Appendix H

Climate Change Risk Assessment

EMM
creating opportunities

Oven Mountain Pumped Hydro Energy Storage Project

Climate Change Risk Assessment

Prepared for OMPS Pty Ltd

July 2024

Oven Mountain Pumped Hydro Energy Storage Project

Climate Change Risk Assessment

OMPS Pty Ltd

E230869C Submissions Report - Climate Change Assessment

July 2024

Version	Date	Prepared by	Reviewed by	Comments
V1	9 July 2024	Paul Boulter, Francine Manansala	Paul Boulter	Draft report
V2	19 July 2024	Paul Boulter, Francine Manansala	Scott Fishwick	Final report

Approved by

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19 July 2024

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Executive summary

ES1 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. The Project is located approximately half-way between Kempsey and Armidale, near Carrai in northern New South Wales (NSW). The objective of the Project is to contribute to the energy needs of NSW by providing energy storage at a significant scale plus providing flexible, dispatchable electricity generation.

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). An environmental impact statement (EIS) for the Project was published in September 2023 (Application 12422997).

This climate change risk assessment (CCRA) report has been prepared for the Project. The report:

- describes the Project
- identifies the assessment requirements
- describes the methodologies for the CCRA assessment
- assesses impacts during construction and operation
- recommends measures to mitigate and manage the impacts identified.

ES2 Climate change risk assessment

The climate in the area of the Project in the near future (2030) and far future (2070) was characterised using a range of data sources, and notably the projection data from the NARCliM 1.0 and NARCliM 1.5 projects. Climate was characterised using variables relating to temperature, fire danger, rainfall, evaporation, droughts, and qualitative information on storms.

A climate risk and adaptation workshop was held with OMPS. The effects of the future changes in climate were considered in relation to potential impacts on Project assets or functions, including areas such as physical structures, transport, and worker safety.

In total, 7 potential impacts were identified during construction and 34 were identified during operation. In the workshop, the potential risks to the Project were discussed with the Project team. In the initial risk profile, with no mitigation/adaption measures, most of the risk ratings were 'low' or 'medium'.

Planned and additional measures were then considered. These included:

- Design:
  - Upgrade the road network to improve resilience. Investigations will need to be done to confirm if this is viable from a cost perspective.
  - Assess the impact of the capacity of the spillways being exceeded on the dam stability and based on risks and costs, consider additional impact of oversizing the spillway crest.
  - Flood flow to be designed to exceed criteria.
  - Implementation of a plan to monitor flooding events.

- Operation:
  - Operations can commence with reduce storage volume if required.
  - Timed or more frequent operational top-ops prior to dry weather events or increased drought reserve in reservoirs.
  - Possibility to apply stop work practices (under investigation).
  - Coordination with the Rural Fire Service (RFS) with respect to planning and water take for firefighting.
  - Consideration of critical spares list for the transmission lines.
- Plans and schedules:
  - Consideration of future water licences.
  - Planning maintenance outside of projected storm events and monitoring of storms.

The final step was the assessment of residual risks once all measures had been applied. Again, for most potential climate change impacts the residual risk was determined to be ‘low’.

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1 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. The Project is located approximately half-way between Kempsey and Armidale, near Carrai in northern New South Wales (NSW). The objective of the Project is to contribute to the energy needs of NSW by providing energy storage at a significant scale plus providing flexible, dispatchable electricity generation.

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). An environmental impact statement (EIS) for the Project was published in September 2023 (Application 12422997).

In its response[1] to the EIS, NSW Department of Planning and Environment requested the following:

> a climate change risk assessment [CCRA] for the proposal that considers risks for both the construction and operational phases of the Project and how they will be mitigated.

This CCRA report has been prepared for the Project to address the request from the DPE. The report briefly describes the Project, identifies assessment guidelines and contains the CCRA itself.

[1] Letter from Damien Rose of NSW Department of Planning and Environment, 12 October 2023.

2 Project description

2.1 Location

The Project is located in the Northern Tablelands region of NSW, approximately halfway between Armidale and Kempsey. Armidale is located approximately 60 km to the north-west of the Project and Kempsey approximately 75 km to the south-east. Other nearby communities include Lower Creek which is located approximately 2 km to the north-east, and Bellbrook located approximately 30 km to the east.

The Project is located on an ephemeral tributary of the Macleay River in the south-eastern corner of the Armidale Regional Council LGA in close proximity to the Kempsey Shire LGA.

The Project area covers approximately 2,400 hectares (ha) and is intersected by the Macleay River with the Carrai National Park to the east. Cunnawarra National Park, Oxley Wild Rivers National Park, and Carrai State Conservation Area are proximate to the Project area.

Much of the Project area contains undulating and steep terrain ranging in elevation from approximately 150 m to 1,000 m above sea level with vegetation ranging from heavy to cleared. A three-dimensional representation of the local topography is presented in Figure 2.1.

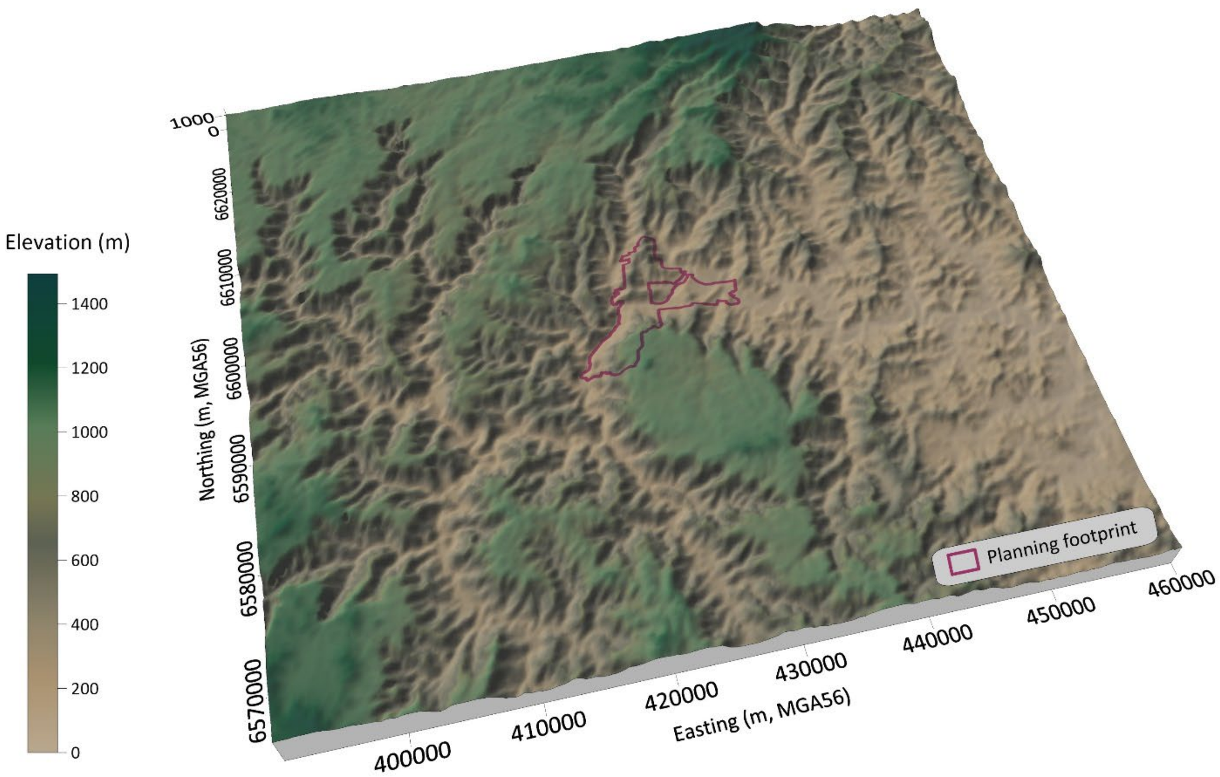


Figure 2.1 Three-dimensional topography surrounding the Project area

Source: NASA Shuttle Radar Topography Mission data

2.2 Project characteristics

The Project is an off-river pumped hydro energy storage system. 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 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. The pumped hydro system will connect to the existing transmission network via new overhead high voltage transmission lines.

By providing up to 900 megawatts (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 eight hours of dispatchable energy at full generation to be stored and made available to the National Electricity Market (NEM). The Project's large capacity and quick-start energy generation will allow it to stabilise the energy generation of nearby wind and solar technologies.

The main elements of the Project are summarised in Table 2.1 and shown in Figure 2.1.

Table 2.1 Main Project elements

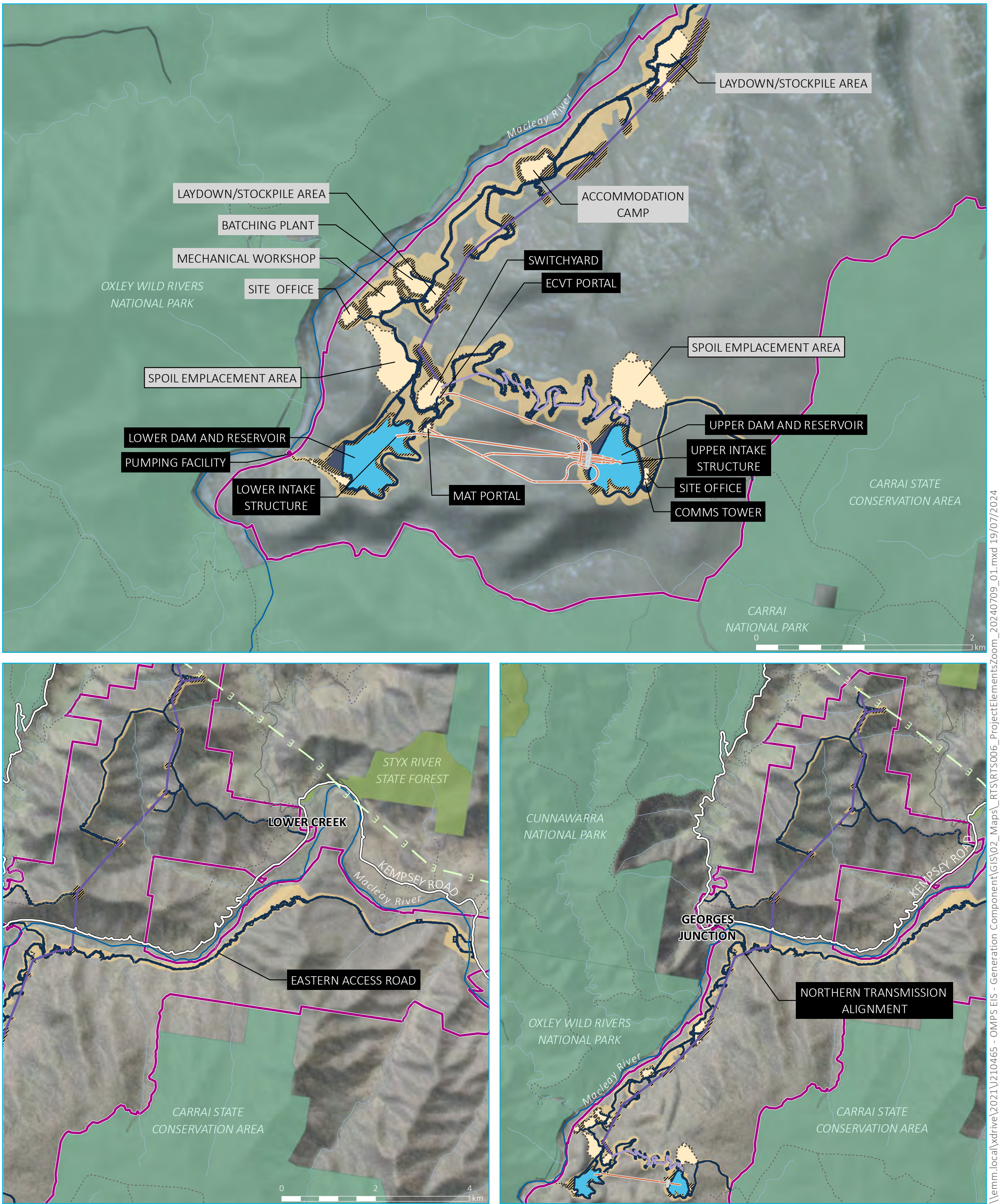
Project element	Description
Pumped hydro-electric and generation works	
Underground power station complex	An underground pumped hydro-electric power station located below the upstream end of the pumped hydro system to optimise the hydraulic arrangement of the Project. The power station complex consists of: • two main caverns, comprising: – the machine hall – the transformer hall • interconnecting tunnels and isolated phase busbar (IPB) galleries.
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 m high and 780 m long. A polymer or asphalt based liner may be added to the upstream face and/or base of the reservoir to prevent water losses. • reservoir covering a total area of approximately 20 hectares (ha) and an inundation extent of approximately 16.7 ha • reservoir height of approximately 881 m Australian Height Datum (AHD) at full supply level (FSL) and approximately 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 provided of a hood to prevent vorticity, 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.

Project element	Description
Spillways	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 edge of the Macleay River, which will include an access road, duty and standby pumps for the initial fill and for ongoing reservoir top-ups as required.
Tunnels	Three main tunnels comprising: • main access tunnel (MAT) • emergency, cable, ventilation tunnel (ECVT). • tailrace surge shaft ventilation tunnel (TSSVT) connected to the ECVT. The MAT 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. The TSSVT will provide service access to the tailrace surge shaft, as well as ventilation service to the surge shaft.
Power waterway	The power waterway will consist of: • an approximately 660 m deep, 6.4 m hydraulic diameter concrete lined vertical pressure shaft • an approximately 130 m long concrete lined high-pressure headrace tunnel, varying from 6.4 to 4.5 m diameter after the bifurcation • four 130 m long steel penstock tunnels, varying from 2.9 to 2.3 m diameter • four 60 m long steel draft tube tunnel at the exit of the draft tube cone an approximate 130 m long steel tailrace up to the tailrace surge shaft • an approximate 155 m deep and 18 m inner diameter surge shaft • an approximately 1,600 m long concrete lined tailrace tunnel.
Transmission connection works	
Connection works	The connection works will consist of: • an approximately 15 km 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.

Project element	Description
Ancillary development (construction and operation)	
Access roads, access tracks and bridges	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 Eastern Access Road (EAR)). The Main Access Road (MAR) will interface with the existing Kempsey-Armidale Road and will require the construction of two new single- or two-lane low--level bridge crossings over the Macleay River (referred to as Smiths Bluff Bridge and Carrolls Creek Bridge). A temporary bridge will be utilised prior to the construction of the Smiths Bluff permanent bridge (referred to as Eastern Access Temporary Bridge).
	A secondary, temporary access is proposed via the construction of a new, temporary bridge crossing of the Macleay River about 600 m upstream and north-west of Georges Junction (referred to as Western Access Temporary Bridge).
	There will be approximately 66.7 km of permanent roads connecting the dams, surface works, portals, transmission assets and spoil sites. Some of these roads are existing roads; however, approximately 29 km will be newly constructed roads. The key road components include: • Main Access Road (MAR) (approximately 4.7 km) • Eastern Access Road (EAR) (up to approximately 12.1 km) • Lower Dam Access Road (LDAR) (approximately 3.6 km) • Upper Dam Access Road (UDAR) (approximately 6.4 km) • access to portals and underground works • Upper Dam Emergency Egress Road (approximately 2.2 km). An initial mobilisation via Carrai Road to the Upper Dam Emergency Egress Road is also proposed, subject to agreement with NPWS. The road would be maintained to ensure all weather access only, with no widening and minor pavement upgrades to the existing road being proposed as part of the Project. The initial mobilisation will be limited to equipment required to commence the construction of the UDAR. 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) • Transmission Tower 8 Access Road (approximately 2.3 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 largely 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 (accommodation 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, which will temporarily accommodate the majority of workers as required throughout the construction period • temporary or fly camps that may be required prior to the main accommodation camp being constructed • works areas, which will contain ancillary facilities such as CBPs, mechanical and electrical workshops, a laboratory and various water treatment and wash areas • temporary stockpiling areas • permanent spoil emplacement areas, which prior to spoil placement may also be used as temporary works areas • staging areas • temporary site offices to be used during construction.

Project element	Description
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 to water storage systems 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).
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 and will be determined during detailed design or construction planning.
Laydown/stockpile areas	Temporary laydown/stockpile areas will be utilised across the Project area, with a total allocated stockpile area of around 119,600 m^2.
Spoil emplacement areas	To accommodate spoil generated through excavation of the reservoirs, underground caverns and tunnels, two permanent spoil placement locations have been identified with a capacity to store around 3.55 million cubic metres (Mm^3) of material. Dead storage space within the reservoirs will also be used for spoil placement, if required. One construction laydown area within the construction envelope has been identified as providing further surplus storage capacity (around 300,000 m^3); however, assessment and approval of this area would be sought separately, if the storage is required.
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 five years. • Construction workforce of over 600 workers at construction peak.
Rehabilitation	Rehabilitation of areas disturbed during pre-construction and construction will be undertaken progressively where practical during all stages and phases of the Project. Progressive rehabilitation will occur over about 62.7 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, 194.7 ha in total will be rehabilitated to native ecosystem (including native vegetation and rock landscape). Approximately 152.1 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 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 20 full-time workers, and up to 30 additional contractors for regular and ad hoc maintenance and repairs.

Project element	Description
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	It is anticipated construction will commence in around mid-2025 and continue for a 5 year period. Operations are anticipated to commence at the end of 2030 and have an operational life of 100+ years. Rehabilitation activities will continue after operations commence.
CIV	Estimated to be a base cost of approximately $1.97 billion.



Source: EMM (2024); DFSI (2020); GA (2011); SMEC (2022); ALINTA (2024)

0 2 4 km
GDA 1994 MGA Zone 56 N

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

Key project elements

Oven Mountain Pumped Hydro Energy Storage Project
Climate Change Risk Assessment
OMPS Pty Ltd
Figure 2.2

EMM creating opportunities

2.3 Project construction

The Project construction will be staged over a period of approximately 5 years.

Two 'off river' water containment structures will be constructed to create an upper and a lower reservoir (referred to as 'the upper dam and reservoir' and 'the lower dam and reservoir', respectively), 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.

Other components of the Project will include the construction of and upgrades of internal access roads, the construction of an electrical substation, and the construction of up to two high voltage transmission lines (132 kilovolt (kV) and 330 kV) that will connect the pumped hydro system to the high voltage transmission lines that connect Kempsey and Armidale (known as Line 965).

The transportation access route to the Project area is via Kempsey Armidale Road. The Project will require a new two-lane unsealed access road and a minimum of one new single lane low-level bridge crossing of the Macleay River, to connect the Project area to Kempsey Armidale Road. Upgrades to Kempsey Armidale Road are required to facilitate construction of the Project. These upgrade works will also be subject to a separate application under the EP&A Act, sought and completed separately by Armidale Regional Council and Kempsey Shire Council and funded by the Project.

It is proposed that water used for construction purposes and the initial one-off filling of the reservoirs will be pumped from the Macleay River during high flow periods in a manner which does not compete against downstream users under a Specific Purpose Access License (SPAL) to be issued under the NSW *Water Management Act 2000* (WM Act). The Project may also require periodic 'top ups' during the operational period.

The Project includes construction worker accommodation on the site with most personnel transported to the Project area by bus. A main accommodation camp is proposed, supplemented with three temporary camps. Construction areas not required for operation, will be progressively rehabilitated throughout the construction and operation stages of the Project.

2.4 Project operation

The expected operational lifespan of the Project is in excess of 100 years.

3 Assessment guidelines

Although a bespoke approach was adopted for the CCRA, it was informed by the following standards, guidelines and data:

- Climate Change Impacts and Risk Management – A Guide for Business and Government (AGO 2006)
- National Climate Risk Assessment Methodology (DCCEEW 2023)
- Hydropower Sector Climate Resilience Guide (IHA 2019)
- AS/NZS 31000:2018 Risk Management – Principles and Guidelines
- Australian Standard 5334-2013, Climate change adaptation for settlements and infrastructure – A risk-based approach
- International Standard ISO 31000:2009, Risk Management – Principles and Guidelines
- International Standard ISO/TS 14092:2020, Adaptation to climate change — Requirements and guidance on adaptation planning for local governments and communities.

4 Climate change risk assessment

4.1 Scope of the assessment

4.1.1 Requirements

A CCRA was conducted to determine the resilience of the construction and operation of the Project to the likely future impacts of climate change.

The Secretary's Environmental Assessment Requirements (SEARs) for the Project required the following:

- measures to minimise emissions and consideration of climate change adaptation related to the project.

In addition and in its response to the EIS, the NSW DPE requested the following:

- a climate change risk assessment [CCRA] for the proposal that considers risks for both the construction and operational phases of the Project and how they will be mitigated.

This report addresses these requirements.

4.1.2 Main steps

The steps involved in a CCRA are well established (e.g. AGO 2006). The main steps are typically:

1. Characterisation of the climate in the area, including:
   a) identification of key climate variables and metrics; the climate variables and metrics considered in the assessment were temperature, rainfall and droughts, fire danger and storms
   b) characterisation of the past climate, based on observations
   c) climate change projections, which describe how each variable may change over the design life of a project.
2. Identification of the broad impacts of the changes in the climate variables on the operation of the Project, and also the impacts on the environment where appropriate.
3. The risk assessment itself, taking into account the following for each identified impact:
   a) the likelihood of the impacts occurring
   b) the consequences of the impacts occurring
   c) the combination of the likelihood and consequences to define a risk rating.
4. Identification of measures to mitigate, adapt or build resilience to the identified risks.
5. Assessment of residual risks for the Project once the measures have been applied.

For the Project, these steps are addressed in Sections 4.2 to 4.5.

Both quantitative and qualitative data has been gathered to inform the assessment in line with the Australian Government's Climate Change Impacts and Risk Management – A Guide for Business and Government (AGO 2006).

A climate risk and adaptation workshop was held in June 2024, involving OMPS and EMM. In the workshop, climate hazards were presented, and the corresponding risks to the Project and the environment were discussed with the Project team. A spreadsheet-based tool (a risk register) was used to facilitate and document the risk assessment (see Annexure B).

4.1.3 Definitions

The terms that are used in this report are defined as follows:

- **Climate hazard**: This is a physical event that can harm human health, livelihoods, or natural resources. A climate hazard can be direct (such as flooding that releases pollution into nearby waterways) or indirect (such as a drought, where water is not available for dust suppression).
- **Impact**: This is the likely effect of a change in a climate change variable on an element of the Project (e.g. damage to equipment due to high temperature, destruction of a facility by bushfire).
- **Likelihood**: This is the likelihood of a climate change impact occurring. Some impacts might happen only once, whereas others may be recurring.
- **Consequence**: This is the consequence of a climate change impact occurring.
- **Climate risk**: This is the potential for adverse consequences for human or ecological systems from climate hazards. It can be viewed as the product of the consequences of climate change and the likelihood of those consequences. In the context of this report, climate risk refers to the potential negative impacts of climate change on the Project and, in particular the environmental performance of the Project. The report focuses on physical[2] risks, which can be event-driven (acute), such as increased severity of extreme weather events (e.g. cyclones, droughts, floods, heatwaves and fires), or can relate to longer-term shifts (chronic) in precipitation and temperature and increased variability in weather patterns (Ramboll 2023).

4.2 Past and future climate

4.2.1 Data sources

The Project is located in the Northern Tablelands region of NSW. The past climate in the area around the Project was characterised using long-term temperature and rainfall data from the Bureau of Meteorology (BoM) monitoring station at Armidale Airport (ID: 056238). Although this station is 60 km to the north-west of the Project, it is at a similar altitude to the proposed upper reservoir.

For the future climate, the collection and processing of data was more involved. CSIRO & BoM (2015) note that impact assessment in the region should consider the risk of both a drier and wetter climate.

The NSW Government's AdaptNSW[3] website provides climate projection data from the NSW and Australian Regional Climate Modelling (NARCliM) project[4]. For this assessment, climate parameters were taken from the AdaptNSW interactive climate change projections map[5]. These projections mostly rely on the first generation of NARCliM projections released in 2014 (known as NARCliM 1.0).

[2] Climate-related risks can also be associated with the transition to a lower-carbon economy ('transition risks'), the most common of which relate to policy, regulation, technology changes, market responses and reputational considerations (Ramboll 2023).

[3] https://www.climatechange.environment.nsw.gov.au/home

[4] NARCliM is led by the NSW Government in partnership with the ACT and South Australian governments, with input from the University of New South Wales's Climate Change Research Centre (UNSW CCRC).

[5] https://www.climatechange.environment.nsw.gov.au/projections-map

The NARCliM 1.0 projections were generated from four global climate models (GCMs) run by climate modelling research centres around the world, including CSIRO and BoM in Australia. These GCMs informed the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4, published in 2007). NARCliM 1.0 uses the GCM runs for the same emissions scenario (the IPCC high emission scenario known as A2) which, at the time, was considered to represent the most likely emission trajectory scenario. In the NARCliM project, the data from the four GCMs were 'dynamically downscaled'[6] for south-east Australia using regional climate models (RCMs). NARCliM generated data for over 100 weather and climate variables, including temperature, number of hot days and cold nights, rainfall and average forest fire danger index (FFDI), and at 10 km grid square resolution.

The simulations are for four distinct 20-year periods:

- an historical (baseline) period (1990 to 2009)
- a near-future period (2020 to 2039)
- a far-future period (2060 to 2079)
- a second far-future period (2080 to 2099).

The values in the interactive map are stated as changes in the near-future and far-future periods, relative to the baseline period, based on the results from the RCMs. Each of the different models produced a range of different projections or outcomes. To reduce the bias and uncertainty from looking at a single model prediction, the approach for this analysis is to combine data from the RCMs to produce a 'model ensemble average'.

The climate projections can be viewed in a 'region view' or 'grid view'. The grid view presents values for each 10 km grid square, and on both an annual basis and by season. The projections for temperature, rainfall and fire danger were extracted for the 10 km grid cell in which most of the Project would be located. Given that the Project would actually cover several different grid cells in the interactive map, the temperature projections (annual values only) for the eight grid cells around the central grid cell were obtained to understand the potential variability across the Project

A wider set of variables, as well as details of the modelling approach, can be accessed from the NSW Climate Data Portal[7].

Some limitations of NARCliM 1.0 led to development of the second iteration of NARCliM, labelled NARCliM1.5 (DPIE 2020a). NARCliM 1.5 predicts a hotter and drier future than NARCliM 1.0 and improves the representation of seasonal patterns and precipitation. The combination of NARCliM 1.0 and NARCliM1.5 provides an improved, more comprehensive dataset for studying climate change (Nishant et al. 2021). It is also worth noting that NARCliM 2.0 is currently under development.

The raw monthly data for temperature, precipitation, and humidity, for both NARCliM 1.0 and NARCliM 1.5, were downloaded from the NSW Climate Data Portal. The RCP 8.5 emission trajectory[8] was selected as being the most plausible. The data represented a single point at the Project location (longitude 152.166071; latitude -30.792295). An overview of the downloaded data is provided in Table 4.1.

[6] Dynamic downscaling is a climate modelling technique where an RCM uses physical principles to determine how the climate system behaves over a particular region of the globe. RCMs rely on input data from GCMs at their boundaries to perform this dynamical downscaling.

[7] https://climatedata-beta.environment.nsw.gov.au/

[8] RCP = representative concentration pathway.

Table 4.1 Overview of raw NARCliM data

Content	NARCliM 1.0	NARCliM 1.5
Climate parameters	• Average temperature[(a)] • Daily maximum temperature • Accumulated precipitation	• Average temperature[(a)] • Daily maximum temperature • Accumulated precipitation
Time periods	• Baseline (1990 to 2009) • Near-future (2020 to 2039) • Far-future (2060 to 2079)	• Baseline (1951 to 2005)[(b)] • Near-future (2020 to 2039) • Far-future (2060 to 2079)
Models	• MPI-M ECHAM5 • JAMSTEC MIROC • CSIRO QCCCE CSIRO-MK3 • CCCma CGCM 3.1	• CSIRO BOM ACCESS1.3 • CSIRO BOM ACCESS 1.0 • CCCma CanESM2
Downscaling approaches[(c)]	• R1 • R2 • R3	• R1 • R2

(a) Referred to as 'near surface temperature'.

(b) For better consistency with NARCliM 1.0, in the NARCliM 1.5 data the baseline period for the assessment was taken to be 1986 to 2005.

(c) Further details of the downscaling approaches are provided by DPIE (2020a).

The raw NARCliM data were processed and for a given parameter and time period, annual average results across all years, models and downscaling approaches were calculated. Seasonal average results were also determined. The incremental results for the future scenarios relative to the baseline were then calculated. For NARCliM 1.0, the results based on the extraction of the raw data were compared with the results from the interactive map, noting the slight difference in the geographical location.

It is worth noting that there are some differences in the underlying units of the various projections, although this should not affect their comparability. For example, in the case of rainfall, the projections are reported here as percentage changes, although for the interactive map the underlying units are not stated, for the NARCliM 1.0 download the units appear to be mm, and for the NARCliM 1.5 download the units are $kg/m^2/s$.

In addition, the Climate Change in Australia project (CSIRO & BoM 2015) developed projections of basic climate change variables. The corresponding website[9] provides climate change projections of Australia's future climate at a national level, and associated work. The projections that are most relevant to this report are those for the 'East Coast' cluster and the 'East Coast South' sub-cluster, which comprises regions in the central part of the eastern seaboard of Australia (Dowdy et al. 2015).

4.2.2 Temperature

The Northern Tablelands region of NSW has a cool and temperate climate. Based on long-term observations, temperatures in the region as a whole have generally been increasing since the 1960s, with higher temperatures experienced in recent decades (OEH 2014a).

Historical temperature data were obtained for the BoM monitoring station at Armidale Airport. Temperature has been measured here since the mid-1990s. Figure 4.1 shows the annual mean maximum and minimum temperatures at Armidale Airport between 1995 and 2022. The values are calculated from the monthly mean maximum and minimum temperatures. The record shows that, at this location, there has generally been a gradual increase in temperature over the period.

9 https://www.climatechangeinaustralia.gov.au/en/overview/

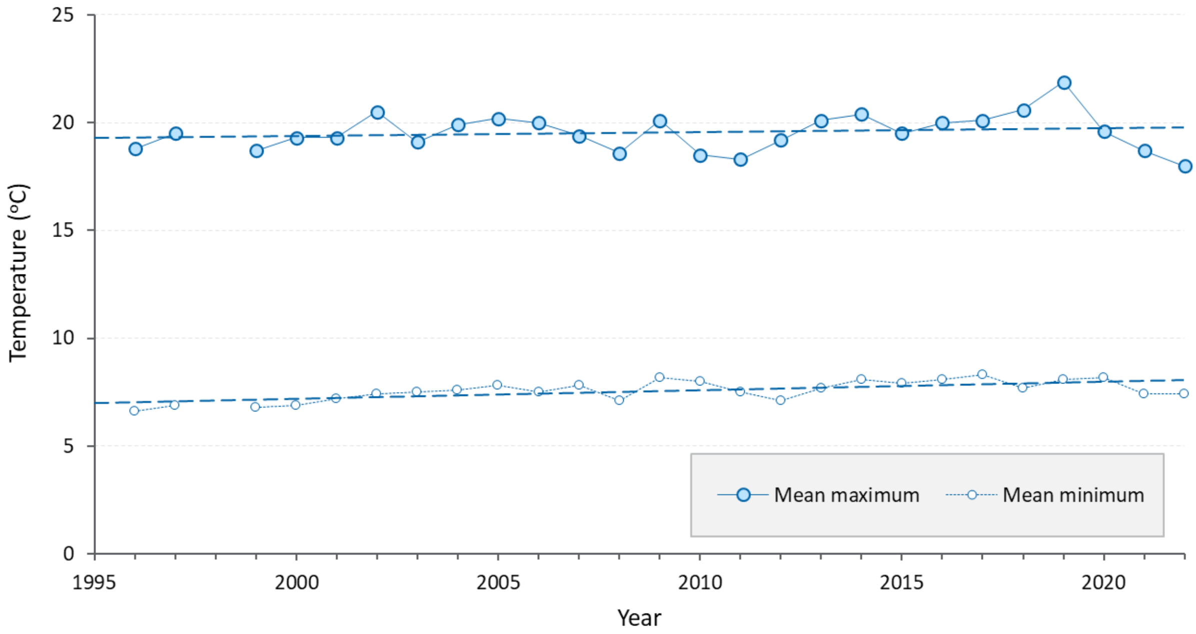


Figure 4.1 Historical temperature data for Armidale Airport

The baseline projections from AdaptNSW are for the period 1990–2009. For Armidale Airport, the temperature statistics for each month over a period in the data that corresponded closely to this baseline (1995–2009) are shown in Table 4.2. The area has warm summers, with a mean maximum temperature of around 26 °C. Winters are cold, with a mean minimum temperature of around 1–2 °C.

Table 4.2 Temperature statistics for Armidale Airport (1995-2009)

Statistic	Jan	Feb	May	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean maximum (°C)	26.0	25.1	23.1	19.7	15.7	12.8	12.0	14.0	17.8	20.5	22.2	24.8	19.5
Mean minimum (°C)	13.0	12.9	11.1	7.4	4.4	2.3	1.2	1.8	4.9	7.2	9.8	11.8	7.3

Table 4.3 summarises the temperature projections from the AdaptNSW interactive map and for the 10 km grid cell containing the Project. On an annual basis, average, maximum and minimum temperatures are all projected to increase by around 0.7 °C in the near future and by around 2 °C in the far future. The increases are generally largest in summer and smallest in winter. The projections indicate that there would be an increase of around two hot days (>35 °C) per year in the near future, and 7.6 hot days per year in the far future. There would also be marked reductions in the number of cold nights (<2 °C) per year.

Table 4.3 Summary of temperature projections (interactive map; 10 km grid cell containing Project)

Parameter/statistic	Near future (2020–2039), rel. to baseline					Far future (2060–2079), rel. to baseline				
	Spring	Summer	Autumn	Winter	Annual	Spring	Summer	Autumn	Winter	Annual
Change in temperature										
Daily average (°C)	+0.73	+0.93	+0.67	+0.50	+0.70	+2.15	+2.23	+2.02	+1.89	+2.07
Daily maximum (°C)	+0.74	+0.93	+0.56	+0.52	+0.69	+2.26	+2.20	+1.77	+1.86	+2.02
Daily minimum (°C)	+0.75	+0.83	+0.77	+0.49	+0.71	+2.21	+2.35	+2.27	+1.91	+2.18

Parameter/statistic	Near future (2020–2039), rel. to baseline					Far future (2060–2079), rel. to baseline				
	Spring	Summer	Autumn	Winter	Annual	Spring	Summer	Autumn	Winter	Annual
Change in cold nights										
Cold nights <2°C (days)	-1.55	0	-0.91	-5.78	-8.25	-3.58	0	-1.57	-17.08	-22.25
Change in hot days										
Hot days >35°C (days)	+0.14	+1.84	+0.01	0	+1.99	+2.20	+5.26	+0.17	0	+7.60

The ranges of values from the eight grid cells around the central (Project) cell are compared with the values for the central grid cell in Table 4.4. For average, maximum, and minimum temperature, the values for the Project cell and the surrounding cells were very similar, suggesting that the Project cell data are sufficiently representative of the wider area covered by the Project. For cold nights and hot days, the surrounding cells have wider ranges, but the central cell provides a typical average value.

Table 4.4 Comparison between projected temperatures for Project cell and surrounding cells

Parameter/statistic (all annual values)	Near future (2020–2039), rel. to baseline		Far future (2060–2079), rel. to baseline	
	Project cell	Surrounding cells	Project cell	Surrounding cells
Change in temperature				
Daily average (°C)	+0.70	+0.69 to +0.70	+2.07	+2.03 to +2.07
Daily maximum (°C)	+0.69	+0.69 (all cells)	+2.02	+1.96 to +2.04
Daily minimum (°C)	+0.71	+0.70 to +0.73	+2.18	+2.12 to +2.20
Change in cold nights				
Cold nights <2°C (days)	-8.25	-7.17 to -9.70	-22.25	-17.08 to -26.66
Change in hot days				
Hot days >35°C (days)	+1.99	+0.72 to +2.86	+7.60	+5.17 to +10.52

Table 4.5 summarises the average and maximum temperature projections based on the raw NARCliM data for Project location. Comparing the NARCliM 1.0 data with the AdaptNSW interactive map outlined in Table 4.3, it can be seen that there is consistency between the data sets. In fact, the only significant difference is the daily average summer temperature in the near-future scenario (+0.88 °C in the raw data, and +0.93 °C in the interactive map)[10]. However, this difference is small compared with the difference between the near-future and far-future results. According to NARCliM 1.5, the increases in temperature would be larger than those in NARCliM 1.0. For example, on an annual basis, average and maximum temperatures are projected to increase by around 1 °C in the near future and by around 3 °C in the far future, compared with 0.7 °C and 2 °C in NARCliM 1.0.

10 It is worth noting that some differences are to be expected, as the data from the interactive map are for a grid cell, whereas the raw data are for a single point.

Table 4.5 Summary of temperature projections (raw NARCliM data for Project location)

Parameter/statistic	Near future (2020–2039), rel. to baseline					Far future (2060–2079), rel. to baseline				
	Spring	Summer	Autumn	Winter	Annual	Spring	Summer	Autumn	Winter	Annual
NARCliM 1.0 (change in temperature)										
Daily average (°C)	+0.74	+0.88	+0.67	+0.52	+0.70	+2.12	+2.22	+2.00	+1.87	+2.05
Daily maximum (°C)	+0.74	+0.94	+0.56	+0.52	+0.69	+2.24	+2.18	+1.74	+1.84	+2.00
NARCliM 1.5 (change in temperature)										
Daily average (°C)	+1.05	+1.21	+1.12	+1.05	+1.11	+3.07	+3.15	+2.69	+2.70	+2.90
Daily maximum (°C)	+1.10	+1.05	+0.99	+0.98	+1.03	+3.49	+3.25	+2.64	+2.85	+3.06

For the east coast of NSW, CSIRO & BoM (2015), note that there is very high confidence in continued substantial increases in projected mean, maximum and minimum temperatures in line with the understanding of the effect of further increases in greenhouse gas (GHG) concentrations. More hot days and warm spells are projected with very high confidence, and fewer frosts are projected with high confidence.

Evaporation data are not available for download through the NSW Climate Data Portal. However, it can be reasonably assumed that given the projected increase in temperature (particularly in the far future), there would also be increases in evaporation.

4.2.3 Rainfall and droughts

The region currently experiences considerable spatial and temporal variation in rainfall. Average annual rainfall ranges from 1,200–1,600 mm along parts of the New England Tablelands through to 400–800 mm on the North West Slopes and Plains. Rainfall generally decreases with distance from the coast. Rainfall is also very seasonal. More rain falls in summer than other seasons, with winter being the driest season (OEH 2014a). Annual rainfall in the region has been relatively stable over the last 30 years (BoM & CSIRO 2019).

The region can also be impacted by decaying tropical cyclones which can bring extreme rainfall. East Coast Lows (ECLs) and persistent onshore flow can result in intense and prolonged flooding rains.

Historical rainfall data were obtained for Armidale Airport, where it has been measured since the mid-1990s. Figure 4.2 shows the time series of annual total rainfall. The record shows that, on average, Armidale receives approximately 800 mm of rain per year, although the annual amount of rainfall is quite variable.

There has been a substantial variation in annual rainfall associated with the El Niño Southern Oscillation and the corresponding La Niña events.

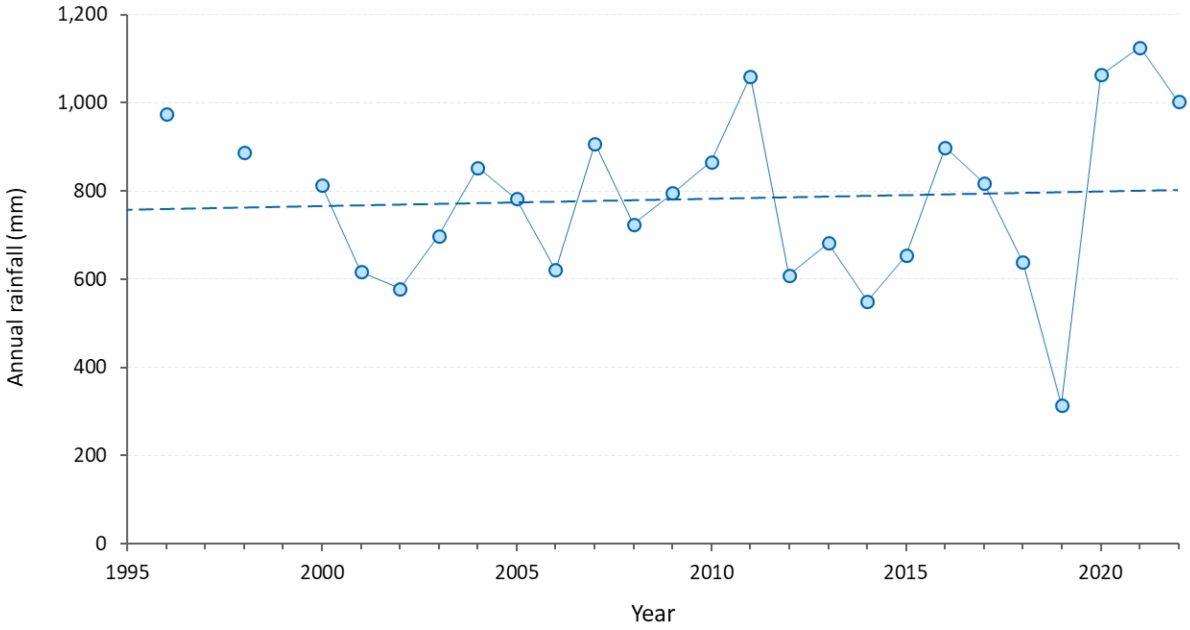


Figure 4.2 Historical rainfall data for Armidale Airport

For comparison with the baseline period in the projections from AdaptNSW, the rainfall statistics for Armidale Airport between 1995–2009 are shown in Table 4.6. As noted earlier for the region as a whole, summer is the wettest season, although November has the highest monthly average rainfall.

Table 4.6 Rainfall statistics for Armidale Airport (1995–2009)

Statistic	Monthly total												Annual total
	Jan	Feb	May	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mean (mm)	88.1	104.0	58.6	35.5	41.4	45.0	39.8	40.2	56.9	79.7	107.4	96.9	771.1
Maximum (mm)	233.6	267.4	192.0	113.8	130.2	126.8	109.2	119.0	197.0	153.8	180.2	189.0	974.2
Minimum (mm)	15.8	44.8	0.0	1.8	2.4	2.8	0.0	0.0	5.6	33.2	40.8	20.6	578.4

CSIRO & BoM (2015) note that, for the East Coast South sub-cluster, the observed trends in rainfall are not as significant as those for temperature. While the sub-cluster experienced extended dry periods in the early 20th century, there is no long-term trend in annual rainfall during the available record.

Table 4.7 summarises the rainfall projections from the AdaptNSW interactive map (based on NARCliM 1.0) and for the 10 km grid cell containing the Project. As noted earlier, the region has considerable variability in rainfall, and this variability is also reflected in the projections. On an annual basis, rainfall is projected to increase slightly (0.6%) in the near future, and to increase more substantially (around 6%) in the far future. In the near future, rainfall is projected to decrease in summer, but increase markedly in autumn. In the far future, the change in rainfall in autumn is similar to that in the near future, but the changes in the other seasons are rather different in the two scenarios.

For the NSW coast in general, decreases in winter rainfall are projected with medium confidence. Other changes are unclear. An increased intensity of extreme rainfall events is projected with high confidence. Time spent in drought is projected, with medium confidence, to increase over the course of the century (CSIRO & BoM 2015).

Table 4.7 Summary of rainfall projections (interactive map; 10 km grid cell with Project)

Parameter	Near future (2020–2039)					Far future (2060–2079)				
	Spring	Summer	Autumn	Winter	Annual	Spring	Summer	Autumn	Winter	Annual
Change in rainfall (%)	+1.5	-4.8	+11.8	+3.1	+0.6	+7.0	+5.1	+12.1	-2.4	+6.1

The rainfall projections for the eight grid cells around the Project grid cell are compared with the values for the Project grid cell in Table 4.8. The central cell provides a broadly representative average value for the area, but is closer to the lower estimates in the surrounding cells.

Table 4.8 Comparison between projected rainfall for Project cell and surrounding cells

Parameter/statistic (all annual values)	Near future (2020–2039)		Far future (2060–2079)	
	Project cell	Surrounding cells	Project cell	Surrounding cells
Change in rainfall (%)	+0.6	+0.7 to +1.3	+6.1	+5.1 to +10.8

Table 4.9 summarises the rainfall projections based on the raw NARCliM data for Project location.

Firstly, comparing the NARCliM 1.0 data with the data from the AdaptNSW interactive map in Table 4.7, it can be seen that there is a general consistency between the data sets. There are, however, discrepancies for winter in both the near future and far future scenarios; the AdaptNSW interactive map shows a decrease, whereas NARCliM 1.0 shows an increase, although the absolute changes are small.

Secondly, the changes in rainfall in NARCliM 1.5 are significantly different from those in NARCliM 1.0; however, the pattern in the change is similar. There is also no common seasonal pattern in the two versions.

Thirdly, in NARCliM 1.5, annual rainfall is projected to increase in the near future and also in the far future overall (noting a projected decrease in winter). The seasonal pattern also changes, with significantly reduced rainfall between the near and far future in spring and winter.

Table 4.9 Summary of rainfall projections (raw NARCliM data for Project location)

Parameter/statistic	Near future (2020–2039), rel. to baseline					Far future (2060–2079), rel. to baseline				
	Spring	Summer	Autumn	Winter	Annual	Spring	Summer	Autumn	Winter	Annual
NARCliM 1.0 (change in rainfall)										
Change in rainfall (%)	+1.1	-3.1	+7.9	-1.5	+0.6	+8.7	+5.0	+11.6	+0.6	+7.0
NARCliM 1.5 (change in rainfall)										
Change in rainfall (%)	-5.4	+15.9	+9.1	+4.8	+7.5	-17.0	+14.7	+4.1	-18.1	+0.5

Information on rainfall (for the East Coast) is also available from the Climate Change in Australia project. Table 4.10 summarises the maximum rainfall projections for the East Coast cluster in the RCP8.5 scenario (Dowdy et al 2015). According to CSIRO & BoM (2015), understanding of the physical processes that cause extreme rainfall, coupled with modelled projections, indicate with high confidence a future increase in the intensity of extreme rainfall events, although the magnitude of the increases cannot be confidently projected.

Table 4.10 Summary of maximum rainfall projections (East Coast cluster)

Parameter/statistic	Near future (2030), rel. to baseline					Far future (2070), rel. to baseline				
	Spring	Summer	Autumn	Winter	Annual	Spring	Summer	Autumn	Winter	Annual
Change in maximum 1-day rainfall (median, %)	-5.6	+5.0	-1.5	-2.5	+1.5	-6.5	+10.8	-1.6	-8.9	+5.2

The combined changes in temperatures, rainfall and evaporation and climate systems are likely to make drought conditions in south-east Australia worse. The Standardised Precipitation Index (SPI) is used to assess the implications of climate change on droughts. Data for the East Coast cluster are summarised in Table 4.11 (Dowdy et al 2015). Time spent in drought is projected, with medium confidence, to increase over the course of the century in the RCP8.5 scenario. An increase in the frequency and duration of extreme drought is projected with low confidence (CSIRO & BoM 2015). With longer and more severe droughts, water flows into dams may decrease[11].

Table 4.11 Summary of time in drought (East Coast cluster; RCP8.5)

Parameter/statistic	Baseline (1995)	Near future (2030)[a]	Far future (2070) [a]
Time in drought (%)[b]	40	50	55
Duration of extreme drought[c] (months)	26	28	34
Freq. of extreme drought[c] (/20 years)	1.3	1.8	2.0

(a) Values are approximate, based on visual interpretation.

(b) Based on estimates of Standardised Precipitation Index (SPI), the proportion of time with SPI ≤ -1.

(c) Based on SPI ≤ -2.

4.2.4 Fire danger

The Forest Fire Danger Index (FFDI) is used in NSW to quantify fire weather. The FFDI combines observations of temperature, humidity, and wind speed with an estimate of the fuel state, with 17 stations in NSW and the ACT (OEH 2014b). FFDI estimates are only available for one station in the region: Moree. The annual and seasonal FFDI values at Moree for the period 1990–2009 are summarised in Table 4.12. The highest average FFDI occurs in spring and the lowest in winter (OEH 2014a).

Fire weather is classified as 'severe' when the FFDI is above 50, and most of the property loss from major fires in Australia has occurred when the FFDI reached this level. FFDI values below 12 indicate low to moderate fire weather, 12–25 high, 25–49 very high, 50–74 severe, 75–99 extreme and above 100 catastrophic. Severe fire weather conditions are estimated to occur, on average, 3.3 days per year at Moree, with spring and summer being the peak seasons for extreme fire weather conditions (OEH 2014a).

[11] https://www.climatechange.environment.nsw.gov.au/drought

Table 4.12 FFDI at locations in the region (OEH 2014a)

Statistic and location	Spring	Summer	Autumn	Winter	Annual
Mean FFDI					
Moree	12.1	13.8	11.9	7.5	15.3
Number of severe fire weather days[(a)]					
Moree	3.3	1.6	0.2	0	1.5

(a) FFDI >50.

There is high confidence that climate change will result in a harsher fire-weather climate in the future. However, there is low confidence in the magnitude of that change because of the significant uncertainties in the rainfall projection (CSIRO & BoM 2015).

Table 4.13 summarises the fire danger projections from the AdaptNSW interactive map and for the 10 km grid cell containing the Project. Relative to the baseline period, the average annual daily FFDI in the grid cell with the Project is projected to increase only very slightly (by 0.05 days) in the near future, and by 0.4 days in the far future.

Table 4.13 Summary of fire danger projections (10 km grid cell containing the Project)

Parameter	Near future (2020–2039), rel. to baseline					Far future (2060–2079), rel. to baseline				
	Spring	Summer	Autumn	Winter	Annual	Spring	Summer	Autumn	Winter	Annual
Change in high fire danger days (days)	0	+0.05	0	0	+0.05	+0.28	+0.12	0	0	+0.40

4.2.5 Storms

Dowdy et al (2015) note that there is a strong annual cycle of thunderstorms throughout the East Coast cluster, with a maximum during the warmer months and a minimum during the cooler months. The cluster has thunderstorms on about 20–50 days per year. Tropical cyclones can occur during the warmer months of the year. The eastern Australian region typically has four tropical cyclones per year, although there is a downward trend in their frequency.

The main causes of extreme storms along the NSW coast are ECLs. A considerable proportion of the heavy rainfall events on the central eastern seaboard can be associated with ECLs, and they also provide important rainfall to fill catchments and reservoirs. Storms caused by ECLs vary from year to year, and decade to decade. This makes it difficult to predict when they will occur, how severe they will be, and how they might be affected by climate change. The literature suggests a decrease in the overall number of ECLs in the future, although the climate modelling predicts that there may be more extreme systems in the warmer months, and fewer small-to-moderate systems in the cooler months (CSIRO & BoM 2015).

For the 'East Coast south' sub-cluster, it is anticipated that the proportion of the most intense storms will increase over the century while the intensity of associated rainfall may increase further.

4.2.6 Summary and limitations

The past and future climate data for the area in which the Project is located are consolidated in Table 4.14. The changes in the climate variables can be broadly summarised as follows:

- **Temperature**: Increases in average and maximum temperatures, as well as the number of hot days per year. The changes are more severe in the far future than in the near future. The confidence in the temperature predictions is very high. Evaporation is expected to increase with increased temperatures.
- **Rainfall**: Based on the latest NARCliM 1.5 data for the Project location:
  - an increase in annual rainfall in the near future, and an overall increase in the far future (noting a decrease in winter)
  - significantly reduced rainfall between the near and far future in spring and winter
  - increased intensity of extreme rainfall events in summer months in the near and far future.

  The confidence in the rainfall projections is generally low, although there is high confidence of an increased intensity.
- **Drought**: More frequent and prolonged droughts, with a low-to-medium level of confidence.
- **Fire danger**: Increase in high fire danger days. The confidence level is high for harsher fire-weather in general, but low for the actual magnitude of the change.
- **Storms**: Decrease in frequency of ECLs and tropical cyclones, but with increase in intensity in warmer months. The predictions for tropical cyclones have a medium confidence level.

Table 4.14 Summary and interpretation of climate projections

Parameter/ statistic	Baseline (historical)	Near future (2020–2039)					Far future (2060–2079)				
		NARCliM 1.0 (annual)	NARCliM 1.5 (annual)	CCA (East Coast)	Interpretation for use in CCRA	Confidence (CCA)	NARCliM 1.0 (annual)	NARCliM 1.5 (annual)	CCA (East Coast)	Interpretation for use in CCRA	Confidence (CCA)
Change in temperature											
Daily average (°C)	-	+0.7	+1.1	+1.0	Moderate increase in average temp	Very high	+2.0	+2.9	+2.7	Large increase in average temp	Very high
Daily maximum (°C)	-	+0.7	+1.0	+1.1	Moderate increase in max. temp	Very high	+2.0	+3.1	+2.7	Large increase in max. temp	Very high
Cold nights <2°C (days)	-	-8.25	-	-	Large reduction in freq. of cold nights	High	-22.3	-	-	Large reduction in freq. of cold nights	High
Hot days >35°C (days)	-	+2.0	-	-	Increased freq., severity & duration of extreme high temp	Very high	+7.6	-	-	Increased freq., severity & duration of extreme temp	Very high
Change in rainfall											
Change in rainfall (%)	-	+0.6	+7.5	-4.5	Rainfall projected to both increase and decrease in near future	Low for both the size and sign of change	+7.5	+0.5	-8.2	Rainfall projected to both increase and decrease in far future	Low for both the size and sign of change

Table 4.14 Summary and interpretation of climate projections

Parameter/ statistic	Baseline (historical)	Near future (2020–2039)					Far future (2060–2079)				
		NARCliM 1.0 (annual)	NARCliM 1.5 (annual)	CCA (East Coast)	Interpretation for use in CCRA	Confidence (CCA)	NARCliM 1.0 (annual)	NARCliM 1.5 (annual)	CCA (East Coast)	Interpretation for use in CCRA	Confidence (CCA)
Change in max. 1-day rain (%)	-	-	-	+1.5	Increased intensity of extreme rainfall events	High for increase in intensity; low for size of increase	-	-	+5.2	Increased intensity of extreme rainfall events	High for increase in intensity; low for size of increase
Droughts											
Time spent in drought (%)	40	-	-	50	Longer periods of drought	Medium	-	-	55	Longer periods of drought	Medium
Duration of extreme drought (months)	26	-	-	28	Increase of 8% in duration	Low	-	-	34	Increase of 30% in duration	Low
Freq. of extreme drought (/20y)	1.3	-	-	1.8	Increase in frequency	Low	-	-	2.0	Increase in frequency	Low
Fire danger											
Change in high fire danger (days)	-	+0.05	-	-	Very small increase in frequency and severity of bushfires	High for harsher fire-weather in general, low for the magnitude of the change	+0.40	-	-	Small increase in frequency and severity of bushfires	High for harsher fire-weather in general, low for the magnitude of the change

Table 4.14 Summary and interpretation of climate projections

Parameter/ statistic	Baseline (historical)	Near future (2020–2039)					Far future (2060–2079)				
		NARCliM 1.0 (annual)	NARCliM 1.5 (annual)	CCA (East Coast)	Interpretation for use in CCRA	Confidence (CCA)	NARCliM 1.0 (annual)	NARCliM 1.5 (annual)	CCA (East Coast)	Interpretation for use in CCRA	Confidence (CCA)
Storms											
Thunderstorms	-	-	-	-	Decline in the number of ECLs, but with more extreme systems in warmer months	N/A	-	-	-	Decline in the number of ECLs, but with more extreme systems in warmer months	N/A
Tropical cyclones (TCs)	-	-	-	-	TCs are projected to become less frequent, but with an increase in the proportion of intense storms	Medium	-	-	-	TCs are projected to become less frequent, but with an increase in the proportion of intense storms	Medium

4.3 Initial risk rating with no measures

4.3.1 Climate risk and adaptation workshop

The effects of the future changes in climate were considered in relation to potential impacts on Project assets or functions, including areas such as physical structures, transport, and worker safety. In total, 7 construction, and 34 operational potential impacts were identified.

A climate risk and adaptation workshop was held with OMPS on 17 June 2024. In the workshop, climate hazards were presented, and the corresponding risks to the Project and the environment were discussed with the Project team. This led to the definition of the risk ratings, and a discussion of potential mitigation and adaptation measures. Residual risks were also defined. The risk register was used to log the outcomes of the workshop (see Annexure B).

The participants in the workshop are given in Table 4.15. These participants were considered to be internal stakeholders for the purpose of the assessment. No external stakeholders were considered to be required for the workshop.

Table 4.15 Workshop attendees

Name	Title	Organisation
Paul Boulter	Associated Director – Air Quality and Climate	EMM Consulting
Francine Manansala	Associated – Air Quality and Climate	EMM Consulting
Ruth Kelly	Associated Director – Environmental Planning and Approvals	EMM Consulting
Alex Frolich	Associate Environmental Scientist	EMM Consulting
Daniel Nugent	Environmental Scientist	EMM Consulting
Mo El Said	Contracts Administrator	OMPS
Jeff Schofield	Project Development Manager	OMPS
Amanda Weston	Planning & Environment Manager	OMPS
Jake Spooner	Project Technical Director	OMPS

4.3.2 Risk rating method

The risk rating approach involved determining the following for each identified impact in the absence of mitigation measures:

- the likelihood of the impacts occurring
- the consequences of the impacts occurring
- the combination of the likelihood and consequences to define a risk rating.

The likelihood and consequence were considered in accordance with AS 5334 Climate change adaptation for settlements and infrastructure – A risk-based approach (see Annexure A) and were informed by the climate and projection data.

The relative levels of risk associated with the various impacts were used to prioritise their management.

4.3.3 Results

The risk ratings with no measures are provided in Annexure B. Following the workshop, EMM finalised the register and distributed it to the Project team for further review and comment. The risk register was updated based on additional feedback received.

The initial risk profile for the Project is summarised in Table 4.16. Most of the risk ratings were 'low' or 'medium'. The potential climate change impacts with 'high' or 'extreme' initial risk are summarised in Table 4.17.

Table 4.16 Initial risk profile for the Project

Risk rating	Near future (2020–2039)	Far future (2060–2079)
Construction		
Low	0	N/A
Medium	5	N/A
High	2	N/A
Extreme	0	N/A
Operation		
Low	17	8
Medium	12	18
High	4	6
Extreme	1	2
Total - construction	7	N/A
Total - operation	34	34

Table 4.17 Initial risk profile - high or extreme risk ratings

Risk ID	Climate hazard	Potential impact	High risk	Extreme risk
Construction				
CON-F-01	• Harsher fire weather in general. • Very small to small increase in the frequency and severity of bushfires.	Fire and smoke events prevent access to site, or result in evacuation of workers, disrupting operation and maintenance.	✓ (2030)	
CON-R-01	• There is an increase in annual rainfall in the near future, which then reduces to a small increase in the far future. There is an expected increase in the intensity of extreme rainfall events and the magnitude of flood flows.	Heavy downpours damage unsurfaced roads, cause slope instability that blocks roads, or cause flooding. Temporary bridges will overtop more frequently and limit access.	✓ (2030)	

Risk ID	Climate hazard	Potential impact	High risk	Extreme risk
Operation				
OP-T-03	• Increase in average and maximum temperatures. • Increased frequency, severity & duration of extreme (high) temperature periods.	Higher temperatures, more frequent hot days, and heatwaves lead to increased evaporation from reservoirs. This could increase the need for operational extraction from the Macleay River. If this is not possible (e.g. during drought periods), then this could potentially reduce hydropower generation.	✓ (2070)	
OP-F-01	• Harsher fire weather in general. • Very small to small increase in the frequency and severity of bushfires.	Bushfire damage to the dam and ancillaries. Extreme fire events damaging structures, buildings and utilities, which disrupts operation.	✓ (2030)	✓ (2070)
OP-F-03		Bushfire damage to transmission lines, and loss of power to the asset affecting operation.	✓ (2030 and 2070)	
OP-F-07		Smoke affects visibility along access roads, causing traffic accidents, resulting in injury and vehicle damage.	✓ (2030 and 2070)	
OP-F-08		Fire and smoke events resulting in death, serious illness, or minor injuries requiring medical treatment.		✓ (2030 and 2070)
OP-R-10	• There is an increase in annual rainfall in the near future, which then reduces to a small increase in the far future. There is an expected increase in the intensity of extreme rainfall events and the magnitude of flood flows.	Rainfall increases risk of traffic accidents, exposure, and need for evacuation if there is flooding.	✓ (2030 and 2070)	
OP-E-01	• Given the increase in temperatures, there is expected to be an increase in annual evaporation in the future. The change in evaporation combined with the change in seasonal flows is expected to have a greater impact on the operation of the scheme. In the near future, rainfall (and flows) will generally increase (i.e. in summer, autumn and winter) and reduce in spring. In the far future, rainfall will increase overall, but with significant reductions in the winter and spring seasons combined with increases in evaporation.	Similar to OP-T-03: increases in evaporation and reductions in seasonal flows can result in requiring more top-up water and/or extended periods where there is less water available for top-ups. This may result in periods with a reduction in the operating volume in the reservoirs and consequently reduced energy output.	✓ (2070)	
OP-D-03	• Longer periods of drought. • Increase in drought duration. • Increase in drought frequency.	Similar to OP-T-03: Drought leads to greatest restrictions on water availability, which can result in less water being available for hydropower generation. Prolonged drought periods cause water levels to drop, potentially reducing operation.	✓ (2070)	

4.4 Identification of current/proposed and additional measures

The next step involved the identification of current/proposed measures to mitigate, adapt or build resilience to the identified risks from an operational perspective. This included an evaluation of the likely effectiveness of these measures, using the following categories:

- substantially effective
- partially effective
- largely ineffective.

Where current/proposed measures were identified as partially or largely ineffective, then additional measures were considered to eliminate or reduce the likelihood or consequence of the identified risks and associated impacts (see Annexure B).

By considering risks in the near future (2030) and far future (2070), this process took into account whether the measures would remain effective over time as climate change risks increase.

4.5 Residual risk

The final step was the assessment of residual risks once all measures had been applied. The residual risk ratings are provided in Annexure B. For most potential climate change impacts the residual risk was determined to be 'low'. For these, it is therefore considered that additional contingencies would not need to be considered. The impacts with a residual risk above 'low' are identified in Table 4.18.

Table 4.18 Climate change impacts with residual risk above 'low'

Risk ID	Climate hazard	Potential impact	Residual risk
OP-E-01	Given the increase in temperatures, there is expected to be an increase in annual evaporation in the future. The change in evaporation combined with the change in seasonal flows is expected to have a greater impact on the operation of the scheme. In the near future, rainfall (and flows) will generally increase (i.e. in summer, autumn and winter) and reduce in spring. In the far future, rainfall will increase overall, but with significant reductions in the winter and spring seasons combined with increases in evaporation.	Similar to OP-T-03: increases in evaporation and reductions in seasonal flows can result in requiring more top-up water and/or extended periods where there is less water available for top-ups. This may result in periods with a reduction in the operating volume in the reservoirs and consequently reduced energy output.	Medium (2070)
OP-D-03	• Longer periods of drought. • Increase in drought duration. • Increase in drought frequency.	Similar to OP-T-03: Drought leads to greatest restrictions on water availability, which can result in less water being available for hydropower generation. Prolonged drought periods cause water levels to drop, potentially reducing operation.	Medium (2070)

4.6 Review

As identified, the residual risk of climate change-related impacts is generally low for the Project. The effectiveness of site management strategies and design would be reviewed on an ongoing basis throughout the life of the Project, in line with annual environmental reporting requirements for the site.

The need to review the climate change impact risk assessment would be considered in alignment with the release of revisions to the NSW NARCliM modelling dataset (i.e. NARCliM 2.0).

5 Summary and conclusions

OMPS is proposing to develop the Oven Mountain Pumped Hydro Energy Storage Project an off-river pumped hydro energy storage system. This report has provided a CCRA for the Project.

The climate in the area of the Project in the near future (2030) and far future (2070) was characterised using a range of data sources, and notably the projection data from the NARCliM 1.0 and NARCliM 1.5 projects. Climate was characterised using variables relating to temperature, rainfall, droughts and fire danger, along with qualitative information on storms.

A climate risk and adaptation workshop was held with OMPS. The effects of the future changes in climate were considered in relation to potential impacts on Project assets or functions, including areas such as physical structures, transport, and worker safety.

In total, 7 potential impacts were identified during construction and 34 were identified during operation. In the workshop, the potential risks to the Project and the environment were discussed with the Project team. In the initial risk profile, with no mitigation/adaption measures, most of the risk ratings were 'low' or 'medium'.

Planned and additional measures were then considered. These included:

- Design:
  - Upgrade the road network to improve resilience. Investigations will need to be done to confirm if this is viable from a cost perspective.
  - Assess the impact of the capacity of the spillways being exceeded on the dam stability and based on risks and costs, consider additional impact of oversizing the spillway crest.
  - Flood flow to be designed to exceed criteria.
  - Implementation of a plan to monitor flooding events.
- Operation:
  - Operations can commence with reduce storage volume if required.
  - Timed or more frequent operational top-ops prior to dry weather events or increased drought reserve in reservoirs.
  - Possibility to apply stop work practices (under investigation).
  - Coordination with the Rural Fire Service (RFS) with respect to planning and water take for firefighting.
  - Consideration of critical spares list for the transmission lines.
- Plans and schedules:
  - Consideration of future water licences.
  - Planning maintenance outside of projected storm events and monitoring of storms.

The final step was the assessment of residual risks once all measures had been applied. Again, for most potential climate change impacts the residual risk was determined to be 'low'.

6 References

AGO 2006, Climate Change Impacts & Risk Management – A Guide for Business and Government, Australian Greenhouse Office, Department of the Environment and Heritage, Canberra.

BoM & CSIRO 2019, Regional Weather and Climate Guide – 019 Northern Tablelands, http://www.bom.gov.au/climate/climate-guides/guides/019-Northern-Tablelands-NSW-Climate-Guide.pdf

CSIRO & BoM (2015), Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report, CSIRO and Bureau of Meteorology, Australia, (https://www.climatechangeinaustralia.gov.au/). The projections for the East Coast of Australia summarised at: https://www.climatechangeinaustralia.gov.au/en/projections-tools/regional-climate-change-explorer/clusters/?current=ECC&popup=true&tooltip=true

DCCEEW 2023, National Climate Risk Assessment Methodology, August 2023, Australian Government Department of Climate Change, Energy, the Environment and Water, Canberra.

Dowdy, A et al 2015, East Coast Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports, eds. Ekström, M. et al., CSIRO and Bureau of Meteorology, Australia.

DPIE 2020a, The NSW and ACT Regional Climate Modelling Project: Climate Projections Version 1.5 NARCliM1.5 Technical Methods Report, NSW Department of Planning, Industry and Environment, https://climatedata-beta.environment.nsw.gov.au/documents/tech.pdf

IHA 2019, Hydropower Sector Climate Resilience Guide, International Hydropower Association, London, https://assets-global.website-files.com/64f9d0036cb97160cc26feba/64f9d0036cb97160cc270fd6_hydropower_sector_climate_resilience_guide.pdf

Nishant N, Evans J P, Di Virgilio G, Downes S M, Ji F, Cheung K K W, Tam E, Miller J, Beyer K and Riley M L 2021, Introducing NARCliM1.5: Evaluating the Performance of Regional Climate Projections for Southeast Australia for 1950–2100, Earth's Future, 9.

OEH 2014a, New England North West - Climate change snapshot, NSW Office of Environment and Heritage, Sydney South.

OEH 2014b, New South Wales - Climate change snapshot, NSW Office of Environment and Heritage, Sydney South.

Ramboll 2023, Guidance note on climate change risk assessment, https://equator-principles.com/app/uploads/Guidance-CCRA_May-2023.pdf

7 Abbreviations

AHD	Australian Height Datum
BoM	Bureau of Meteorology
CCRA	climate change risk assessment
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ECL	East Coast Low
EIS	environmental impact statement
FFDI	Forest Fire Danger Index
FSL	full-supply level
GCM	global climate model
GHG	greenhouse gas
ha	hectare
IPCC	Intergovernmental Panel on Climate Change
km	kilometre
NARCliM	NSW and Australian Regional Climate Modelling
NEM	National Electricity Market
NSW	New South Wales
RCM	regional climate model
SEARs	(NSW Planning) Secretary's Environmental Assessment Requirements
TC	tropical cyclone

Annexure A

Risk rating method

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Table A.1 Likelihood criteria

Rating	Recurrent risks	Single events
Almost certain	Could occur several times per year	More likely than not – probability greater than 50%
Likely	May arise about once per year	As likely as not – 50/50 chance
Possible	May arise once in 10 years	Less likely than not but still appreciable – probability less than 50% but still quite high
Unlikely	May arise once in 10 to 25 years	Unlikely but not negligible – probability low but noticeably greater than zero
Rare	Unlikely during the next 25 years	Negligible – probability very small, close to zero

Table A.2 Consequence criteria

	Impact area				
Consequence	**Safety**	**Production**	**Environment**	**Compliance**	**Workforce**
Catastrophic	Large numbers of serious injuries or loss of lives	Loss of a key source of supply or ceasing of activity, threatening production	Major widespread loss of environmental amenity and progressive irrecoverable environmental damage	Obvious and proven breaches of legal and regulatory requirements with the prospect of corporate or individual penalties	Severe shortages of personnel or workplace disruption would make it difficult to sustain operations
Major	Isolated instances of serious injuries or loss of lives	Disruption to a key source of supply or to an activity, having a serious effect on production	Severe loss of environmental amenity and a danger of continuing environmental damage	Significant amounts of management and advisers' effort would be required to answer charges of compliance failures	Operations would be severely affected by shortages of personnel
Moderate	Small numbers of injuries	Components of the supply chain or the activity would require additional management attention to maintain production levels	Isolated but significant instances of environmental damage that might be reversed with intensive efforts	Formal action would be required to answer perceived breaches or charges of compliance failure	Parts of the workforce and staff team would require more than normal levels of management attention
Minor	Serious near misses or minor injuries	Isolated supply or activity issues would arise but would be resolved	Minor instances of environmental damage that could be reversed	Minor perceived or actual breaches of compliance would be resolved	Isolated personnel shortages would be resolved
Insignificant	Appearance of a threat but no actual harm	Minor supply or activity issues would arise but would pass without special attention	No environmental damage	Concerns about compliance would be resolved without special action	Minor workforce issues would pass without any special attention

Table A.3 Risk matrix

Likelihood	Consequence				
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	Medium risk	Medium risk	High risk	Extreme risk	Extreme risk
Likely	Low risk	Medium risk	High risk	High risk	Extreme risk
Possible	Low risk	Medium risk	Medium risk	High risk	High risk
Unlikely	Low risk	Low risk	Medium risk	Medium risk	Medium risk
Rare	Low risk	Low risk	Low risk	Low risk	Medium risk

Annexure B

Climate change risk register

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The climate change risk register is provided in Table B.1. Note that 'CON' refers to construction and 'OP' refers to operations.

Table B.1 Climate change risk register

Risk ID	Climate hazard	Potential impact on Project asset or function	Risk assessment (no measures) 2030 Likelihood	2030 Consequence	2030 Rating	2070 Likelihood	2070 Consequence	2070 Rating	Planned measures Description	Planned measures Effectiveness	Additional measures	Residual risk 2030 Rating	Residual risk 2070 Rating
CON-T-01	**Temperature** • Increase in average and maximum temperatures. • Increased frequency, severity & duration of extreme (high) temperature periods.	Increased temperatures lead to delays to the initial fill of the reservoirs and commissioning of the units.	Possible	Minor	Medium	N/A	N/A	N/A	Consideration of water license conditions for abstracting water from the river during the construction schedule to enable early impoundment and to maximise filling time as much as possible.	Substantially effective	Require sufficient water to enable commissioning of the units. Can commence operations with reduced storage volume if required.	Low	N/A
CON-T-02		Extreme temperatures lead to heat stress on workers, or restricted working conditions/hours due to WHS policies. NB: ~600 workers during construction phase.	Possible	Minor	Medium	N/A	N/A	N/A	- Already taken into account in current design, and allowed for in contractor arrangements. - In addition, worker activities could be redirected.	Substantially effective	Not required.	Low	N/A
OP-T-01		Higher temperatures, more frequent hot days and heatwaves lead to damage, deterioration or performance of dam and ancillaries (turbines, pumps, condensers, communications, heating, air conditioning, etc.), requiring repair and increased maintenance, with disruption to operation. Hot weather decreases the lifetime of transformers.	Rare	Minor	Low	Unlikely	Moderate	Medium	- Cooling water pumped through turbines. Operations cease prior to damage to assets (if no water availability). - The infrastructure will be new and therefore deterioration is likely to be insignificant. - Concrete structures unlikely to be affected by 2-3°C temperature change. - Flagging higher temperatures in the design specifications for structures and equipment. - HVAC will include a climate change sensitivity analysis as it is governed by the surface temperature.	Substantially effective	Not required.	Low	Low
OP-T-02		Increase in temperature within the powerhouse causing issues for workers and equipment.	Rare	Minor	Low	Rare	Minor	Low	The powerhouse is underground and therefore the temperature of the powerhouse should be relatively constant.	Substantially effective	Not required.	Low	Low
OP-T-03		Higher temperatures, more frequent hot days, and heatwaves lead to increased evaporation from reservoirs. This could increase the need for operational extraction from the Macleay River. If this is not possible (e.g. during drought periods), then this could potentially reduce hydropower generation.	Possible	Moderate	Medium	Almost certain	Moderate	High	There is a 85 ML drought reserve in reservoir.	Partially effective	Timed or more frequent operational top-ops prior to dry weather events or increased drought reserve in reservoirs.	Low	Low
OP-T-04		Increased temperatures cause higher general demand for water (mostly upstream of the pumping station), particularly in drought years, which can result in less water being available for hydropower. NB: The risks for this have been considered under drought (OP-D-03), and therefore the cells to the right are blank.											
OP-T-05		Increased temperature leads to a reduction in conductor efficiency and durability (IHA).	Likely	Minor	Medium	Likely	Minor	Medium	- Maintenance of the asset. - Captured in design (design life of component parts).	Substantially effective	Not required.	Low	Low
OP-T-06		Unexpected variations in reservoir temperature and increase in algae.	Possible	Minor	Medium	Likely	Minor	Medium	- Maintenance of the asset. - Captured in design (design life of component parts).	Substantially effective	Not required.	Low	Low

Risk ID	Climate hazard	Potential impact on Project asset or function	Risk assessment (no measures)						Planned measures		Additional measures	Residual risk	
			2030			2070			Description	Effectiveness		2030	2070
			Likelihood	Consequenc	Rating	Likelihood	Consequenc	Rating				Rating	Rating
OP-T-07		Increased water temperatures causing problems for cooling water operation in closed circuits. Leading to service interruption and increased maintenance.	Possible	Minor	Medium	Likely	Minor	Medium	- Considered in the design of components and ability to upgrade during future maintenance.	Substantially effective	Not required.	Low	Low
OP-T-08		Extreme temperatures lead to heat stress on workers (or restricted working conditions/hours due to WHS policies), affecting the functioning of the asset. NB: There will only be a small number of workers during operation phase.	Possible	Insignificant	Low	Likely	Insignificant	Low	- WHS policies. - Ability to schedule major maintenance periods accordingly. - Can modify operating requirements to adapt.	Substantially effective	Not required.	Low	Low
CON-F-01	**Fire danger** • Harsher fire weather in general. • Very small to small increase in the frequency and severity of bushfires.	Fire and smoke events prevent access to site, or result in evacuation of workers, disrupting operations and maintenance.	Possible	Catastrophic	High	N/A	N/A	N/A	- Maintain safe access and egress. - WHS policies. - Significant discussions with contractors. - The number of fire risk days will be taken into account in the construction schedule.	Partially effective	Possibility to apply stop work practices (under investigation).	Low	N/A
OP-F-01		Bushfire damage to the dam and ancillaries. Extreme fire events damaging structures, buildings and utilities, which disrupts operation.	Possible	Catastrophic	High	Likely	Catastrophic	Extreme	- Firefighting water and assets on site. - Asset Protection Zones (APZ) and refuge. - Emergency access and egress routes. - Emergency management plans. - Potential to design structures to withstand fire conditions.	Substantially effective	Not required.	Low	Low
OP-F-02		Burned vegetation/debris falling into the reservoirs, including runoff, potentially impacting/blocking reservoir intakes.	Possible	Minor	Medium	Possible	Minor	Medium	- Trash screens to be installed on intakes. - Visual observations. - Potential for clearing.	Substantially effective	Not required.	Low	Low
OP-F-03		Bushfire damage to transmission lines, and loss of power to the asset affecting operation.	Possible	Major	High	Likely	Major	High	Transmission easements and maintenance of easement.	Partially effective	Coordination with Rural Fire Service (RFS).	Low	Low
OP-F-04		Increased bushfires may mean more water taken from reservoirs for firefighting, reducing availability for electricity generation and requiring more frequent top-ops.	Unlikely	Significant	Low	Possible	Minor	Medium	Minor drought reserve within reservoir.	Partially effective	Coordination with RFS with respect to planning and water take for firefighting.	Low	Low
OP-F-05		Impacts on transport network (internal/external roads). Access routes to the asset affected by physical damage to roads from fire (short-term, or long-term if damage is extensive).	Possible	Insignificant	Low	Possible	Insignificant	Low	- Alternate access routes for emergency. - Helicopter landings. - Remote operations. - Planning of maintenance activities to avoid bushfire risk seasons.	Substantially effective	Not required.	Low	Low
OP-F-06		Fire and smoke events prevent access to site, or result in evacuation of workers, disrupting operations and maintenance.	Unlikely	Minor	Low	Possible	Minor	Medium	- WHS policies. - Alternate access routes for emergency (Upper Dam Access Road and Carrai). - Helicopter landings. - Firefighting provisions on site and firefighting water. - Evacuation. - Coordination with RFS.	Substantially effective	Not required.	Low	Low

Risk ID	Climate hazard	Potential impact on Project asset or function	Risk assessment (no measures)						Planned measures		Additional measures	Residual risk	
			2030			2070			Description	Effectiveness		2030	2070
			Likelihood	Consequenc	Rating	Likelihood	Consequenc	Rating				Rating	Rating
OP-F-07		Smoke affects visibility along access roads, causing traffic accidents, resulting in injury and vehicle damage.	Likely	Major	High	Likely	Major	High	- WHS policies. - Alternate access routes for emergency (Upper Dam Access Road and Carrai). - Helicopter landings. - Firefighting provisions on site and firefighting water. - Evacuation. - Coordination with RFS.	Substantially effective	Not required.	Low	Low
OP-F-08		Fire and smoke events resulting in death, serious illness, or minor injuries requiring medical treatment.	Likely	Catastrophic	Extreme	Almost certain	Catastrophic	Extreme	- WHS policies. - Alternate access routes for emergency (Upper Dam Access Road and Carrai). - Helicopter landings. - Firefighting provisions on site and firefighting water. - Evacuation. - Design of HVAC system. - Coordination with RFS	Substantially effective	Not required.	Low	Low
CON-R-01	**Rainfall** There is an increase in annual rainfall in the near future, which then reduces to a small increase in the far future. There is an expected increase in the intensity of extreme rainfall events and the magnitude of flood flows.	Heavy downpours damage unsurfaced roads, cause slope instability that blocks roads, or cause flooding. Temporary bridges will overtop more frequently and limit access.	Possible	Major	High	N/A	N/A	N/A	- Separate access road. - Major repairs to previous damage to increase stabilisation.	Partially effective	Further upgrades of the road network to improve resilience. Investigations will need to be done to confirm if this is viable from a cost perspective.	Medium	N/A
OP-R-01		Extreme rainfall exceeds the design criteria of dam or other components, resulting in damage, shutdown or extended disruption.	Rare	Major	Low	Unlikely	Major	Medium	Probable Maximum Flood (PMF) design (expected to increase due to climate change). Will need to take into account latest information on uplifts on flood flows.	Substantially effective	Assess the impact of the capacity of the spillways being exceeded on the dam stability and based on risks and costs, consider additional impact of oversizing the spillway crest.	Low	Low
OP-R-02		Slope instability. Surface water triggers failures (IHA).	Possible	Minor	Medium	Possible	Minor	Medium	- Rehab and monitoring. - Spoil slope design to ensure stable landform	Substantially effective	Not required.	Low	Low
OP-R-03		Flooding of powerhouse (IHA).	Rare	Major	Low	Unlikely	Major	Medium	Tunnel portals will be clear of flood prone areas.	Substantially effective	Not required.	Low	Low
OP-R-04		Slope instability. Heavy rain triggers slope movement, rockfall, mudslides into reservoir (IHA).	Rare	Moderate	Low	Rare	Moderate	Low	- PMF design. Will need to take into account latest information on uplifts on flood flows. - Consider reservoir rim stability in design.	Substantially effective	Not required.	Low	Low
OP-R-05		Sediment load. Increased sediment load resulting in loss of reservoir storage capacity (and turbine erosion) (IHA).	Rare	Minor	Low	Rare	Minor	Low	Not required.	Substantially effective	Not required.	Low	Low

Risk ID	Climate hazard	Potential impact on Project asset or function	Risk assessment (no measures) 2030 Likelihood	Consequenc	Rating	2070 Likelihood	Consequenc	Rating	Planned measures – Description	Effectiveness	Additional measures	Residual risk 2030 Rating	2070 Rating
OP-R-06		Slope instability. Heavy rain triggers slope movement, rockfall, mudslides (IHA).	Rare	Moderate	Low	Unlikely	Moderate	Medium	Maintenance of access tracks.	Partially effective	As maintenance is carried out over the life of the scheme, further upgrades of the road network to improve resilience may be required or could be considered appropriately.	Low	Low
OP-R-07		Flooding along transmission route. Damage to transmission towers, and more difficult access for maintenance.	Unlikely	Moderate	Medium	Possible	Moderate	Medium	Design of infrastructure and access.	Partially effective	As maintenance is carried out over the life of the scheme, further upgrades of the road network to improve resilience may be required or could be considered appropriately.	Low	Low
OP-R-08		Increased variability in water levels leads to more unpredictable electricity generation (peak, time day, seasonal) (IHA).	Rare	Insignificant	Low	Rare	Insignificant	Low	Not required.	Substantially effective	Not required.	Low	Low
OP-R-09		Heavy downpours damage unsurfaced roads, cause slope instability that blocks roads, or cause flooding.	Unlikely	Minor	Low	Possible	Minor	Medium	Maintenance of access tracks.	Partially effective	As maintenance is carried out over the life of the scheme, further upgrades of the road network to improve resilience may be required or could be considered appropriately.	Low	Low
OP-R-10		Rainfall increases risk of traffic accidents, exposure, and need for evacuation if there is flooding.	Possible	Major	High	Possible	Major	High	- Use of suitable weather forecasting to provide weather warnings of expected storm events. - Provision of alternative access routes in the event of emergency. - Traffic movements before and during storm events will be considered.	Substantially effective	Not required.	Low	Low
OP-R-11		Increased rainfall and flooding could increase the risk of more frequent dam spilling. Potential impacts include scouring, impacts on downstream habitat, water quality impacts, potential flooding downstream, and damage to property.	Rare	Moderate	Low	Unlikely	Moderate	Medium	- Consider suitable flood flow for the spillway design. - Monitoring of erosion and scour at the spillway. - Consider scheme operation during spilling events (not to exacerbate spill flows).	Substantially effective	- Design to exceed criteria. - Implement monitoring plan.	Low	Low
CON-E-01	**Evaporation** There is expected to be an increase in annual evaporation in the future based on the projected temperature data. In the near future, rainfall (and flows) will generally increase (i.e. in summer, autumn and winter) and reduce in spring. In the far future, rainfall will increase overall, but with significant reductions in the winter and spring seasons.	Similar to CON-T-01, increased evaporation, combined with reduced seasonal rainfall leads to delays to the initial fill of the reservoirs.	Possible	Minor	Medium	N/A	N/A	N/A	Consideration of water license conditions for abstracting water from the river during the construction schedule to enable early impoundment and to maximise filling time as much as possible.	Substantially effective	Not required	Low	N/A
OP-E-01		Similar to OP-T-03: increases in evaporation and reductions in seasonal flows can result in requiring more top-up water and/or extended periods where there is less water available for top-ups. This may result in periods with a reduction in the operating volume in the reservoirs and consequently reduced energy output.	Possible	Moderate	Medium	Almost certain	Moderate	High	Climate change impacts will be considered when specifying the drought reserve volume in the lower reservoir.	Partially effective	Consideration of future water licences	Low	Medium
CON-D-01	**Drought**	Similar to CON-T-01: Droughts lead to longer delays to the initial fill of the reservoirs.	Possible	Minor	Medium	N/A	N/A	N/A	Consideration of water license conditions for abstracting water from the river during the construction schedule to enable early impoundment and to maximise filling time as much as possible.	Substantially effective	Not required.	Low	N/A

Risk ID	Climate hazard	Potential impact on Project asset or function	Risk assessment (no measures) 2030			2070			Planned measures		Additional measures	Residual risk 2030	2070
			Likelihood	Consequenc	Rating	Likelihood	Consequenc	Rating	Description	Effectiveness		Rating	Rating
OP-D-02	• Longer periods of drought. • Increase in drought duration. • Increase in drought frequency.	If drought is followed by intense rainfall, there could be damage to roads and erosion and sediment control (ERSED), project infrastructure and slope instability.	Possible	Minor	Medium	Possible	Minor	Medium	Risk and impacts will be considered in design.	Substantially effective	Not required.	Low	Low
OP-D-03		Similar to OP-T-03: Drought leads to greatest restrictions on water availability, which can result in less water being available for hydropower generation. Prolonged drought periods cause water levels to drop, potentially reducing operation.	Possible	Minor	Medium	Likely	Moderate	High	Climate change impacts to be considered when specifying the drought reserve volume in the lower reservoir.	Partially effective	Timed or more frequent operational top-ops prior to dry weather events; or increased drought reserve in reservoirs.	Low	Medium
CON-S-01	**Storms (other than extreme rainfall)** • Decrease in the number of East Coast Lows, but with more extreme systems in warmer months. • Tropical cyclones becoming less frequent, but with an increase in the proportion of intense	Storms damage or block access routes.	Possible	Moderat	Medium	N/A	N/A	N/A	Culverts and drainage paths to be kept clear, and will ensure suitable maintenance of access routes.	Substantially effective	Not required.	Low	N/A
OP-S-01		High winds and/or lightning cause damage to structures and systems, including electricity poles/cables, power systems, motors etc. Interruptions to power supply and loss of amenity (e.g. lighting) or communication systems, equipment failure, impacting the asset operations.	Rare	Moderate	Low	Unlikely	Moderate	Medium	Inclusion of lightning conductors in design, underground fibre optic for comms.	Substantially effective	Not required.	Low	Low
OP-S-02		Storms could result in damage to transmission lines.	Unlikely	Moderate	Medium	Possible	Moderate	Medium	Comply with required design standards, and use standard design with replacement parts that are readily available to undertake repairs if required.	Substantially effective	Consideration of critical spares list.	Low	Low
OP-S-03		Debris in water from storms. Storms result in increased large suspended material in the water (e.g. tress, branches), leading to blockages and damage, thereby increasing maintenance and affecting operation.	Rare	Insignificant	Low	Likely	Insignificant	Low	Trash screens on intakes, maintenance	Substantially effective	Not required.	Low	Low
OP-S-04		Impacts on transport network. More severe storms causing damages to trees, resulting in blocked local roads, preventing access by operators and essential services (usually short-term).	Possible	Insignificant	Low	Possible	Insignificant	Low	Not required.	Substantially effective	Not required.	Low	Low
OP-S-05		Danger to staff that are on-site during an event. On-site staff could be vulnerable to storm-related injury and death (e.g. wind-blown objects, electric shock).	Rare	Catastrop	Medium	Unlikely	Catastrop	Medium	Remote operation of asset, WHS policies	Substantially effective	Planning maintenance events and monitoring.	Low	Low

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