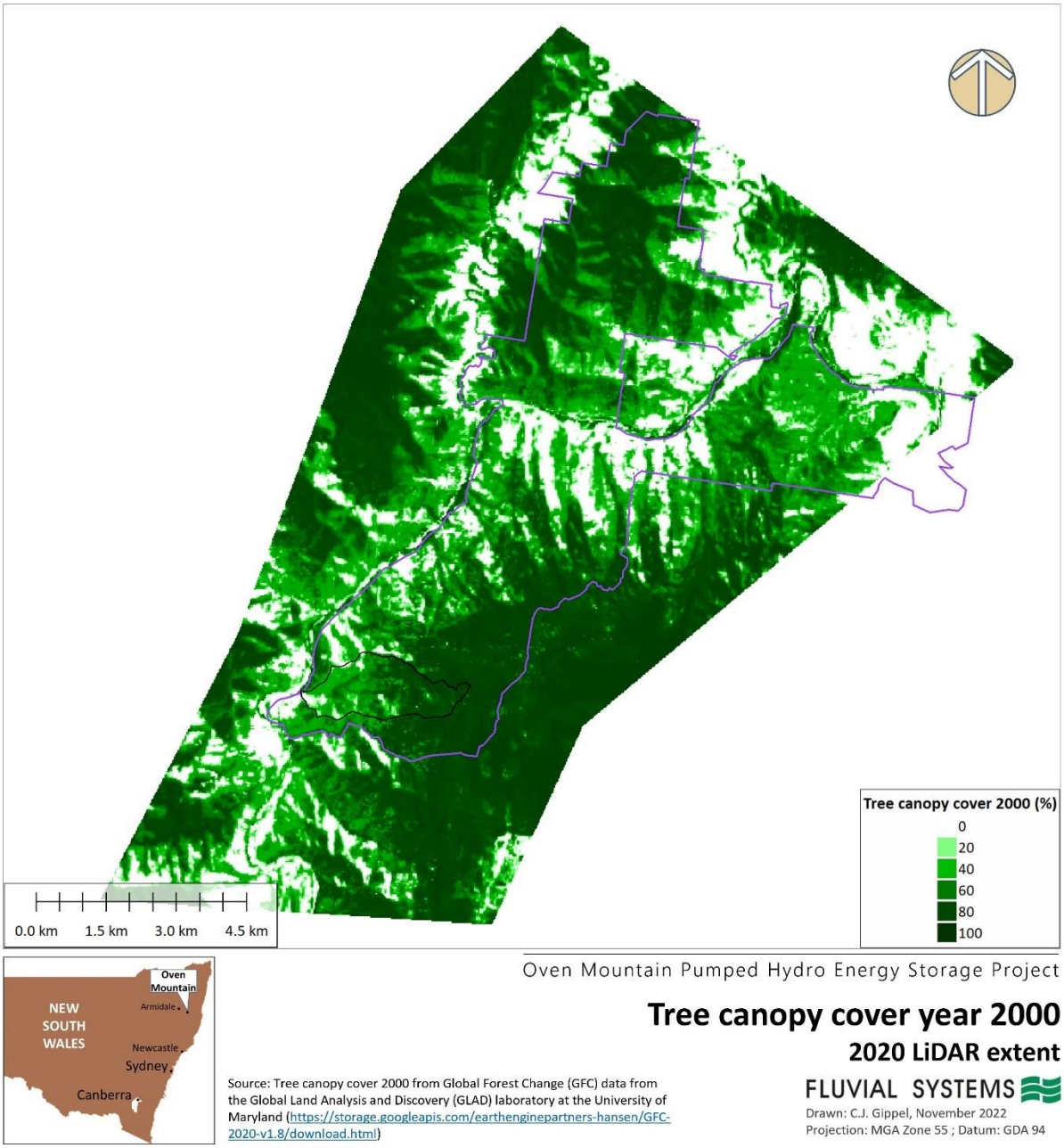

Figure 30. Tree canopy cover at year 2000.

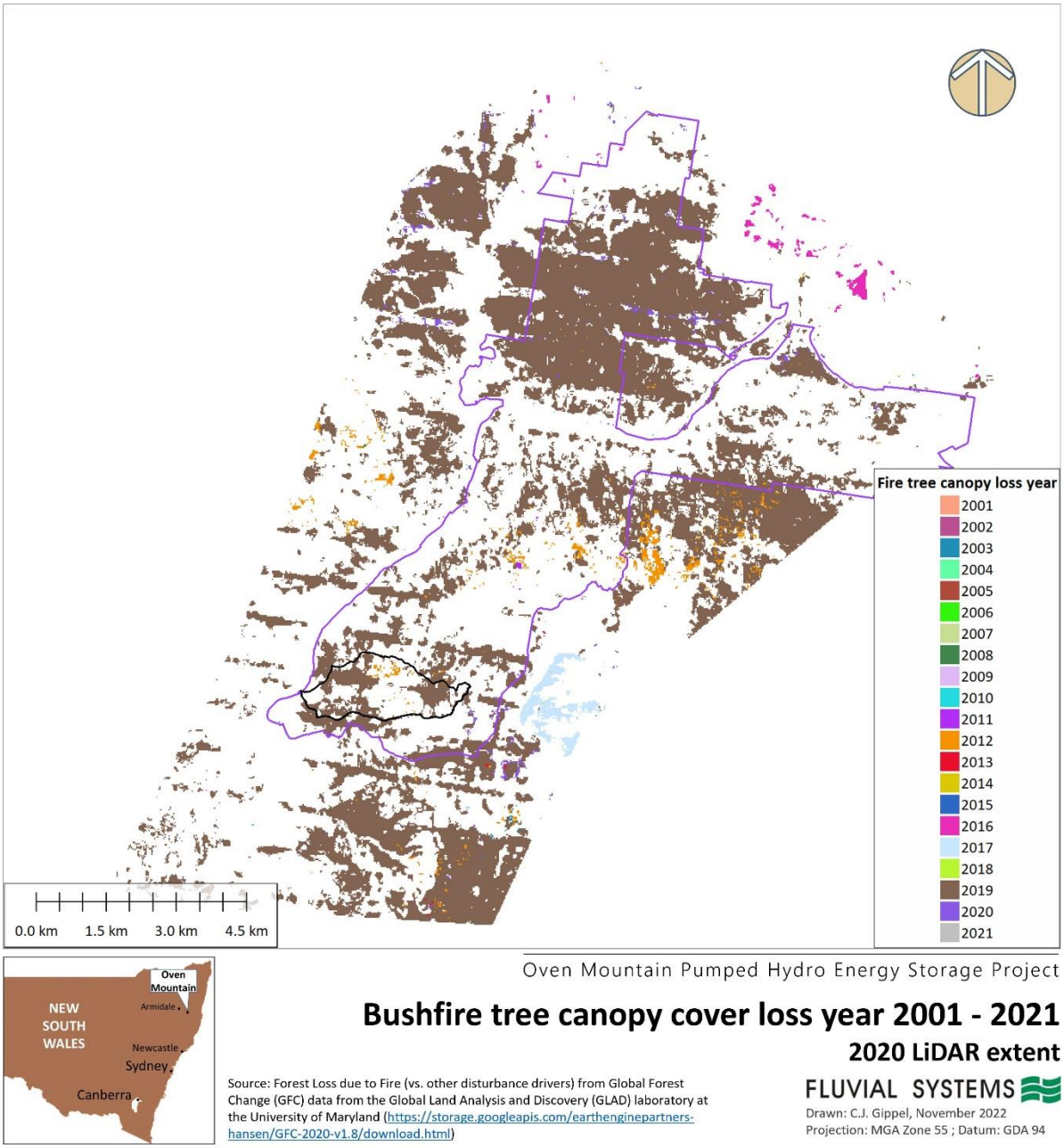

Figure 31. Tree canopy cover loss year due to fire from 2001 to 2021. The 2019 data appear to contain banding that is not related to loss of tree canopy cover and may be an artefact of the Landsat image collection or processing.

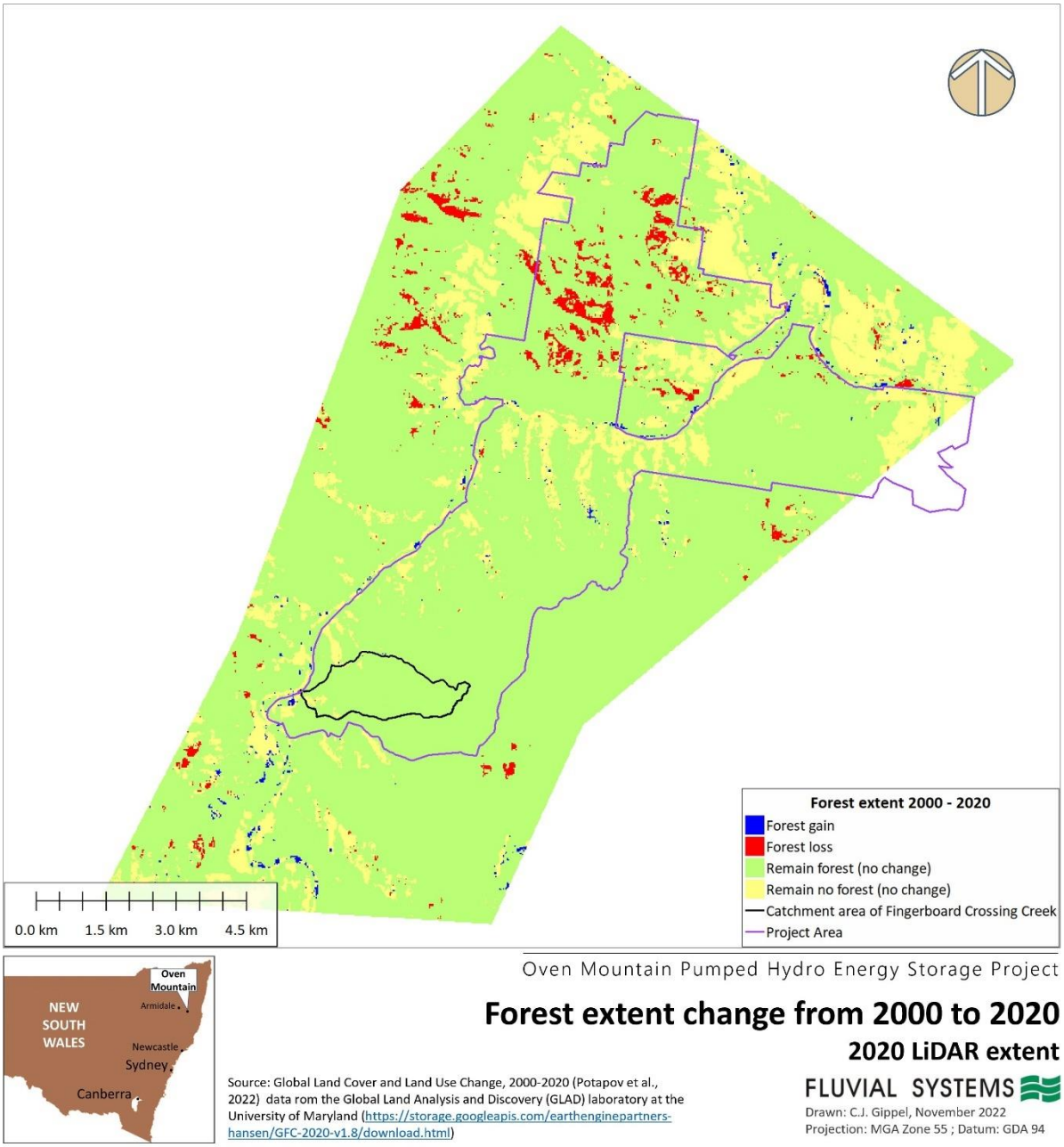

Figure 32. Forest extent change from 2000 to 2020.

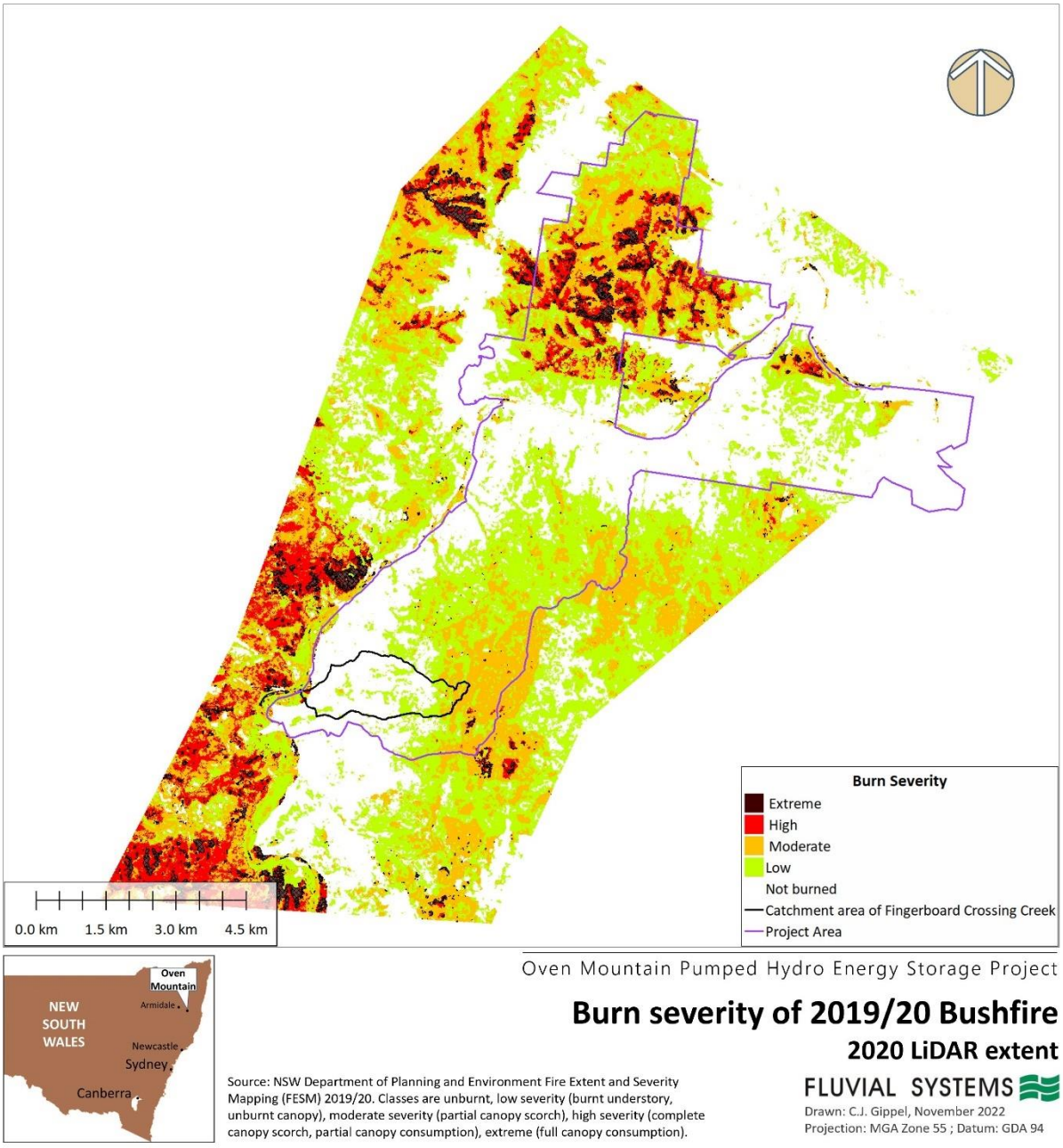

Figure 33. Burn severity of 2019/20 bushfire.

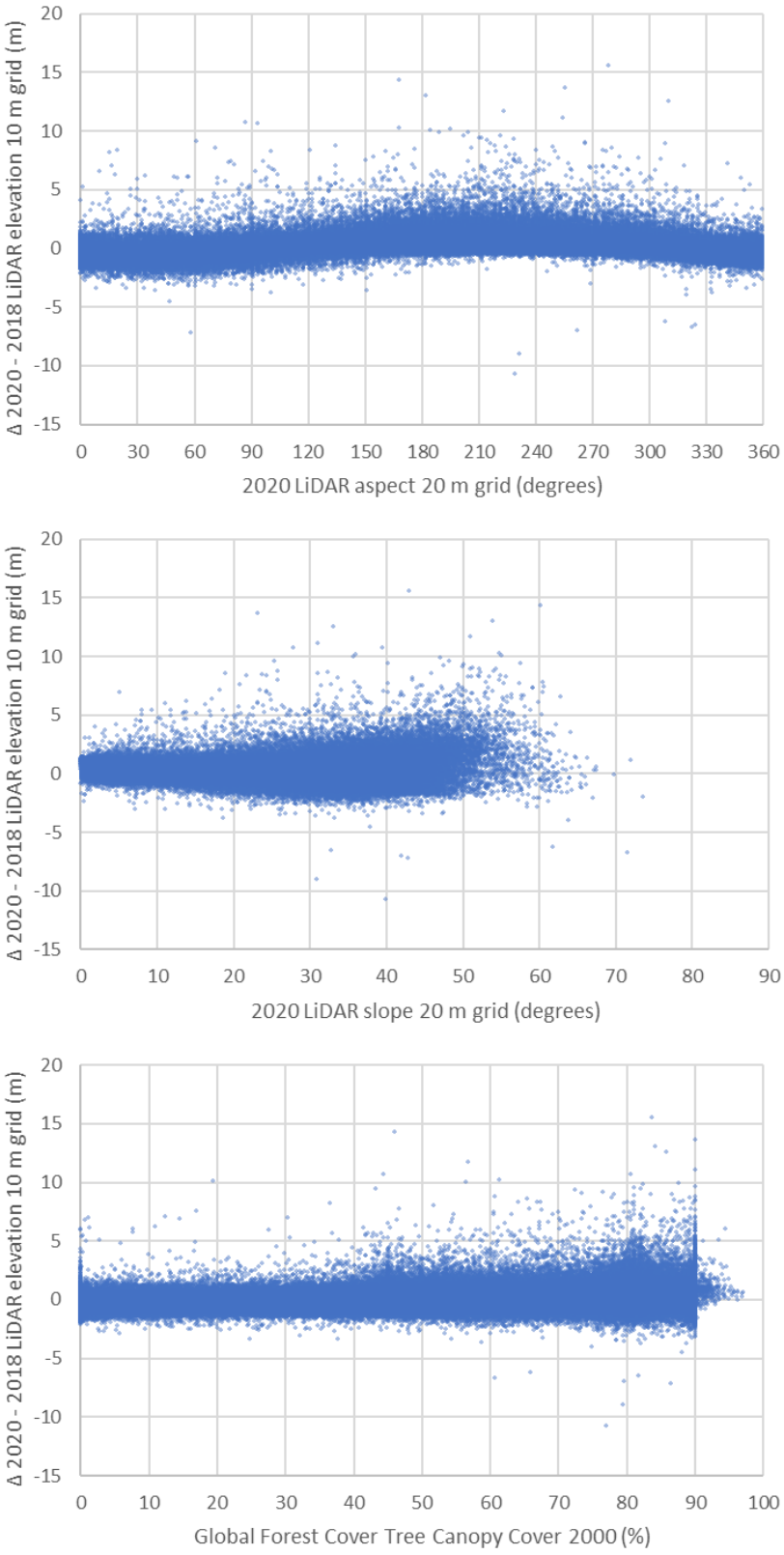

Figure 34. Difference in elevation of the two DEMs across individual grids, plotted against aspect (top), slope (middle) and tree canopy cover in year 2000 (bottom).

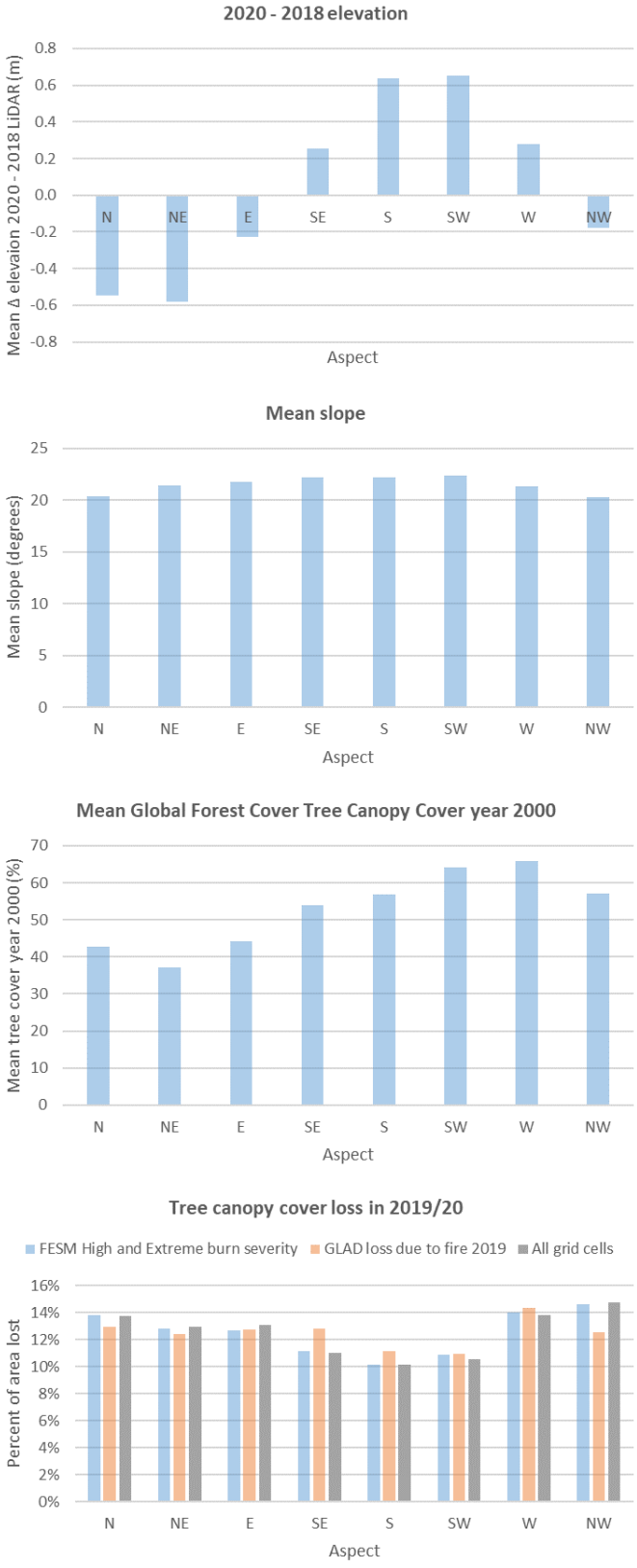

Figure 35. Mean difference in elevation of the two DEMs, mean slope, mean tree canopy cover in year 2000 and area of forest burned in 2019/20 bushfire, plotted against aspect, classified by the major and minor cardinal sectors. The lower plot includes the distribution of aspect over the entire evaluated area.

8 Appendix 2. Selected photographs from field sites

Selected photographs were provided to illustrate the physical character of the range of watercourses observed in the field, with location identified by numbered waypoints (Figure 3) (Figure 36, Figure 37, Figure 38, Figure 39, Figure 40, Figure 41 and Figure 42).

Figure 36. Field sites WP 1, WP 2 and WP 3.

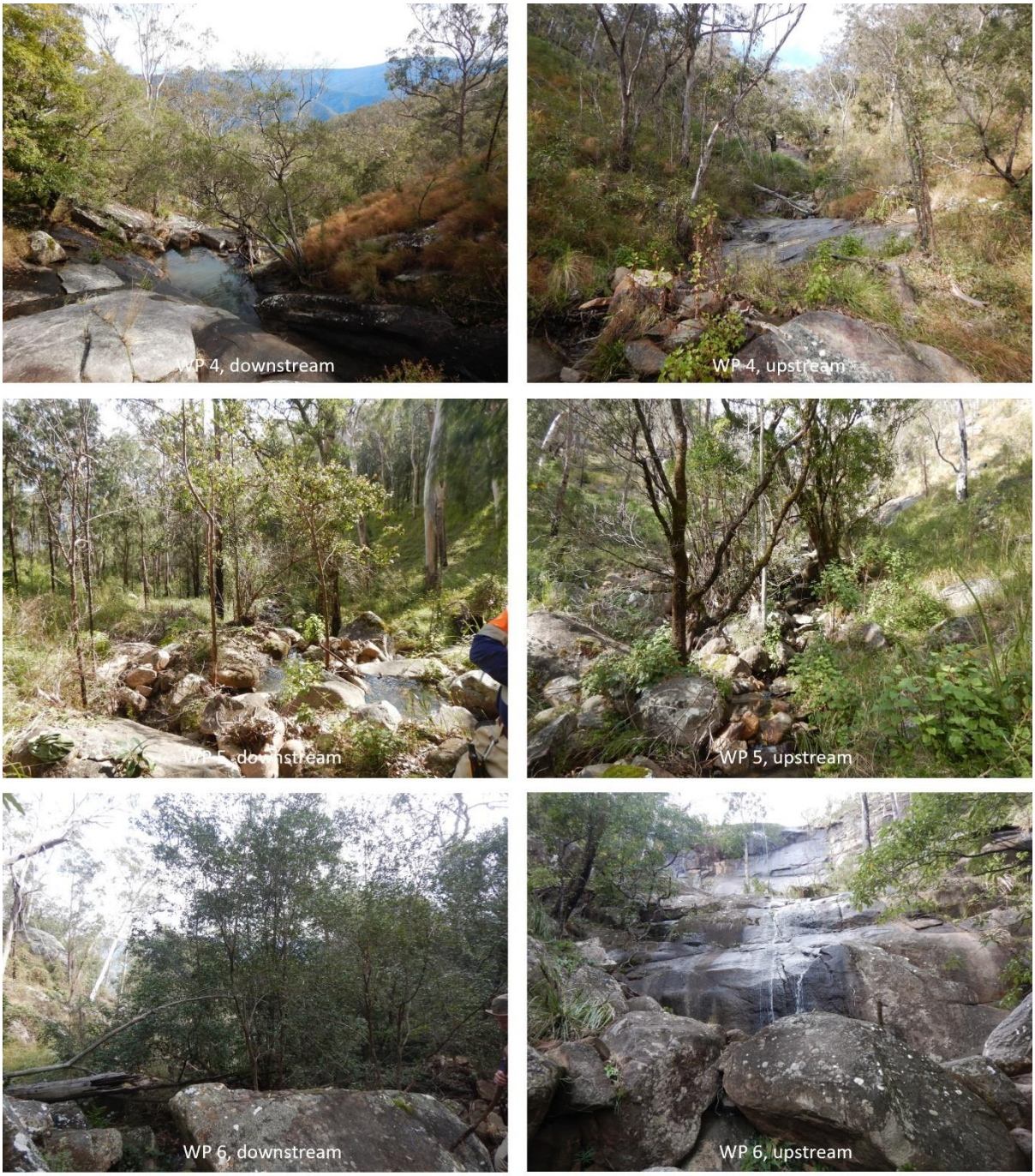

Figure 37. Field sites WP 4, WP 5 and WP 6.

Figure 38. Field sites WP 8, WP 9 and WP 10.

Figure 39. Field sites WP 11, WP 12 and WP 13.

Figure 40. Field sites WP 20, WP 21 and WP 22.

Figure 41. Field sites WP 23, WP 24 and WP 25.

Figure 42. Field sites WP 26 and WP 27.

Attachment C

Surface water monitoring program

EMM
creating opportunities

C.1 Overview

A baseline monitoring program for the Project commenced in August 2021 and is ongoing. The data collection program includes surface water and groundwater monitoring as well as several field surveys. Surface water data collected up to the beginning of August 2022 (ie 12 months of data) is documented in this report. Groundwater data that was collected as part of the baseline monitoring program is described in the groundwater impact assessment (EMM, 2022a) in Appendix M of the EIS.

C.2 Monitoring locations

Surface water quality data was collected from the Macleay River, Fingerboard Crossing Creek, and several minor watercourses within the Project area. Surface water monitoring locations are described in Table C.1 and shown alongside the groundwater monitoring network in Figure 4.15.

Table C.1 Surface water quality baseline monitoring locations

Watercourse	Location ID	Description	Number of samples
Fingerboard Crossing Creek	SW2101	Unnamed tributary in proximity to lower reservoir location.	2 samples collected
	SW2102	Unnamed tributary in proximity to lower reservoir location.	3 samples collected
	SW2106	Unnamed tributary near proposed switchyard.	5 samples collected
	SW2107	Unnamed tributary near proposed switchyard.	5 samples collected
	SW2109	Headwater reach in proximity to upper reservoir footprint.	5 samples collected
	SW2110	Headwater reach in proximity to upper reservoir footprint.	4 samples collected
	SWG2101	Fingerboard Crossing Creek at lower reservoir dam wall location.	4 samples collected
Macleay River	SW2104	Macleay River adjacent to concrete batching plant pad.	3 samples collected
	SW2105	Macleay River approximately 800 m downstream of Fingerboard Crossing Creek.	1 sample collected
	SW2112	Macleay River at Fingerboard Crossing Creek confluence.	4 samples collected
	SW2202	Macleay River at confluence with Georges Creek.	3 samples collected
	SW2206	Macleay River approximately 500 mm upstream of Fingerboard Crossing Creek confluence.	2 samples collected
	SW2207	Macleay River at Peach Tree Creek confluence.	1 sample collected
Minor watercourses	SW2103	Unnamed watercourse adjacent to mechanical workshop pad.	6 samples collected
	SW2108	Headwaters of unnamed watercourse in proximity to identified fen.	5 samples collected
	SW2111	Headwaters of unnamed watercourse in proximity to identified fen.	5 samples collected
	SW2201	Headwaters of Peach Tree Creek.	5 samples collected
	SW2204	Unnamed drainage line that discharges to Macleay River upstream of Fingerboard Crossing Creek.	3 samples collected

C.3 Monitoring frequency

Generally, monitoring was undertaken at a monthly frequency, predominantly during dry conditions. The monitoring timeline at each location is shown in Table C.2.

Table C.2 Surface water monitoring frequency

		Sample taken (denoted by blue dot)											
		Aug 2021	Sep 2021	Oct 2021	Nov 2021	Dec 2021	Jan 2022	Feb 2022	Mar 2022	Apr 2022	May 2022	Jun 2022	Jul 2022
Fingerboard Crossing Creek	SW2101	●											●
	SW2102	●										●	●
	SW2106	●								●	●	●	●
	SW2107	●								●	●	●	●
	SW2109	●								●	●	●	●
	SW2110	●								●	●		●
	SWG2101					●		●		●			●
Macleay River	SW2104	●										●	●
	SW2105	●											
	SW2112					●		●		●			●
	SW2202							●		●			●
	SW2206											●	●
	SW2207											●	
Minor watercourses	SW2103	●				●		●		●		●	●
	SW2108	●								●	●	●	●
	SW2111	●								●	●	●	●
	SW2201							●		●	●	●	●
	SW2204										●	●	●

C.4 Summary of monitoring results

A summary of the surface water quality monitoring results is provided in Table C.3.

Table C.3 Water quality summary

					Minor watercourses				Fingerboard Crossing Creek				Macleay River			
Group	**Parameter**	**Units**	**EQL[1]**	**WQO[2]**	**#exceedances /#samples**	**Min.**	**Median**	**Max.**	**#exceedances/ #samples**	**Min.**	**Median**	**Max.**	**#exceedances/ #samples**	**Min.**	**Median**	**Max.**
Physico-chemical	Temperature (field)	°C		-	-/23	6.1	12.8	22.1	-/28	9.7	13.7	25.2	-/13	10.3	13.7	24.8
	pH (field)	-		6.5–8.5	15/24	**5.0**	**6.3**	9.4	6/28	**5.9**	6.9	7.7	0/13	6.7	7.5	8.0
	Electrical conductivity	uS/cm		300	0/24	39	51	245	4/27	50	105	1610	0/14	73	149	192
	Dissolved oxygen (field)	%		85–110	11/19	**41**	**80**	103	16/23	**37**	**75**	109	5/10	**72**	85	103
	Total suspended solids	mg/L	5	-	-/24	5	7	2,160	-/27	5	5	190	-/14	5	6	24
	Total dissolved solids	mg/L	1	-	-/24	25	33	159	-/27	32	68	1,050	-/14	47	97	125
	Turbidity	NTU	0.1	5	15/24	1	**7**	**362**	13/27	0	5	**158**	6/14	2	4	**9**
Alkalinity and hardness	Alkalinity (bicarbonate as $CaCO_3$)	mg/L	1	-	-/24	BDL	15	79	-/27	8	34	191	-/14	22	55	70
	Alkalinity (carbonate as $CaCO_3$)	mg/L	1	-	-/24	BDL	BDL	BDL	-/27	BDL	BDL	BDL	-/14	BDL	BDL	BDL
	Alkalinity (hydroxide) as $CaCO_3$	mg/L	1	-	-/24	BDL	BDL	BDL	-/27	BDL	BDL	BDL	-/14	BDL	BDL	BDL
	Alkalinity (total) as $CaCO_3$	mg/L	1	-	-/24	BDL	15	79	-/27	8	34	191	-/14	22	55	70
	Hardness as $CaCO_3$	mg/L	1	-	-/24	1	2	49	-/27	2	25	627	-/14	18	57	65
Nutrients	Ammonia as N	µg/L	10	20	3/24	BDL	BDL	**80**	1/27	BDL	BDL	**30**	0/14	BDL	BDL	10
	Oxidised nitrogen	µg/L	10	40	1/24	BDL	BDL	**80**	0/27	BDL	BDL	40	12/14	40	95	310
	Kjeldahl nitrogen total	µg/L	100	-	0/24	BDL	400	13,800	0/27	BDL	200	1,800	0/14	200	300	900
	Nitrite (as N)	µg/L	10	-	0/24	BDL	BDL	BDL	0/27	BDL	BDL	10	0/14	BDL	BDL	BDL
	Nitrate (as N)	µg/L	10	-	0/24	BDL	BDL	80	0/27	BDL	BDL	40	0/14	40	95	310

Table C.3 Water quality summary

					Minor watercourses				Fingerboard Crossing Creek				Macleay River			
Group	**Parameter**	**Units**	**EQL[1]**	**WQO[2]**	**#exceedances /#samples**	**Min.**	**Median**	**Max.**	**#exceedances/ #samples**	**Min.**	**Median**	**Max.**	**#exceedances/ #samples**	**Min.**	**Median**	**Max.**
	Total nitrogen	µg/L	100	350	13/24	BDL	**400**	**13,800**	7/27	BDL	200	**1,800**	10/14	200	**400**	**1,100**
	Reactive Phosphorus	µg/L	10	20	0/24	BDL	BDL	10	1/27	BDL	BDL	**70**	3/14	BDL	10	**40**
	Total phosphorus	µg/L	10	25	10/24	BDL	20	**600**	7/27	BDL	BDL	**260**	14/14	**30**	**40**	**100**
Major ions	Calcium	µg/L	1,000	-	-/24	BDL	1,000	8,000	-/27	BDL	5,000	144,000	-/14	4,000	12,000	13,000
	Chloride	µg/L	1,000	250,000	0/24	6,000	8,000	30,000	0/27	7,000	14,000	104,000	0/14	7,000	11,000	15,000
	Fluoride	µg/L	100	1,500	0/24	BDL	BDL	100	0/27	BDL	BDL	200	0/14	BDL	BDL	BDL
	Sodium	µg/L	1,000	180,000	0/24	5,000	8,500	27,000	0/27	6,000	15,000	118,000	0/14	8,000	10,500	13,000
	Magnesium	µg/L	1,000	-	-/27	BDL	BDL	7,000	-/29	BDL	3,000	65,000	-/14	2,000	6,500	8,000
	Potassium	µg/L	1,000	-	-/24	BDL	1,000	5,000	-/27	BDL	1,000	5,000	-/14	1,000	2,000	3,000
	Sulfate as SO_4	µg/L	1,000	-	-/24	BDL	BDL	10,000	-/27	BDL	6,000	543,000	-/14	6,000	10,000	12,000
	Anions total	meq/L	0.01	-	-/24	0.2	0.5	2.4	-/27	0.5	1.3	18.0	-/14	0.8	1.6	2.0
	Cations total	meq/L	0.01	-	-/24	0.2	0.4	2.3	-/27	0.4	1.2	17.8	-/14	0.7	1.7	1.9
	Ionic balance	%	0.01	-	-/0	0.0		0.0	-/4	0.5	1.2	2.9	-/0	0.0		0.0
	Sodium absorption ratio	-	0.01	-	-/24	1.1	1.6	2.2	-/27	0.6	1.4	2.1	-/14	0.6	0.6	0.8
Metals (dissolved)	Aluminium	µg/L	10	55	19/24	BDL	**370**	**1,720**	13/27	BDL	**100**	**2,620**	4/14	BDL	BDL	**140**
	Arsenic	µg/L	1	10	0/24	BDL	BDL	10	0/27	BDL	BDL	10	0/14	BDL	BDL	3
	Antimony	µg/L	1	3	0/24	BDL	BDL	1	1/27	BDL	BDL	**10**	4/14	BDL	BDL	**10**
	Cadmium	µg/L	0.1	0.2	0/24	BDL	BDL	BDL	0/27	BDL	BDL	BDL	0/14	BDL	BDL	BDL
	Chromium (III+VI)	µg/L	1	1	0/24	BDL	BDL	BDL	0/27	BDL	BDL	BDL	0/14	BDL	BDL	BDL

Table C.3 Water quality summary

					Minor watercourses				Fingerboard Crossing Creek				Macleay River			
Group	**Parameter**	**Units**	**EQL[1]**	**WQO[2]**	**#exceedances /#samples**	**Min.**	**Median**	**Max.**	**#exceedances/ #samples**	**Min.**	**Median**	**Max.**	**#exceedances/ #samples**	**Min.**	**Median**	**Max.**
	Copper	µg/L	1	1.4	2/24	BDL	BDL	**10**	2/27	BDL	BDL	**2**	2/14	BDL	BDL	**2**
	Iron	µg/L	50	200	15/24	BDL	**285**	**2,000**	6/27	50	70	**1,240**	1/14	60	130	**230**
	Lead	µg/L	1	3.4	0/24	BDL	BDL	BDL	0/27	BDL	BDL	BDL	0/14	BDL	BDL	BDL
	Manganese	µg/L	1	500	0/21	BDL	BDL	40	0/25	BDL	BDL	210	0/14	BDL	10	34
	Mercury	µg/L	0.1	0.06	0/24	BDL	BDL	BDL	0/27	BDL	BDL	BDL	0/14	BDL	BDL	BDL
	Nickel	µg/L	1	11	0/24	BDL	BDL	3	0/27	BDL	BDL	3	0/14	BDL	BDL	2
	Zinc	µg/L	5	8	1/24	BDL	BDL	**20**	0/27	BDL	BDL	BDL	1/14	BDL	BDL	**10**
Hydrocarbons	Benzene	µg/L	1	1	0/24	BDL	BDL	BDL	0/27	BDL	BDL	BDL	0/14	BDL	BDL	BDL
	Ethylbenzene	µg/L	2	3	0/24	BDL	BDL	BDL	0/27	BDL	BDL	BDL	0/14	BDL	BDL	BDL
	Toluene	µg/L	2	25	0/24	BDL	BDL	BDL	0/27	BDL	BDL	BDL	0/14	BDL	BDL	BDL
	Total BTEX	µg/L	1	-	-/24	BDL	BDL	BDL	-/27	BDL	BDL	BDL	-/14	BDL	BDL	BDL
	Xylene (m & p)	µg/L	2	-	-/24	BDL	BDL	BDL	-/27	BDL	BDL	BDL	-/14	BDL	BDL	BDL
	Xylene (o)	µg/L	2	200	0/24	BDL	BDL	BDL	0/27	BDL	BDL	BDL	0/14	BDL	BDL	BDL
	Xylene Total	µg/L	2	20	0/24	BDL	BDL	BDL	0/27	BDL	BDL	BDL	0/14	BDL	BDL	BDL
	Naphthalene	µg/L	5	2.5	0/24	BDL	BDL	BDL	0/27	BDL	BDL	BDL	0/14	BDL	BDL	BDL
	C6-C10	µg/L	20	-	-/24	BDL	BDL	BDL	-/27	BDL	BDL	BDL	-/14	BDL	BDL	BDL
	C6-C10 (F1 minus BTEX)	µg/L	20	-	-/24	BDL	BDL	BDL	-/27	BDL	BDL	BDL	-/14	BDL	BDL	BDL
	C10-C16	µg/L	100	-	-/24	BDL	BDL	BDL	-/27	BDL	BDL	130	-/14	BDL	BDL	BDL
	C10-C16 (F2 minus naphthalene)	µg/L	100	-	-/24	BDL	BDL	BDL	-/27	BDL	BDL	130	-/14	BDL	BDL	BDL

Table C.3 Water quality summary

					Minor watercourses				Fingerboard Crossing Creek				Macleay River			
Group	**Parameter**	**Units**	**EQL[1]**	**WQO[2]**	**#exceedances /#samples**	**Min.**	**Median**	**Max.**	**#exceedances/ #samples**	**Min.**	**Median**	**Max.**	**#exceedances/ #samples**	**Min.**	**Median**	**Max.**
	C16-C34	µg/L	100	-	-/24	BDL	BDL	540	-/27	BDL	BDL	350	-/14	BDL	BDL	BDL
	C34-C40	µg/L	100	-	-/24	BDL	BDL	220	-/27	BDL	BDL	BDL	-/14	BDL	BDL	BDL
	C10-C40 (sum of total)	µg/L	100	-	-/24	BDL	BDL	860	-/27	BDL	BDL	480	-/14	BDL	BDL	BDL
	C6-C9	µg/L	20	-	-/24	BDL	BDL	BDL	-/27	BDL	BDL	BDL	-/14	BDL	BDL	BDL
	C10-C14	µg/L	50	-	-/24	BDL	BDL	80	-/27	BDL	BDL	110	-/14	BDL	BDL	BDL
	C15-C28	µg/L	100	-	-/24	BDL	BDL	340	-/27	BDL	BDL	300	-/14	BDL	BDL	BDL
	C29-C36	µg/L	50	-	-/24	BDL	BDL	340	-/27	BDL	BDL	110	-/14	BDL	BDL	BDL
	+C10-C36 (sum of total)	µg/L	50	-	-/24	BDL	BDL	760	-/27	BDL	BDL	520	-/14	BDL	BDL	BDL

Attachment D

Operational water balance model

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D.1 Climate data

Historical daily rainfall and evaporation data between 1970 and 2021 obtained as patched point data (at -30.75, 152.20) from the SILO database, as discussed in Section 4.2.1 was applied the water balance model. Daily rainfall was applied to calculate direct rainfall onto the simulated water surface of the reservoirs. Morton's shallow lake evaporation data was used to estimate evaporation losses from the simulated water surface of the reservoirs. Morton's potential evapotranspiration data was used in Australian Water Balance Model (AWBM) catchment runoff calculations to estimate soil moisture losses.

D.2 Macleay River streamflow

Historical daily streamflow data for the Macleay River obtained from the Macleay River at D/S Georges River Junction stream gauge between 1970 and 2021, as discussed in Section 4.4.2, was adopted for the water balance model. The historical streamflow data was used to determine the volume of water available to top-up the operational system to offset losses such as evaporation and leakage.

D.3 Catchment and reservoir data

The contributing catchment area to the upper and lower dams and reservoirs is shown in Figure 4.1. Table D.1 provides the dam and reservoir details represented in the water balance model.

Table D.1 Dam and reservoir data

Element	Upper reservoir	Lower reservoir
Spillway crest level	883 m AHD	250.2 m AHD
Full supply level	881 m AHD	250 m AHD
Minimum operating level	830 m AHD	215 m AHD
Lowest operating level (drought condition)	–	205 m AHD
Live reservoir volume	4.98 GL	5.18 GL
Total reservoir volume	5.06 GL	6.47 GL
Drought reserve volume	–	0.9 GL
Surface area at full supply level	16.7 ha	21.6 ha
Surface area at minimum operating level	4.8 ha	10.1 ha
Total catchment area	41 ha	267 ha

D.4 Hydrologic model data

The catchment runoff parameters adopted for the AWBM within the water balance model are presented in Table D.2. Calibration of AWBM parameters was undertaken using streamflow data obtained from the Macleay River at D/S Georges River Junction stream gauge between 1971 and 1976 and daily rainfall and pan evaporation data obtained from the SILO database for the Uralla (Blue Nobby) weather station (57091).

Table D.2 Calibrated AWBM parameters

Parameter	Value
BFI	0.29
K Base	0.973
K Surf	0.17
Average capacity	195.2
C_1, C_2, C_3 (mm)	14.6, 148.8, 297.6
A_1, A_2, A_3	0.134, 0.433, 0.433

D.5 Operational data

Operational data used as input to the water balance model is shown in Table D.3.

Table D.3 Operational data

Parameter	Value
Transfer from lower reservoir to upper reservoir	Max 100.3 m^3/s
Transfer from upper reservoir to lower reservoir	Max 120.3 m^3/s
Hours of pumping from lower reservoir to upper reservoir	16 hours
Hours of generation (i.e. flow from upper reservoir to lower reservoir)	12 hours
Groundwater inflows to upper reservoir	45 ML/year
Groundwater outflows from upper reservoir	58 ML/year
Groundwater inflows to lower reservoir (including power waterway and tunnels)	275 ML/year
Groundwater outflows from lower reservoir (including power waterway and tunnels)	643 ML/year
Pumped top-up from Macleay River	Max 86 ML/day
Minimum flows in Macleay River prior to top-up pumping	597 ML/day
Top-up trigger	98% of total storage capacity

A summary of the inputs and outputs modelled for the reservoirs is provided in Table D.4. Outputs are numbered in order of priority for each storage.

Table D.4 Summary of modelled inputs and outputs

Reservoir	Inputs	Outputs
Upper dam and reservoir	• Rainfall on reservoir surface • Catchment runoff • Groundwater inflows • Pumped transfers from lower reservoir	1. Evaporation from reservoir surface 2. Groundwater outflows 3. Pumped transfer to lower reservoir
Lower dam and reservoir	• Rainfall on reservoir surface • Catchment runoff • Groundwater inflows • Pumped transfers from upper reservoir • Top-up transfers from Macleay River	1. Evaporation from reservoir surface 2. Groundwater outflows 3. Discharges to Macleay River 4. Pumped transfer to upper reservoir

Attachment E

Fingerboard Crossing Creek flood model

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Oven Mountain Pumped Hydro Project

Flood assessment: Fingerboard Crossing Creek

Prepared for OMPS Pty Ltd

March 2023

Oven Mountain Pumped Hydro Project

Flood assessment: Fingerboard Crossing Creek

OMPS Pty Ltd

J210465 RP1

March 2023

Version	Date	Prepared by	Approved by	Comments
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Approved by

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

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1 Introduction

1.1 Background

OMPS Pty Ltd (OMPS) is proposing to develop the Oven Mountain Pumped Hydro Energy Storage Project (the Project), an off-river pumped hydro energy storage system (referred to as the 'pumped hydro system') located approximately half-way between Kempsey and Armidale in northern NSW (the site). The pumped hydro system will consist of upper and lower water reservoirs, a pipeline connecting them, and a hydro-electric power station connected to the national energy grid that is capable of generating or consuming electricity. The pumped hydro system will be situated on an intermittent tributary of the Macleay River, Fingerboard Crossing Creek.

The key project elements and hydrologic context of Fingerboard Crossing Creek are presented in Figure 1.1.

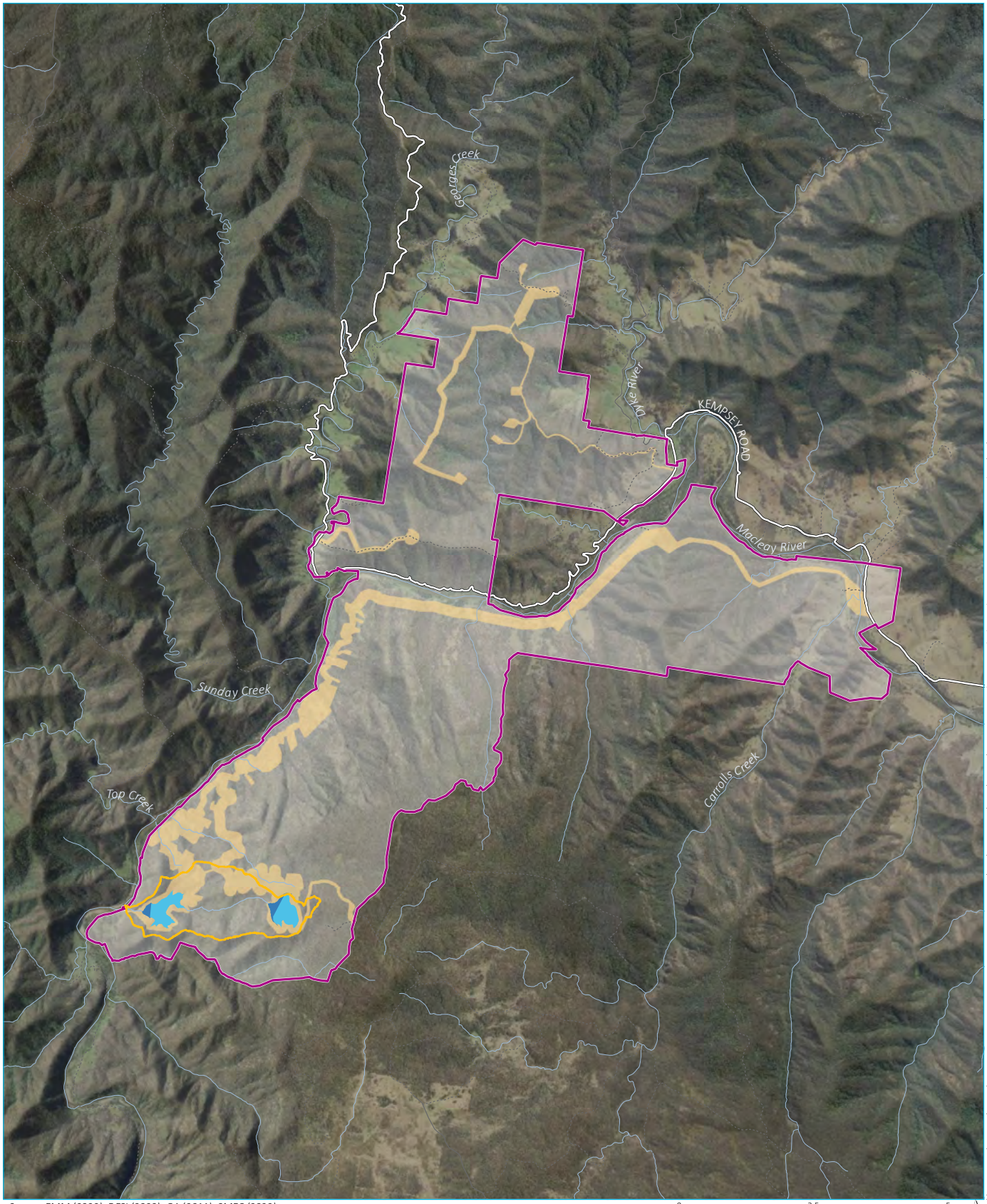
1.2 Report purpose and structure

This report describes hydraulic modelling of Fingerboard Crossing Creek undertaken to support the surface water assessment (EMM, 2022) (Appendix L of the EIS) and geomorphology assessment (Gippel, 2022) (Attachment B to Appendix L of the EIS) for the project.

The following sections describe:

- the assessment approach, available data and assessment methodology (Section 2)
- the hydraulic model setup (Section 3)
- hydraulic model results (Section 4).

Flood mapping for the hydraulic assessment is provided as Attachment A.



Source: EMM (2022); DFSI (2020); GA (2011); SMEC (2022)

0 2.5 5 km

GDA 1994 MGA Zone 56

N

KEY

- Project area
- Fingerboard Crossing Creek catchment
- Watercourse/drainage line
- Kempsey-Armidale Road
- Minor road
- Vehicular track
- Reservoir
- Dam wall

Study area and hydrological context

Oven Mountain Pumped Hydro Energy Storage Project
Fingerboard Crossing Creek flood assessment
OMPS Pty Ltd
Figure 1.1

EMM creating opportunities

\\emmsvr1\EMM3\2021\J210465 - OMPS EIS - Generation Component\GIS\02_Maps_EIS_SWA\SWA001_StudyAreaHydrologicalContext_20221121_01.mxd 13/12/2022

2 Assessment approach

2.1 Overview

The focus of this assessment was to estimate the changes to flood characteristics within Fingerboard Crossing Creek as a result of the Project. The following approach was undertaken:

- collation of available data (Section 2.2) to inform the hydraulic assessment
- development of a 2D hydraulic model of Fingerboard Crossing Creek (Section 3)
- post processing of results to create difference maps of key results (Section 4 and Attachment A).

2.2 Available data

The following data was available to inform the flood assessment:

- results of hydrologic modelling (Section 2.2.1) undertaken for the Project feasibility design (SMEC, 2022)
- Light Detection and Ranging (LiDAR) survey and aerial imagery of the Project area, captured between 3 February and 19 March 2020
- field observations and photographs from a site inspection undertaken in July 2022 by EMM personnel.

2.2.1 Hydrologic model data

Hydrologic modelling of the Fingerboard Crossing Creek catchment was undertaken with the XP-RAFTS modelling software (SMEC, 2022) to determine peak flows for the two reservoir spillways for inclusion in a preliminary dam break assessment. The results of each modelled annual exceedance probability (AEP) event applied to this assessment at each of the dam and reservoir inflow locations are provided in Table 2.1.

Table 2.1 Reservoir peak inflow results

Storm event (AEP %)	Upper reservoir inflow		Lower reservoir inflow	
	Critical duration (min)	Peak flow (m^3/s)	Critical duration (min)	Peak flow (m^3/s)
63.2	60	2.0	60	13.5
50	60	2.5	45	16.4
20	45	4.2	45	26.8
5	60	6.6	45	39.6
1	45	10.0	45	57.2
0.2	30	13.7	45	76.5

Source: Project feasibility design report (SMEC, 2022).

2.3 Modelling approach

Peak flow results from the XP-RAFTS model were proportionally adjusted based on sub-catchment area and applied to a purpose-built TUFLOW hydraulic model as a constant (steady-state) flow, to simulate the change in hydraulic behaviour along Fingerboard Crossing Creek. The hydraulic model setup is described in Section 3.

Two scenarios were assessed:

- existing conditions (i.e. without the Project dams and reservoirs)
- proposed conditions, simulating the reduction in flow as a result of impounding the upper portion of the Fingerboard Crossing Creek catchment with the upper dam and reservoir.

The hydraulic assessment included the 63.2%, 50%, 20%, 5%, 1% and 0.2% AEP storm events. These events were selected to provide resolution on frequent flows for the geomorphology assessment (Gippel, 2022) (Attachment B to Appendix L of the EIS) and higher magnitude floods for planning purposes.

3 Hydraulic model setup

3.1 Overview

This section describes the development of the TUFLOW hydraulic model. Model results are discussed separately in Section 4.

3.2 Model domain, grid size and version

The hydraulic model was developed for the 2.7 kilometre (km) section of Fingerboard Crossing Creek between the proposed reservoirs, extending from approximately 500 metres (m) upstream of the confluence with the Macleay River to the spillway of the upper dam and reservoir. The model domain and key features are shown in Figure 3.1.

The TUFLOW model was represented entirely in 2D with a model grid size of 2 m, informed by the Project LiDAR data set. TUFLOW classic, version 2020-10-AD was used for the simulation with sub grid sampling implemented to provide a higher resolution of storage within the model.

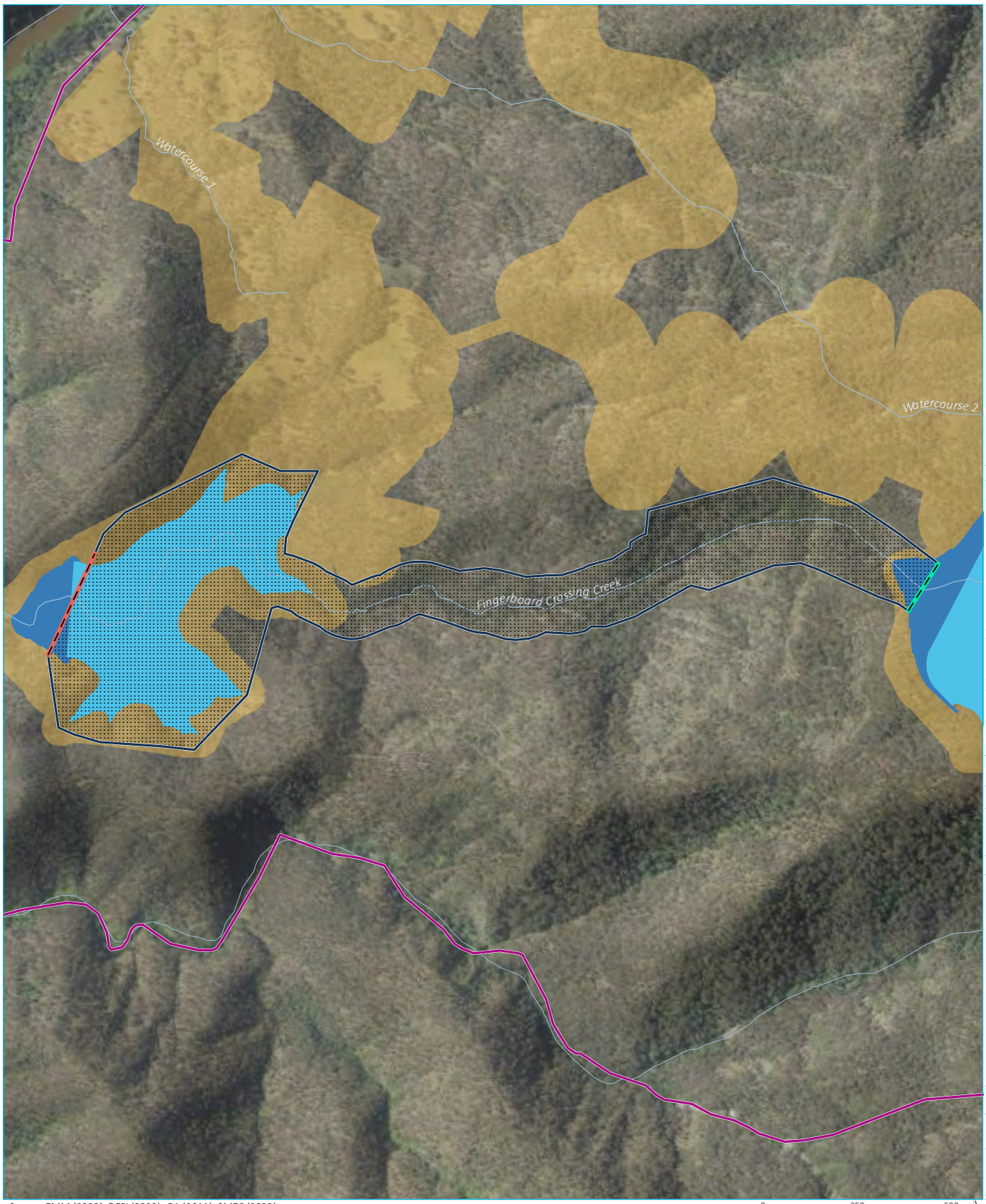
3.3 Hydraulic roughness

The floodplain surface within Fingerboard Crossing Creek is highly variable, where the upstream reaches of the creek consist of heavy vegetation (vines and brush), debris, rocks and pool sections. Downstream flows are more confined within channel banks, however, have similarly characterised surface conditions. Portions of the upstream watercourse consist of steep vertical drops over granite bedrock. An example section of Fingerboard Crossing Creek, which presents the variation in surface roughness is shown in Photograph 3.1.

The following hydraulic roughness values (Manning's n) were adopted for the model:

- Manning's n of 0.1 was applied to the majority of the model domain. Given the expanse and localised variability of the model domain, detailed variation in hydraulic roughness was not considered appropriate.
- Manning's n of 1 was applied to areas of steep terrain where required to improve model stability.

Photograph 3.1 Example section of Fingerboard Crossing Creek

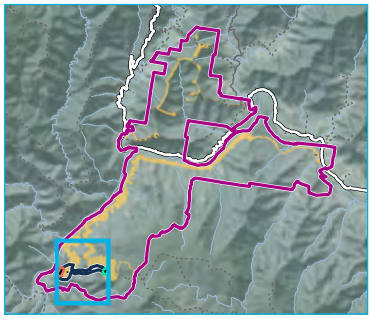


Source: EMM (2022); DFSI (2020); GA (2011); SMEC (2022)

0 250 500 m

GDA 1994 MGA Zone 56

N



KEY

- Project area
- TUFLOW model boundary
- Reservoir
- Dam wall
- Outflow boudnary
- Inflow boudnary

Mannings roughness

- Moderate to dense vegetation
- Watercourse/drainage line
- Kempsey-Armidale Road

Hydraulic model features

Oven Mountain Pumped Hydro Energy Storage Project
Fingerboard Crossing Creek flood assessment
OMPS Pty Ltd
Figure 3.1

EMM creating opportunities

\\emmsvr1\EMM3\2021\J210465 - OMPS EIS - Generation Component\GIS\02_Maps_EIS_SWA\SWA002_HydrologicModelFeatures_20221213_02.mxd 13/12/2022

3.4 Boundary conditions

Boundary conditions applied to the hydraulic model are outlined in Table 3.1 and presented in Figure 3.1.

Table 3.1 Model boundary conditions

Boundary condition	Type	Boundary assumptions
Catchment inflows	Surface area inflow applied along Fingerboard Crossing Creek within each sub-catchment (2D SA).	Flows from Table 2.1 were proportionally adjusted based on sub catchment area.
Downstream boundary	Normal depth boundary (HQ).	Slope of 5%.

Peak flows reported by the hydraulic model at the lower reservoir were compared to the XP-RAFTS results to verify that the proportioning of sub-catchment inflows achieved consistency with the hydrologic model. Results of the comparison are provided in Table 3.2.

Table 3.2 Comparison of hydrologic and hydraulic model flows (0.2% AEP event)

Model	TUFLOW result (m^3/s)	XPRAFT inflow result (m^3/s)	Difference (%)
Existing conditions	89.6	90.2	0.7%
Proposed conditions	75.4	76.5	-1.5%

The comparison of model results in Table 3.2 indicates flows generated with the TUFLOW model are consistent with those produced by XP-RAFTS.

4 Hydraulic model results

4.1 Overview

The hydraulic model described in Section 3 was applied to establish existing and proposed design flood characteristics within Fingerboard Crossing Creek. Mapping of flood depth and velocity for a frequent event (63.2% AEP event) and rare event (1% AEP event) is provided in Attachment A. Difference maps showing the change in flood behaviour under proposed conditions are also provided.

4.2 Model results

Changes to flood inundation, depth and velocity for all modelled events are summarised in Table 4.1.

Table 4.1 Predicted changes to flooding in Fingerboard Crossing Creek

AEP event	Overall reduction in inundation area (ha)	Approximate reduction in upper reach flood depth (m)	Approximate reduction in lower reach flood depth (m)	Approximate reduction in upper reach flood velocity (m/s)	Approximate reduction in lower reach flood velocity (m/s)
63.2 %	0.77	0.05 – 0.15	0.02 – 0.10	0.7 – 1.2	0.1 – 0.2
50 %	0.85	0.05 – 0.15	0.02 – 0.12	0.9 – 1.3	0.1 – 0.3
20 %	0.90	0.05 – 0.15	0.03 – 0.13	0.8 – 1.3	0.2 – 0.4
5 %	0.99	0.1 – 0.3	0.05 – 0.15	0.9 – 1.8	0.3 – 0.5
1 %	1.00	0.1 – 0.4	0.05 – 0.2	1.0 – 2.0	0.4 – 0.7
0.2 %	1.01	0.2 – 0.5	0.1 – 0.2	2.0 – 3.0	0.5 – 0.7

4.3 Results discussion

Flooding depths, extents and velocities within Fingerboard Crossing Creek will decrease with construction of the Project due to the capacity of the upper dam and reservoir to collect all runoff upstream of the dam wall, up to the probable maximum flood (PMF) event. Predicted changes to flood depth and velocity along Fingerboard Crossing Creek are generally higher in the upper portions of the watercourse, due to the proportionally larger reduction in contributing catchment area.

References

EMM. (2022). *Oven Mountain Pump Hydro: Surface water assessment.* Prepared by EMM Consulting Pty Ltd for OMPS Pty Ltd.

Gippel, C. J. (2022). *Oven Mountain Pumped Hydro Project: Geomorphology Assessment.* Prepared by Fluvial Systems Pty Ltd, Stockton for OMPS Pty Ltd, November 2022.

SMEC. (2022). *Oven Mountain Pumped Hydro Energy Storage Project - 15% Design.* Prepared by SMEC Australia for OMPS Pty Ltd.

Attachment A
Flood mapping

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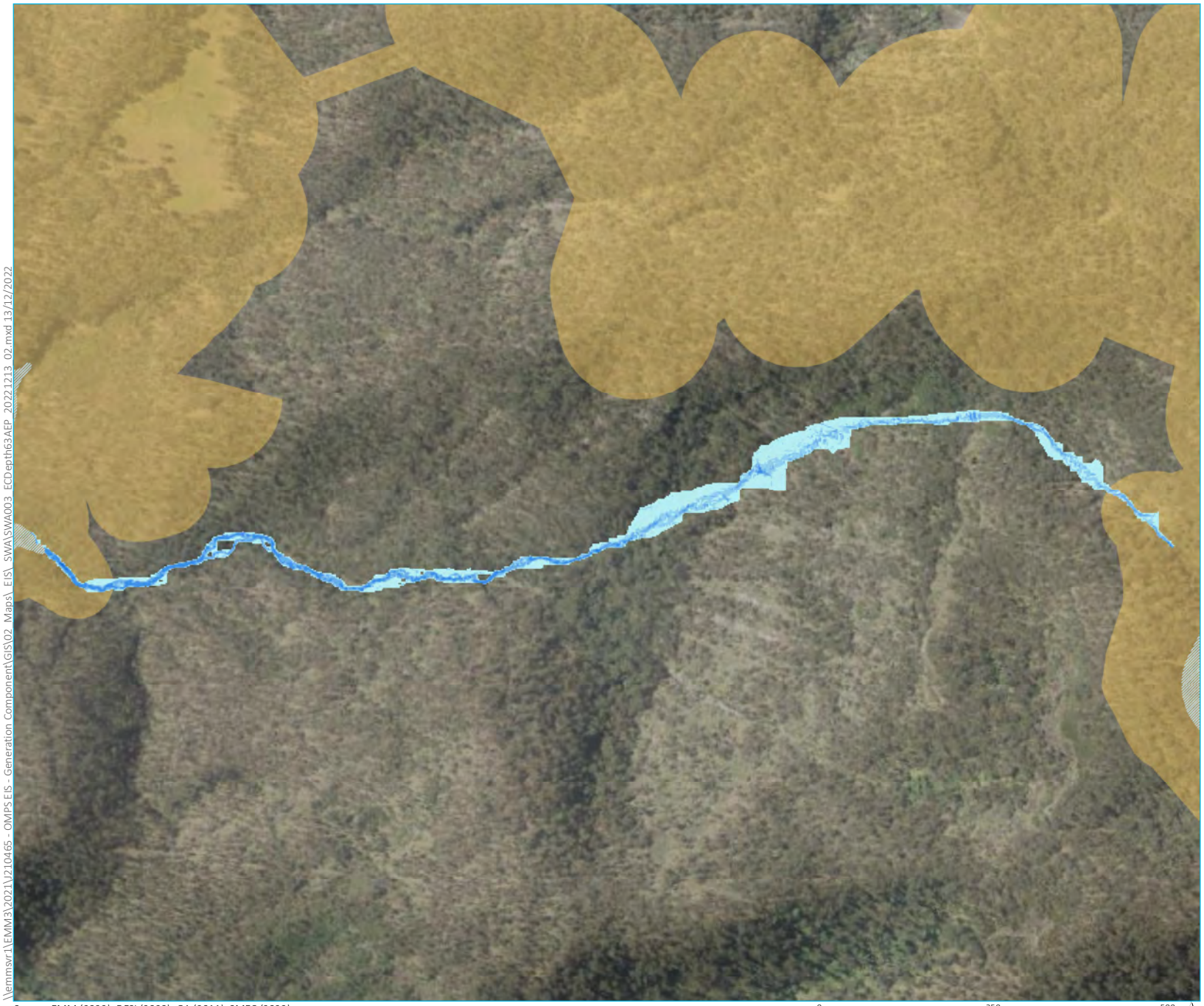

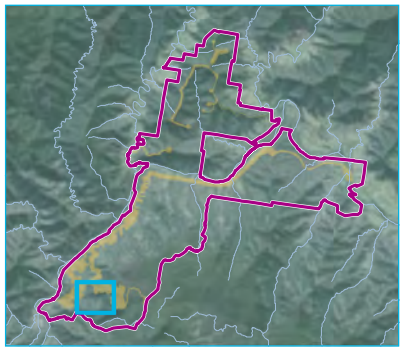

KEY

- Project area
- Reservoir
- Construction envelope

Maximum water depth (m)

- < 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 1.5

Source: EMM (2022); DFSI (2020); GA (2011); SMEC (2022)

0 250 500 m

GDA 1994 MGA Zone 56

N

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Existing conditions – Peak flood depth (63.2% AEP event)

Oven Mountain Pumped Hydro
Energy Storage Project
Fingerboard Crossing Creek flood assessment
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Figure A.1

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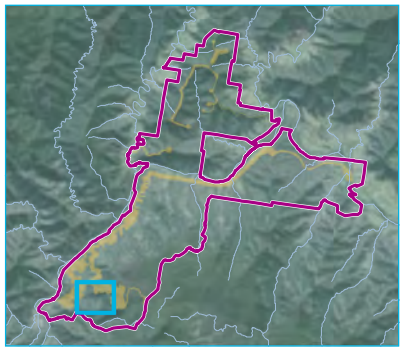

KEY

- Project area
- Reservoir
- Construction envelope

Maximum water depth (m)

- > 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3

Source: EMM (2022); DFSI (2020); GA (2011); SMEC (2022)

0 250 500 m

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N

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Existing conditions – Peak flood depth (1% AEP event)

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Fingerboard Crossing Creek flood assessment
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Figure A.2

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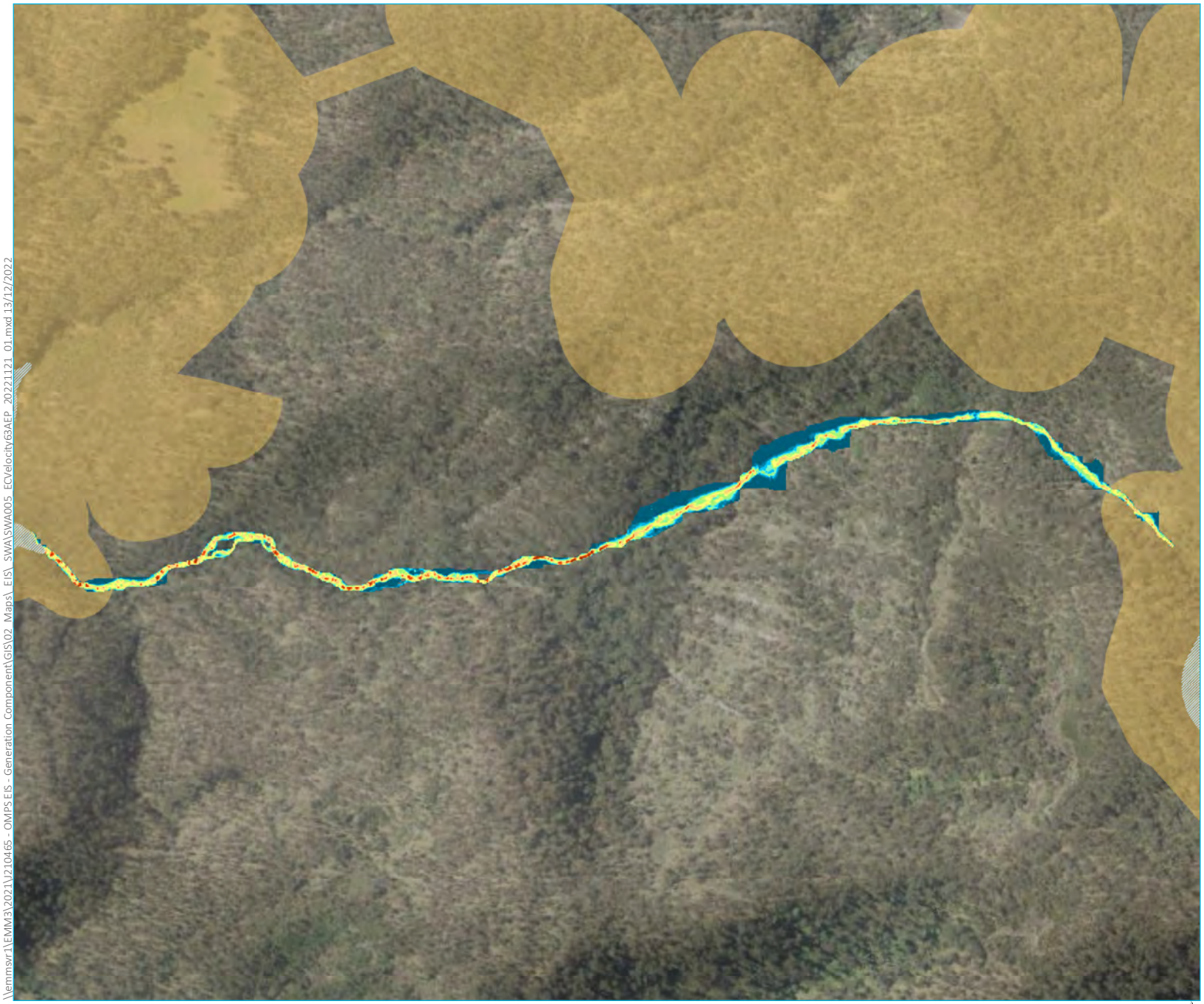

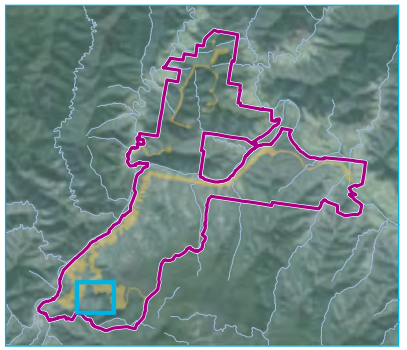

KEY

- Project area
- Reservoir
- Construction envelope

Maximum water velocity (m/s)

- < 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- > 3

Source: EMM (2022); DFSI (2020); GA (2011); SMEC (2022)

0 250 500 m

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N

Existing conditions – Peak flood velocity (63.2% AEP event)

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Fingerboard Crossing Creek flood assessment
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Figure A.3

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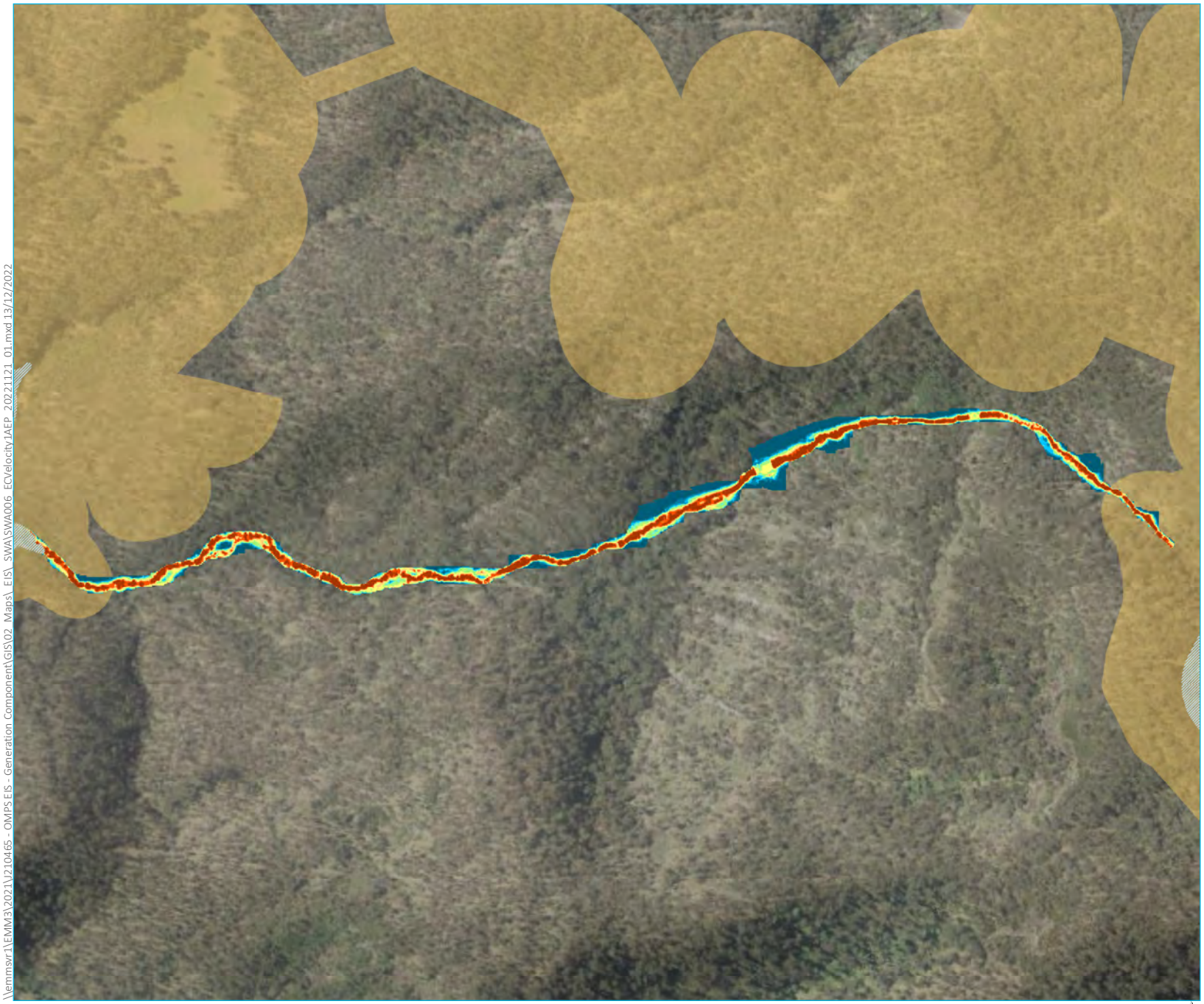

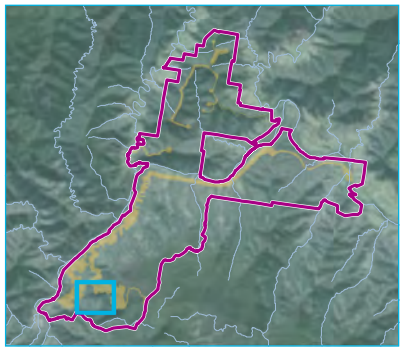

KEY

- Project area
- Reservoir
- Construction envelope

Maximum water velocity (m/s)

- < 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- > 3

Source: EMM (2022); DFSI (2020); GA (2011); SMEC (2022)

0 250 500 m

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N

Existing conditions – Peak flood velocity (1% AEP event)

Oven Mountain Pumped Hydro Energy Storage Project
Fingerboard Crossing Creek flood assessment
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Figure A.4

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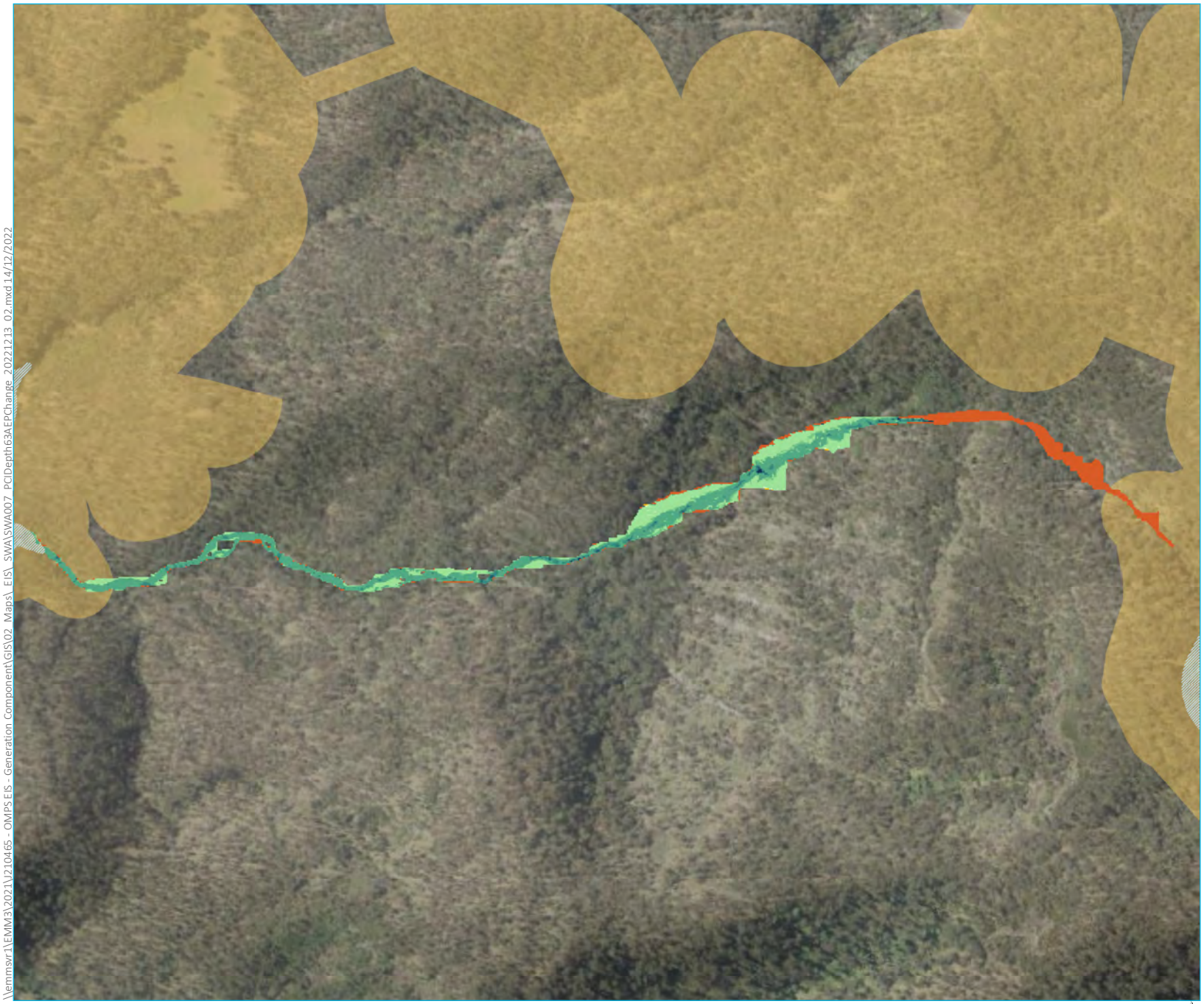

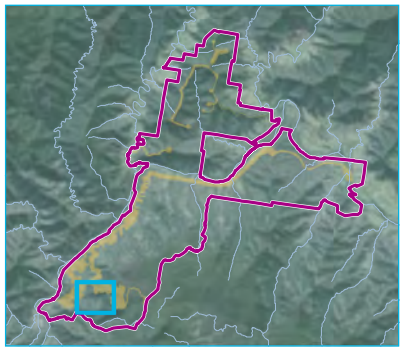

KEY

- Project area
- Reservoir
- Construction envelope
- Was wet now dry
- Was dry now wet

Maximum water depth change (m)

- < -0.2
- -0.2 - -0.15
- -0.15 - -0.1
- -1 - -0.02
- -0.02 - -0.01
- -0.01 - 0
- 0 - 0.1

Source: EMM (2022); DFSI (2020); GA (2011); SMEC (2022)

0 250 500 m

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N

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Proposed conditions impact – Peak depth change (63.2% AEP event)

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Energy Storage Project
Fingerboard Crossing Creek flood assessment
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Figure A.5

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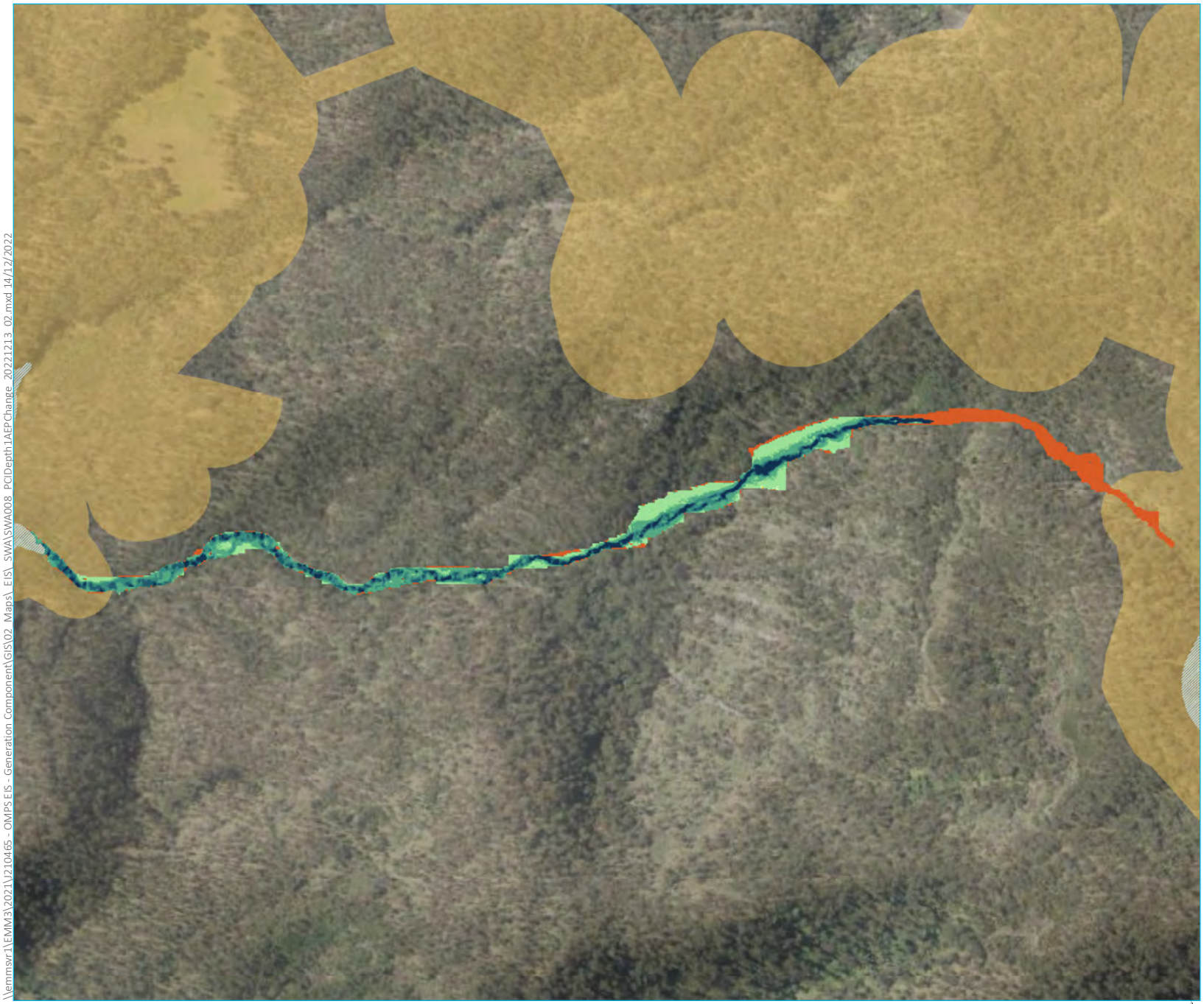

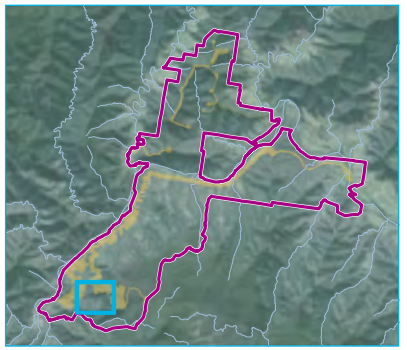

KEY

- Project area
- Reservoir
- Construction envelope
- Was wet now dry
- Was dry now wet

Maximum water depth change (m)

- < -0.2
- -0.2 - -0.15
- -0.15 - -0.1
- -1 - -0.02
- -0.02 - -0.01
- -0.01 - 0
- 0 - 0.1

Source: EMM (2022); DFSI (2020); GA (2011); SMEC (2022)

0 250 500 m

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N

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Proposed conditions impact – Peak depth change (1% AEP event)

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Energy Storage Project
Fingerboard Crossing Creek flood assessment
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Figure A.6

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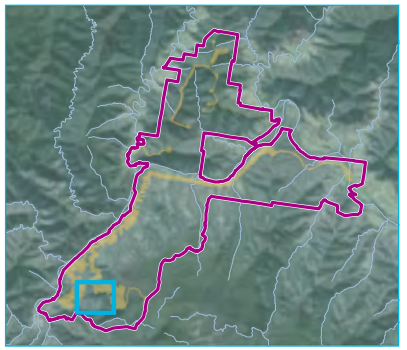

KEY

- Project area
- Reservoir
- Construction envelope
- Was wet now dry
- Was dry now wet

Maximum water velocity change (m/s)

- < -1
- -1 - -0.8
- -0.8 - -0.5
- -0.5 - -0.2
- -0.2 - -0.1
- -0.1 - 0
- > 0

Source: EMM (2022); DFSI (2020); GA (2011); SMEC (2022)

0 250 500 m

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Proposed conditions impact – Peak velocity change (63.2% AEP event)

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Energy Storage Project
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Figure A.7

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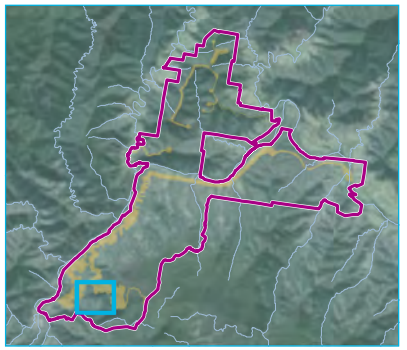

KEY

- Project area
- Reservoir
- Construction envelope
- Was wet now dry
- Was dry now wet

Maximum water velocity change (m/s)

- < -2
- -2 - -1.5
- -1.5 - -1
- -1 - -0.4
- -0.4 - -0.2
- -0.2 - 0
- > 0

Source: EMM (2022); DFSI (2020); GA (2011); SMEC (2022)

0 250 500 m

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N

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Proposed conditions impact – Peak velocity change (1% AEP event)

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Figure A.8

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