EnergyCo

September 2023

Central-West Orana Renewable Energy Zone Transmission project

Technical paper 14 – Hydrology and water quality

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Central-West Orana Renewable Energy Zone Transmission project
Technical paper 14 – Hydrology and water quality

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WSP acknowledges that every project we work on takes place on First Peoples lands.
We recognise Aboriginal and Torres Strait Islander Peoples as the first scientists and engineers and pay our respects to Elders past and present.

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Glossary

Term	Definition
Access roads	Permanent access roads to switching stations and energy hubs.
Access tracks	Temporary and permanent access tracks to transmission lines.
Annual Exceedance Probability (AEP)	The probability that a design event (rainfall or flood) has of occurring in any 1-year period.
The Blue Book	The *Managing Urban Stormwater – Soils and Construction* (Landcom, 2004) series of handbooks, also known as the Blue Book, are an element of the NSW Government's urban stormwater program specifically applicable to the construction phase of developments. These provide guidance for managing soils in a manner that protects the health, ecology and amenity of urban streams, rivers estuaries and beaches through better management of stormwater quality.
Catchment	The area drained by a stream or body of water or the area of land from which water is collected.
Central-West Orana REZ	A geographic area of approximately 20,000 square kilometres centred on the regional towns of Dubbo and Dunedoo and extending west to Narromine and east beyond Mudgee and to Wellington in the south and Gilgandra in the north, that will combine renewable energy generation, storage and HV transmission infrastructure to deliver energy to electricity consumers.
Construction area	The area that would be directly impacted by the construction of the project including (but not limited to) transmission towers and lines, brake and winch sites, access roads to switching stations and energy hubs, access tracks, energy hubs, switching stations, communications infrastructure workforce accommodation camps, construction compounds and laydown and staging areas.
Construction compound	An area used as the base for construction activities, usually for the storage of plant, equipment and materials, and/or construction site offices and worker facilities. It can also comprise concrete batching plant, crushing, grinding and screening plant, testing laboratory and wastewater treatment plant.
Construction routes	Roads used by construction vehicles (light and heavy).
Earthworks	All operations involved in loosening, excavating, placing, shaping and compacting soil or rock.
Enabling works	Activities that would be carried out before the start of substantial construction in order to make ready the key construction sites (including workforce accommodation camps and compounds), facilitate the commencement of substantial construction, manage specific features or issues and collect additional information required to finalise the final design and construction methodology.
EnergyCo	The Energy Corporation of New South Wales constituted by section 7 of the *Energy and Utilities Administration Act 1987* as the NSW Government-controlled statutory authority responsible for the delivery of NSW's REZs.

Term	Definition
Energy hub/s	An energy hub is a substation where energy exported from renewable energy generators or storage is aggregated, transformed to 500 kV (where required) and exported to the transmission network. For the project, this includes Merotherie Energy Hub and Elong Elong Energy Hub.
Erosion	A natural process where wind or water detaches a soil particle and provides energy to move the particle.
Floodplain	Area of land which is inundated by floods up to and including the probable maximum flood event (i.e. flood prone land).
Geomorphology	The geomorphology of watercourses and floodplains can be defined as the form that the landscape takes in response to long term dynamic interactions between catchment runoff processes, vegetation and underlying soils and geology. Sedimentation and erosion processes are the key catchment runoff processes that affect geomorphology.
Groundwater	Water found in the saturated zone below the water table or piezometric surface.
Groundwater dependent ecosystems (GDEs)	Groundwater dependent ecosystems (GDEs) are defined as ecosystems that require access to groundwater to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services.
Hydrology	Term given to the study of the rainfall and runoff process, including surface and groundwater interaction; with particular focus on the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Hydrology and surface water quantity and quality study area	The hydrology and surface water quantity and quality study area refers to the watercourse catchment areas that the project intersects. As defined above the catchment is the area drained by a stream or body of water or the area of land from which water is collected. The water sources (as described in the Macquarie-Bogan Water Resource Plan and the Hunter River Water Sharing Plan) boundaries are the extent of the study areas for this project.
Impact	Influence or effect exerted by a project or other activity on the natural, built and community environment.
Infiltration	The downward movement of water into soil and rock. It is largely governed by the structural condition of the soil, the nature of the soil surface (including presence of vegetation) and the antecedent moisture content of the soil.
Operation area	The area that would be occupied by permanent components of the project and/or maintained, including transmission line easements, transmission lines and towers, energy hubs, switching stations, communications infrastructure, access roads to the switching stations and energy hubs, maintenance facilities and permanent access tracks to the easements.
Pollutant	Any measured concentration of solid or liquid matter that is not naturally present in the environment.
(the) proponent	EnergyCo
(the) project	The Central-West Orana REZ Transmission project as described in the Environmental Impact Statement

Term	Definition
Regulated river	A regulated river is a river, stream or other watercourse, the flow of which is regulated by artificial structures such as dams, weirs, off-takes and storages. Releases are made to downstream users.
Renewable energy zone (REZ)	A geographic area identified and declared by the NSW Government as a REZ.
Runoff	The amount of rainfall that ends up as streamflow, also known as rainfall excess.
Stream order	A classification system which assigns an 'order' to watercourses according to the number of additional tributaries associated with each watercourse, to provide a measure of system complexity.
Study area	The hydrology and surface water quantity and quality study area for this assessment is defined as the catchment areas that the project is located within, being the Macquarie and Hunter Rivers including all major and minor tributaries within these catchments.
Substation	A facility used to increase or decrease voltages between incoming and outgoing lines (e.g. 330 kV to 500 kV).
Switching station	A facility used to connect two or more distinct transmission lines of the same designated voltage.
Transmission line easement	An area surrounding and including the transmission lines which is a legal 'right of way' and allows for ongoing access and maintenance of the transmission lines. Landowners can typically continue to use most of the land within transmission line easements, subject to some restrictions for safety and operational reasons.
Twin transmission line	A pair of single or double circuit transmission lines running parallel.
Unregulated River	Unregulated rivers are rivers that are not controlled by releases from a dam or regulated via the use of weirs and gated structures (i.e. they are 'free flowing').
Water Access Licence (WAL)	A water access licence for surface water is called an unregulated river access licence if the water is taken from and unregulated river, or a general security, high security or supplementary water access licence if the water is taken from a regulated river. The type of licences defines the priority of the water access, such that a high security licence has first priority. In regulated river systems, a high security regulated river licence provides a more reliable supply than a general security licence, as water is allocated to high security licences before remaining water in storage is allocated to general security licences. A supplementary water access licence is the lowest priority and is a right to take water from (unregulated) flows that come into a regulated river downstream of the regulating dam.
Watercourse	Any flowing stream of water, whether natural or artificially regulated (not necessarily permanent).
Water quality	Water quality refers to the chemical and physical quality of the water in all surface water features.
Water resource plan	Water resource plans set rules on how much water can be taken from the Basin, ensuring that the sustainable diversion limit is not exceeded over time.

Term	Definition
Water sharing plan	Water sharing plans are established under the WM Act and are the primary tool for defining water-sharing arrangements in NSW. The plans establish rules for sharing water between water users and the environment, and rules for water trading.
Workforce accommodation camps	Areas that would be constructed and operated during construction to house the construction workforce.

Abbreviations

Acronym	Definition
AEP	Annual Exceedance Probability
AHD	Australian height datum
ANZECC	Australian and New Zealand Environment Conservation Council
BoM	Bureau of Meteorology
CEMP	Construction Environmental Management Plan
CSSI	Critical State Significant Infrastructure
DO	Dissolved oxygen
DPE	(NSW) Department of Planning and Environment
EC	Electrical conductivity
EIS	Environmental Impact Statement
EY	Exceedances per year
GDE	Groundwater dependent ecosystems (GDEs)
GIS	Geographic information systems
km	Kilometres
LGA	Local government area
mAHD	Metres above Australian Height Datum
ML	Megalitre
NEM	National Electricity market
NSW	New South Wales
OEH	Office of Environment and Heritage (NSW Government)
REZ	Renewable Energy Zone
SWMP	Soil and Water Management Plan
TDS	Total dissolved solids
TN	Total Nitrogen
TP	Total Phosphorus
WAL	Water access licence

Executive summary

This technical paper assesses the potential impacts to hydrology and surface water quantity and quality from the construction and operation of the Central-West Orana Renewable Energy Zone Transmission project (the project) and has been prepared to support and inform the Environmental Impact Statement (EIS) for the project.

The impacts have been assessed in accordance with the Secretary's Environmental Assessment Requirements (SEARs) issued by the NSW Department of Planning and Environment (DPE) and against the relevant legislation and guidelines as they apply to hydrology and surface water quantity and quality.

Project overview

The NSW Government is leading the development of Renewable Energy Zones (REZ) across NSW to deliver renewable energy generation and storage, supported by high voltage transmission infrastructure. Energy Corporation of NSW (EnergyCo) is proposing the construction and operation of new electricity transmission infrastructure and new energy hubs and switching stations to connect new energy generation and storage projects within the Central-West Orana REZ to the existing electricity network (the project). The project is located within the Warrumbungle, Mid-Western Regional, Dubbo Regional and Upper Hunter local government areas (LGAs) and extends generally north to south from Cassilis to Wollar and east to west from Cassilis to Goolma.

The project would enable 4.5 gigawatts of new network capacity to be unlocked by the mid-2020s (noting the NSW Government's proposal to amend the Central-West Orana REZ declaration to allow for a transfer capacity of six gigawatts), and enable renewable energy generators within the Central-West Orana REZ who are successful in their bids to access the new transmission infrastructure to export electricity to the rest of the network. Importantly, the development of renewable energy generation projects in the Central-West Orana REZ is the sole responsibility of private generators and subject to separate planning and environmental approvals.

Legislative and policy context

Impacts to hydrology and surface water quantity and quality from construction and operation of the project have been assessed in accordance with the relevant legislation and guidelines as they apply to hydrology and surface water quantity and quality. Key guidelines considered as part of this assessment include:

- *Water Act 2007* (Cth)
- *Water Management Act 2000* (NSW)
- Macquarie Bogan Unregulated Rivers Water Sources 2012
- Hunter Unregulated and Alluvial Water Sources 2022
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018)
- National Water Quality Management Strategy
- Murray-Darling Basin Plan 2012
- Macquarie–Castlereagh Water Resource Plan June 2020
- Castlereagh Unregulated River Water Sources Water Sharing Plan 2011
- NSW Water Quality Objectives
- NSW Guidelines for controlled activities on waterfront land, 2012
- Landcom Managing Urban Stormwater – Soils and Construction, 2004
- Hunter River Salinity Trading Scheme, 2018.

Methodology

The methodology for this hydrology and surface water quantity and quality impact assessment includes:

- determination of the study area for this assessment
- describing the existing environment relevant to the study area, through a review of existing publicly available information, and other relevant information provided by EnergyCo
- conducting an assessment of the potential impacts of the project in relation to the surface water resources in the study area
- determining whether these impacts are significant
- development of appropriate mitigation measures for residual impacts.

The hydrologic processes include the annual rainfall and stream flows for the catchments the project is within, and this informs the understanding of the volume of available surface water resources. The water supply, water storage and existing water entitlements within the water source, such as domestic, public utility and agricultural uses was assessed against the potential water demands of the project to understand the impact of the project on the catchment and watercourse health.

Water quality refers to the chemical and physical quality of the water in all surface water features for the catchment and the hydrology and water quality study area. The assessment involved a desktop review of available water quality studies to determine the existing water quality baseline conditions, the environmental values and the level of protection required to inform the design and mitigation.

Existing environment

The hydrology and water quality study area for this assessment is defined as the catchment areas of the Macquarie and Hunter Rivers that the project is located within and includes all major and minor tributaries within these catchments. Within the Macquarie River catchment the Talbragar River is the major tributary (of the Macquarie River) intersecting the project. The Talbragar River is classified as a Strahler 9th order stream and has a number of tributaries including Coolaburragundy River whose catchment is beyond the operational and construction areas for the project. The Cudgegong River, which is a tributary of the Macquarie River, does not intersect the project but a number of its tributaries intersect the project and drain into Wialdar Creek and then into the Cudgegong River. The Hunter River is made up of a number of large tributaries with the eastern portion of the project located within the Goulburn River and the project intersects Wollar Creek which is a tributary of the Goulburn River.

The Macquarie River has a catchment area of 74,800 square kilometres to its junction with the Barwon River. The Talbragar River has a catchment area of 3,050 square kilometres to where it intersects with the Elong Elong Energy Hub. The project is estimated to cover approximately 0.36% of the total Macquarie River catchment.

The Hunter River catchment is 37,000 square kilometres (NSW DPE, 2020a), and around 0.2% of the project is located within this catchment. The Goulburn River is main sub-catchment that the project is located in, which is a Strahler 6th order stream.

The mean annual rainfall is 651.2 millimetres at Gulgong and 615.4 millimetres for Dunedoo (BoM, 2022). The NSW and ACT Regional Climate Modelling (NARCliM) project data for the Central West and Orana region predicts an increase of up to 0.2% in annual rainfall across the study area, but this varies across the region. However, the seasonal projections show a decrease in winter and spring rainfall but an increase in summer and autumn rainfall for the near future (2020–2039) period. For the far future (2060–2079) period the annual change is predicted to be an increase of up to 7.5%.

The project is located across the Macquarie Bogan, Hunter, and Castlereagh Unregulated and Alluvial Water Sharing plans (WSP), the unregulated Cudgegong River and the unregulated Goulburn River catchments. Where the unregulated parts of the catchments occur upstream of controls such as dams, the flows are dependent on rainfall and groundwater ingress. The project is located within the following surface water sources:

- Upper Talbragar Water Source
- Lower Talbragar Water Source
- Cooyal Wialdra Creek Water Source (part of the unregulated Cudgegong River catchment)
- Wollar Creek Water Source (part of the Goulburn River catchment), and
- Upper Goulburn River Water source.

These water sources would be the main source of surface water for the project. The NSW Water stream gauge data for the period between 1970 and 2022, indicates that on average the Elong Elong gauge on the Talbragar River has recorded flow for 28%. This means that for approximately two thirds of the year there is unlikely to be visible flow in the Talbragar River to allow extraction.

The water quality for the project can be separated into the Macquarie-Castlereagh Catchment and the Hunter Catchment. For the sections within the Macquarie-Castlereagh, water quality is rated mainly as ‘fair’, and then ‘poor’ at Elong Elong. For sections in the Hunter River catchment, there nearest water quality data is at Denman, some 160 kilometres downstream of the Wollar Substation. This site had rating of ‘fair’ for Total Nitrogen (TN) and ‘very poor’ for Total Phosphorus (TP), and then in 2020–2021 had an average daily salinity level of 855 micro siemens per centimetre which is within guidelines.

Potential construction impacts

The key water quality objective for the project is to appropriately manage water quality, including salinity, for environmental, social, cultural, and economic activity and therefore protect downstream environments from the potential impacts of surface runoff and discharge during construction and operation. It is anticipated that through correct implementation of the standard mitigation measures during construction there would be minimal impacts to the existing water quality in the study area. As such construction of the project would not cause significant changes to the water quality environment against the identified water quality objectives.

Where there are sensitive receiving environments located along the project, water quality impacts from the construction of the project are anticipated to be short-term and limited in extent.

There is a high chance of water being available for all construction activities for the 2024 and 2027 construction years. The impact to available water for other uses including the existing licences in the Upper and Lower Talbragar Rivers is low due to the low non-potable water demand volumes for the project during these construction years.

For the construction years 2025 and 2026, the available surface water for extraction would be limited by the preceding rainfall. These construction years are estimated to have an impact on water source supply volumes in both the Upper and Lower Talbragar Rivers. However, the Lower Talbragar has a large volume of potential water available and therefore the impact would be less and could be the preferred source for non-potable water for the project during low rainfall periods.

Potential operational impacts

Transmission line towers that are potentially located within watercourses may have minor, localised geomorphological impacts to the existing watercourses during flood events. The potential placement of the towers may be within minor low flow paths (1^{st} and 2^{nd} order streams) which would result in changes in the position of these flow paths and movement of sediment locally within the flow path. However, this would not affect the main watercourse channels and regular flow regimes within the channels.

The potential water quality impacts as a result of accidental spills or litter generated from operation and maintenance activities near watercourses, is expected to be minor and localised.

Management measures

It is anticipated that the implementation of appropriate soil and water management measures would mitigate and minimise the potential impacts to the hydrologic environment and water quality.

1 Introduction

1.1 Background

New South Wales (NSW) is currently undergoing an energy sector transformation that will change how we generate and use energy. The NSW Government is leading the development of Renewable Energy Zones (REZs) across NSW to deliver renewable energy generation and storage projects, supported by transmission infrastructure. A REZ connects renewable energy generation and energy storage systems to transmission infrastructure via energy hu, requiring the coordination of power generation and transmission infrastructure. By doing so, REZs capitalise on economies of scale to deliver clean, affordable and reliable electricity for homes, businesses and industry in NSW.

The Central-West Orana REZ was formally declared on 5 November 2021 under the *Electricity Infrastructure Investment Act 2020* As NSW's first REZ, the Central-West Orana REZ will play a pivotal role in underpinning NSW's transition to a clean, affordable and reliable energy sector.

The Central-West Orana REZ declaration (November 2021) provides for an initial intended network capacity of three gigawatts. The NSW Government is proposing to amend the declaration to increase the intended network capacity to six gigawatts, which would allow for more renewable energy from solar, wind and storage projects to be distributed through the NSW transmission network.

The proposed amendment is consistent with the NSW Network Infrastructure Strategy (EnergyCo, 2023) which identifies options to increase network capacity to 4.5 gigawatts initially under Stage 1 (which would be based on the infrastructure proposed in this assessment) and up to six gigawatts by 2038 under Stage 2 (which would require additional infrastructure beyond the scope of this assessment, and subject to separate approval). The proposed amendment also supports recent modelling by the Consumer Trustee in the draft 2023 Infrastructure Investment Objectives Report (AEMO, 2023) showing more network capacity will be needed to meet NSW's future energy needs as coal-fired power stations progressively retire.

Energy Corporation of NSW (EnergyCo), a NSW Government statutory authority, has been appointed as the Infrastructure Planner under the *Electricity Infrastructure Investment Act* 2020, and is responsible for the development and delivery of the Central-West Orana REZ. EnergyCo is responsible for coordinating REZ transmission, generation, firming and storage projects to deliver efficient, timely and coordinated investment.

EnergyCo is seeking approval for the construction and operation of new electricity transmission infrastructure and new energy hubs and switching stations to connect energy generation and storage projects within the Central-West Orana REZ to the existing electricity network (the project).

1.2 Purpose of this paper

This technical paper assesses the potential impacts to hydrology and water quantity and quality from the construction and operation of the project and has been prepared to support and inform the Environmental Impact Statement (EIS).

This technical paper has been prepared to address the relevant Secretary's environmental assessment requirements (SEARs) for the project issued by the Secretary of the NSW Department of Planning and Environment (DPE) for the project on 7 October 2022, and the supplementary SEARs on 2 March 2023. The SEARs relevant to the assessment of hydrology, flooding and water quality are presented in Table 1-1.

Table 1-1 SEARs relevant to this paper

Reference	Assessment requirement	Location where it is addressed
Water	An assessment of the impacts of the project on the quantity and quality of the region's surface water resources, including the Talbragar River, Coolaburragundy River, and the Castlereagh, Macquarie-Bogan and Hunter catchment areas, having regard to NSW Water Quality Objectives;	— Chapter 2, Section 2.3.4 — Chapter 4, Section 4.3 — Chapter 5, Section 5.2 and 5.3.7 (Construction assessment) — Chapter 6, Section 6.2 and 6.3 (Operational assessment) It is noted that the Coolaburragundy River catchment is beyond the construction and operational areas of the project. Impacts to this catchment is not expected.
	Details of water requirements, supply arrangements and wastewater disposal arrangements for construction and operation;	— Chapter 5, Section 5.2 (Construction assessment) — Chapter 6, Section 6.2 (Operational assessment)
	An assessment of the impacts of the project on groundwater aquifers and groundwater dependent ecosystems having regard to the NSW Aquifer Interference Policy and relevant Water Sharing Plans; and	Refer to Technical paper 17 – Groundwater
	An assessment of potential flooding impacts and risks to the project.	Refer to Technical paper 15 – Flooding
	Where the project involves works within 40 metres of the high bank of any river, lake or wetlands (collectively waterfront land), identify likely impacts to the waterfront land, and how the activities are to be designed and implemented in accordance with the DPI Guidelines for Controlled Activities on Waterfront Land (2018) and (if necessary) Why Do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings (DPI 2003); and Policy & Guidelines for Fish Habitat Conservation & Management (DPI, 2013); and	Chapter 7 (Recommended management and mitigation measures)
	a description of the erosion and sediment control measures that would be implemented to mitigate any impacts in accordance with the Managing Urban Stormwater: Soils & Construction series, including Volumes 1, 2A and 2C (Landcom);	Chapter 7 (Recommended management and mitigation measures)

1.2.1 Related technical papers

Other technical papers that have been prepared to support the EIS that are relevant to this Hydrology and Surface Water quantity and quality impact assessment include:

- Technical paper 17 – Groundwater: Connectivity between groundwater and surface water largely occurs via alluvial aquifers and changes to surface water can affect groundwater, so Technical paper 17 focuses on the potential changes to the alluvial aquifers as a result of the project.
- Technical paper 15 – Flooding: The hydrologic environment includes the annual and long term hydrologic cycle while the rainfall burst and flood producing rain events are covered by Technical paper 15 as part of the flooding impact assessment.

1.3 Project overview

The project comprises the construction and operation of new electricity transmission infrastructure, energy hubs and switching stations within the Central-West Orana REZ. The project would enable 4.5 gigawatts of new network capacity to be unlocked by the mid-2020s (noting the NSW Government’s proposal to amend the Central-West Orana REZ declaration to allow for a transfer capacity of six gigawatts), and enable renewable energy generators within the Central-West Orana REZ who are successful in their bids to access the new transmission infrastructure to export electricity onto the National Electricity Market (NEM). A detailed description of the project, including a description of key project components, the construction methodology and how it would be operated is provided in Chapter 3 of the EIS.

1.3.1 Features

The project would comprise the following key features:

- a new 500 kV switching station (the New Wollar Switching Station), located at Wollar to connect the project to the existing 500 kV transmission network
- around 90 kilometres of twin double circuit 500 kV transmission lines and associated infrastructure to connect two energy hubs to the existing NSW transmission network via the New Wollar Switching Station
- energy hubs at Merotherie and Elong Elong (including potential battery storage at the Merotherie Energy Hub) to connect renewable energy generation projects within the Central-West Orana REZ to the 500 kV network infrastructure
- around 150 kilometres of single circuit, double circuit and twin double circuit 330 kV transmission lines, supported on towers, to connect renewable energy generation and storage projects within the Central-West Orana REZ to the two energy hubs
- thirteen switching stations along the 330 kV network infrastructure at Cassilis, Coolah, Leadville, Merotherie, Tallawang, Dunedoo, Cobbora and Goolma, to transfer the energy generated from the renewable energy generation projects within the Central-West Orana REZ onto the project’s 330 kV network infrastructure
- underground fibre optic communication cables along the 330 kV and 500 kV transmission lines between the energy hubs and switching stations
- a maintenance facility within the Merotherie Energy Hub to support the operational requirements of the project
- microwave repeater sites at locations along the alignment, as well as outside of the alignment to Botobolar, to provide a communications link between the project and the existing electricity transmission and distribution network. The Botobolar site would be subject to assessment at the submissions report stage

- establishment of new, and upgrade of existing access tracks for transmission lines, energy hubs, switching stations and other ancillary works areas within the construction area, (such as temporary waterway crossings, laydown and staging areas, earthwork material sites with crushing, grinding and screening plants, concrete batching plants, brake/winch sites, site offices and workforce accommodation camps)
- property adjustment works to facilitate access to the transmission lines and switching stations. These works include the relocation of existing infrastructure on properties that are impacted by the project
- utility adjustments required for the construction of the transmission network infrastructure, along with other adjustments to existing communications, water and wastewater utilities. This includes adjustments to Transgrid's 500 kV transmission lines 5A3 (Bayswater to Mount Piper) and 5A5 (Wollar to Mount Piper) to provide a connection to the existing NSW transmission network, including new transmission line towers along the Transgrid network along the frontage of the New Wollar Switching Station, and other locations where there is an interface with Transgrid’s network.

1.3.2 Location

The project is located in central-west NSW within the Warrumbungle, Mid-Western Regional, Dubbo Regional and Upper Hunter Local Government Areas (LGAs). It extends north to south from Cassilis to Wollar and east to west from Cassilis to Goolma. The location of the project is shown in Figure 1-1.

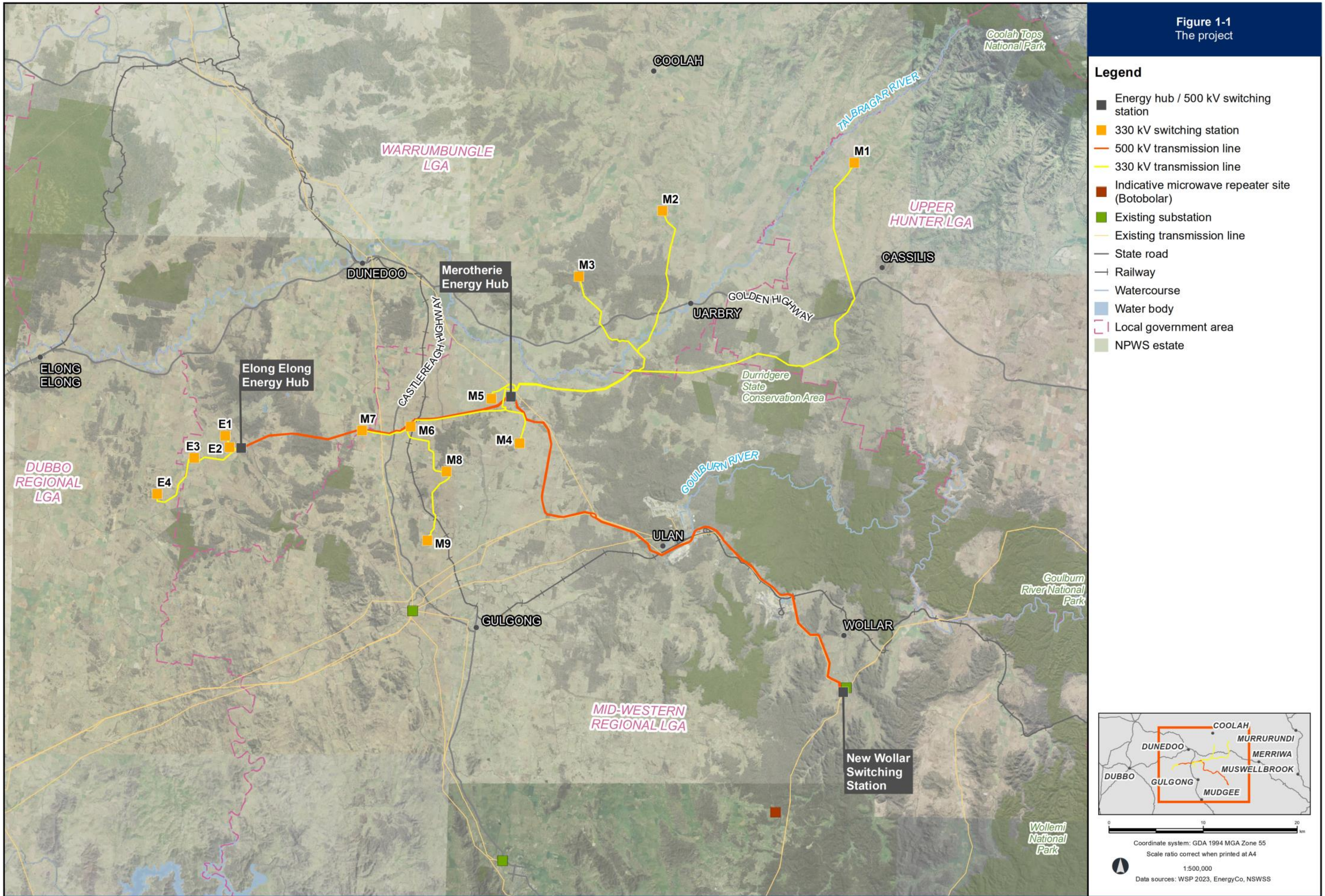


Figure 1-1
The project

C:\Users\AUJB505996\WSP O365\AU-WKG - Geospatial - AIS - Projects\PS130593_EnergyCo_CWO_Substation\Mxd\10_Hydrology\PS130593_HYDRO_F001_1_ProjectOverview_r1v7.mxd

1.3.3 Timing

Construction of the project would commence in the second half of 2024, subject to NSW Government and Commonwealth planning approvals, and is estimated to take about four years. The project is expected to be commissioned/energised (i.e. become operational) in late 2027.

1.3.4 Construction

Key construction activities for the project would occur in the following stages:

- enabling works
- construction works associated with the transmission lines
- construction works associated with energy hubs and switching stations
- pre-commissioning and commissioning of the project
- demobilisation and rehabilitation of areas disturbed by construction activities.

Excavation and land forming works within the construction area would be required for transmission line tower construction, site preparation works at the energy hubs and switching station sites to provide level surfaces, to create trenches for drainage, earthing, communications infrastructure and electrical conduits, and to construct and upgrade access tracks.

Construction vehicle movements would comprise heavy and light vehicles transporting equipment and plant, construction materials, and waste from construction activities including from workforce accommodation camps. There would also be additional vehicle movements associated with construction workers travelling to and from construction areas and workforce accommodation camps. These movements would occur daily for the duration of construction.

To support the construction of the project a number of construction compounds would be required in addition to staging and laydown facilities, concrete batching plants, workforce accommodation camps and construction support facilities. The main construction compounds would be established as enabling works and demobilised at the completion of construction. The size of the construction workforce would vary depending on the stage of construction and associated activities. During the peak construction period, an estimated workforce of up to around 1,800 people would be required.

1.3.5 Operation

During operation, the project would transfer high voltage electricity from the Central West-Orana REZ to the NEM. Permanent project infrastructure would be inspected by field staff and contractors on a regular basis, with other operational activities occurring in the event of an emergency (as required). Regular inspection and maintenance activities are expected to include:

- regular inspection (ground and aerial) and maintenance of electrical equipment and easements
- fault and emergency response (unplanned maintenance)
- general building, asset protection zone and landscaping maintenance
- fire detection system inspection and maintenance
- stormwater maintenance
- remote asset condition monitoring
- network infrastructure performance monitoring.

Operation of the project would require the establishment of transmission line easements. These easements would be around 60 metres for each 330 kV transmission line and 70 metres for each 500 kV transmission lines. Where network infrastructure is collocated, easement widths would increase accordingly (for example, a twin double circuit 500 kV transmission line would have an easement about 140 metres wide). Vegetation clearing would be required to some extent for the full width of the transmission line easement, depending on the vegetation types present.

1.4 Structure of the paper

The structure and content of this hydrology and surface water quantity and quality technical paper is as follows:

- Chapter 1 – provides an introduction to this technical paper (this chapter)
- Chapter 2 – provides an overview of the regulatory context for the hydrology and surface water quantity and quality assessment, including an overview of the legislation, policy and guidelines that apply to the project
- Chapter 3 – outlines the methodology adopted for this hydrology and surface water quantity and quality impact assessment
- Chapter 4 – describes the existing environment of the study area as it relates to hydrology and surface water quantity and quality
- Chapter 5 – describes the potential impacts to hydrology and surface water quantity and quality from construction of the project
- Chapter 6 – describes the potential impacts to hydrology and surface water quantity and quality from operation of the project
- Chapter 7 – provides recommended mitigation and management measures to avoid, minimise and manage any potential impacts to hydrology and surface water quantity and quality from construction and/or operation of the project
- Chapter 8 – identifies the key reports and documents used to generate this paper.

2 Legislative and policy context

Environmental planning approval for the project is required in accordance with the *Environmental Planning and Assessment Act 1979* (EP&A Act). The project is also a controlled action and therefore requires Commonwealth assessment and approval under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Sections 5.12 and 5.13 of the EP&A Act provide for the declaration of State significant infrastructure (SSI) and Critical State significant infrastructure (CSSI). On 23 November 2020, the Minister for Planning made the Environmental Planning and Assessment Amendment (Central-West Orana Renewable Energy Zone Transmission Order) 2020. The Order declares the whole Central-West Orana REZ Transmission project to be CSSI.

This section describes the Commonwealth and State legislation and policies relevant to the assessment of hydrology and surface water quantity and quality impacts.

2.1 Commonwealth legislation

2.1.1 Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is administered by the Australian Department of Climate Change, Energy, the Environment and Water and provides a legal framework to protect and manage nationally important flora, fauna, ecological communities, and heritage places defined as 'matters of national environmental significance' (MNES).

Under the EPBC Act, proposed actions (i.e., activities or projects) with the potential to significantly impact matters protected by the EPBC Act must be referred to the Australian Minister for the Environment to determine whether they are controlled actions, requiring approval from the Minister.

The legislation is relevant to the project because water, and particularly surface water, is a key factor for the survival of flora, fauna and ecological communities. In addition, river banks and water bodies are often associated with heritage sites and locations of cultural significance. Refer to Technical paper 4 – Biodiversity Development Assessment Report and Technical paper 5 – Aboriginal cultural heritage assessment report for further details.

Following a referral under the EPBC Act to the Department of Climate Change, Energy, the Environment and Water (DCCEEW), the project was determined to be a controlled action and would therefore require Commonwealth assessment and approval under the EPBC Act.

2.1.2 Water Act 2007

The *Water Act 2007* allows the Commonwealth in conjunction with the Basin States (South Australia, Victoria, New South Wales, Queensland, and the Australian Capital Territory) to manage Australia's largest water resource, the Murray-Darling Basin (MDB), in the national interest. Notably it gives functions to the Bureau of Meteorology (BOM) in reporting of water information and transferred the powers and functions of the Murray-Darling Basin Commission to the Murray-Darling Basin Authority (MDBA) through the Murray-Darling Basin Agreement.

The MDBA is responsible for calculating each state's share of water in the River Murray system, while Basin state governments allocate water within each water catchment in accordance with the bilateral agreement. For NSW, the states' share of the water is then defined by the Water Resource Plans (refer to Section 2.3.4).

The Macquarie-Castlereagh catchment, within which the project is partly located makes up 7% of the MDB and contributes 8.4% of the inflow of surface water for the MDB. (MDBA, 2022). The Macquarie River is the main water source interacted by the project and therefore the impacts to the Macquarie River water source need to be considered within the requirements of the *Water Act 2007*.

2.2 NSW legislation

2.2.1 Environmental Planning and Assessment Act 1979

The EP&A Act and Environmental Planning and Assessment Regulation 2000 (EP&A Regulation) establish a framework for the assessment and approval of developments in NSW.

The project was declared to be Critical State significant infrastructure (CSSI) under section 5.13 of the EP&A Act by the (then) Minister for Planning on 23 November 2020. Under Section 5.14 of the EP&A Act, the approval of the Minister for Planning is required for SSI projects (including CSSI), and an EIS has been prepared under Division 5.2 of the EP&A Act.

2.2.2 Water Management Act 2000

The *Water Management Act 2000* (WM Act) recognises the need to allocate and provide water for the environmental health of our rivers and groundwater systems, while also providing licence holders with access to water. The WM Act focuses on protecting, enhancing, and restoring water resources and encouraging best practice management and use of water.

Section 89 of the WM Act relates to water use approvals and Section 90 relates to water management works approvals. There are three kinds of water management work approvals, namely, water supply work approvals, drainage work approvals and flood work approvals.

Under Section 91 of the WM Act a controlled activity approval is required for certain types of developments and activities that have the potential to affect water quality that are carried out at a specified location in, on or under waterfront land.

However, under Section 5.23 of the EP&A Act, a water use approval, water management works or an activity approval (including a controlled activity approval) under sections 89, 90 and 91 of the WM Act are not required for SSI projects. The design and construction of the project would consider the NSW DPE – Water guidelines for controlled activities on waterfront land (NSW 2018) to enable the mitigation of potential impacts to water quality.

This legislation will apply to and guide the requirements for accessing water for use as part of the construction phase of the project.

2.2.2.1 Water sharing plans

Water sharing plans are established under the WM Act and are the primary tool for defining water-sharing arrangements in NSW. The plans establish rules for sharing water between water users and the environment, and rules for water trading. Water sharing plans describe the annual surface and groundwater recharge volumes for each identified water source and the volumes of water that are available for sharing. Available water volumes are based on calculated long-term average annual extraction limit (LTAAEL). Provisions are made for environmental water allocation, basic landholder rights, domestic and stock rights, and native title rights. Water sharing plans are typically in place for ten years, however they may be suspended in times of severe water shortages.

Due to the MDBA bilateral agreement multiple new water sharing plans have commenced across NSW, even though the corresponding Basin Plan Water Resource Plans (WRPs) have not been accredited (refer to Section 2.3.4). There are three Water Sharing plans that cover surface water within the study area, the Macquarie Bogan Unregulated Rivers Water Sources 2012, Macquarie–Castlereagh Water Resource Plan 2020 and the Hunter Unregulated and Alluvial Water Sources 2022. These three plans therefore outline the annual volumes of water that is available for all users in the water sources that the project intersects.

2.2.3 Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations Act 1997* (POEO Act) establishes, amongst other things, the procedures for issuing licences for environmental protection on aspects such as waste, air, water, and noise pollution control. The project is not classified as a 'scheduled activity' based on the development type. However, Section 120 "Prohibition of pollution of waters" is relevant to this assessment as the project may generate wastewater.

2.3 Policy, standards and guidelines

2.3.1 National Water Quality Management Strategy

The NWQMS (Australian Government, 2018) has been developed by the Australian and New Zealand governments in cooperation with state and territory governments. Endorsed by the Australian and New Zealand Environment and Conservation Council (ANZECC), the strategy establishes objectives to achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development.

The NWQMS includes guidelines, including the ANZG 2018, (refer to Section 2.3.1) for protection of water resources across Australia. These guidelines have been used to determine the existing condition of catchments and water quality objectives for the project.

2.3.2 Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018)

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG 2018) is a key guideline within the *National Water Quality Management Strategy* (NWQMS) that is used to identify catchment and watercourse specific water quality management goals. These guidelines are an updated version of the previous guidelines referred to as the ANZECC 2000 guidelines.

The ANZG 2018 guidelines provide a process for assessing existing water quality conditions and developing water quality objectives to sustain current or likely future community values for catchments. Default guideline values for parameters are provided for different community values as generic starting points for setting receiving water values where site specific information is not available. The default guideline trigger values are used to evaluate the existing water quality conditions against long term water quality goals.

The ANZG 2018 guidelines provide the most up to date databases to derive guideline trigger values for toxicants and sediments in aquaculture and aquatic foods, physical and chemical stressors, and guideline trigger values for agricultural water users. Where the ANZG 2018 does not provide a value, the values as used in the previous ANZECC 2000 guidelines still apply.

The default guideline trigger values have not been designed for direct application in activities such as discharge licences, recycled water quality or stormwater quality. These values are provided for various levels of protection of catchments which are considered when describing the existing water quality and key indicators of concern. The proposed guideline trigger values are for a slightly disturbed to moderately disturbed ecosystems, which means should these trigger values be exceeded then a management response for of surface water activities is required. Table 2-1 presents the default guideline values (DGVs) for a range on indicators for upland rivers for the Hunter River catchment.

Table 2-1 ANZG Default Guideline Values

Indicator	Unit	Lowland River
Total Phosphorus	µg/L	20
Total Nitrogen	µg/L	250
Turbidity	NTU	2–25
Salinity (electrical conductivity)	uS/cm	30–350
Dissolved oxygen	%	90–110
pH		6.5–8

2.3.3 Murray-Darling Basin Plan 2012

The Murray–Darling Basin Plan (the Basin Plan 2012) (which was last updated in 2021) aims to provide a coordinated approach to water use across the Murray–Darling Basin's four states and the ACT. It provides a framework to balance environmental, social and economic considerations for water use and water quality to an environmentally sustainable level. The Plan addresses both surface and groundwater use and water quality. Elements of the plan include:

- overall environmental management objectives and outcomes
- sustainable diversion limits (SDL) – on how much surface water and groundwater can be taken from the Basin and a mechanism for adjustments to these limits
- an environmental watering plan – to protect and restore the Basin's rivers and wetlands
- a water quality and salinity management plan that sets objectives and targets
- identifying the risks to continued water availability in the Basin, and strategies to manage them
- a monitoring and evaluation program, including an annual report on the effectiveness of the Basin Plan.

The overarching objective for the Basin Plan 2012 regarding water quality and salinity is to maintain appropriate water quality, including salinity levels, for environmental, social, cultural and economic activity in the Murray-Darling Basin. The Basin Plan 2012 sets water quality targets and objectives to protect water quality in the Basin's catchments for people and livestock as well as for wetlands and floodplains. The Basin Plan requires water managers to consider water quality targets when making decisions about environmental watering and running the river.

The State of the Environment (SoE) 2012 report demonstrated that there was little relationship between standard water quality targets and aquatic ecosystem health, due to the highly variable nature of natural water quality regionally (see the discussion under 'Water quality by river valley' in the Water quality section of SoE 2012). This highlighted a need for regional guidelines to be established, reflecting the natural regional variability noted.

The Basin Plan 2012 (Schedule 11) (last updated in 2021) outlines water quality zones (also referred to as target application zones) and provides water quality targets which are used to assess water quality at inland monitoring stations. These replace the previous default trigger values for slightly disturbed ecosystems listed in the National Water Quality Management Strategy and are reproduced in the water resource plans for each sub-catchment of the Murray Darling Basin along with water quality objectives for each catchment. These water quality objectives contribute to the overall water quality objective for the Murray-Darling Basin to maintain appropriate water quality, including salinity, for environmental, social, cultural, and economic activity and provide a context for the management of surface water quality from the project.

2.3.4 Water resource plans

The Basin Plan 2012 requires the preparation of water resource plans (WRP). The water resource plans set rules on how much water can be taken from the Basin, ensuring that the sustainable diversion limit is not exceeded over time. The Murray-Darling Basin Authority (MDBA) is responsible for monitoring and enforcing compliance with water resource plans. NSW submitted all 20 WRPs (11 groundwater and 9 surface water resource plans) to the MDBA for assessment, in the first half of 2020. The MDBA and NSW have agreed to a new bilateral agreement that will cover the 2020–21 water year as the NSW WRPs were not accredited before 1 July 2020. In June 2022, further amendments to the 2020 NSW Bilateral Agreement were agreed, primarily to reflect the adjustment of responsibilities between the MDBA and the Inspector-General of Water Compliance (MDBA, accessed November 2022). The WRP is therefore still being drafted in consultation with the MDBA to ensure it meets the requirement of the Basin Plan. The project would be governed by Macquarie Castlereagh Surface Water Resource Plan.

The water sharing plan (refer to Section 2.2.2.1) is a key component of the WRP, as it sets out how the available water resources (how much is set by the WRP) are to be shared between different water users and the environment. The water sharing plan sets out rules for the allocation of water entitlements, which are legal rights to access and use water resources. It also sets out rules for managing water during times of scarcity, such as during droughts, to ensure that water is allocated fairly and sustainably.

The water resource plans also provide water quality management plans to support water quality management within the catchments. The plans include water quality objectives as shown in Table 2-2. These values form part of a broader framework to protect, improve and restore water quality.

Table 2-2 NSW Macquarie – Castlereagh water resource plan water quality objectives

Basin Plan water quality objective	Description	Basin Plan reference
Maintain water quality to protect First Nations people's water dependent values and uses	The objective is to ensure water quality is sufficient to maintain the spiritual, social, customary and economic values and uses of water by First Nations people.	10.52
Maintain water quality to protect and restore water quality dependent ecosystems	The objective is to ensure water quality is sufficient to: — protect and restore ecosystems and ecosystem functions — ensure ecosystems are resilient to climate change — maintain the ecological character of Ramsar wetlands.	9.04
Maintain the quality of raw surface water for treatment for human consumption	The objective is to minimise the risk that the quality of raw water taken for human consumption results in: — adverse human health effects — the odour of drinking water being offensive to consumers. The objective also aims to maintain the palatability of rating of drinking water at the level of good as set out in the Australian Drinking Water Guidelines.	9.05
Maintain the quality of surface water for irrigation use	The objective is to ensure the quality of surface water, when used in accordance with the best irrigation and crop management practices and principles of ecologically sustainable development, does not result in crop yield loss or soil degradation. This objective applies at sites where water is extracted by an irrigation infrastructure operator for the purpose of irrigation.	9.06

Basin Plan water quality objective	Description	Basin Plan reference
Maintain the quality of surface water for recreational use	The objective ensures a low risk to human health from water quality threats posed by exposure through ingestion, inhalation or contact during recreational use of NSW Murray and Lower Darling Water resources.	9.07
Maintain good levels of water quality	The objective is to maintain the value of a water quality characteristic if it is at a level that is better than the target value set out in Chapter 6.	9.08

The water resource plans identify water quality zones within their jurisdiction. Water quality targets are then provided for each water quality zone as shown in Table 2-3. The Basin Plan 2012 and water resource plans provide values for Ramsar declared wetlands and 'Other water dependent ecosystems' which covers all other waterbodies, streams and rivers. Table 2-3 shows the water quality targets for 'Other water dependent ecosystems' for the water quality zones in the relevant water resource plans.

Table 2-3 Water quality targets under the Basin Plan 2012 for 'Other water dependent ecosystems' for the water quality zones in the relevant water resource plans

Water quality zone	Turbidity (NTU) (annual median)	pH	Total nitrogen (ug/L)	Total phosphorus (ug/L)	Dissolved oxygen (mg/L; or % saturation) (Annual median)	Pesticides, heavy metals and other toxic contaminants[1]
B3 (Castlereagh Macquarie valleys, Upland Zone)	20	7.0–8.0	600	35	>8 mg/L or 90–110%	The protection of 95% of species

(1) Refer to values in table 3.4.1 of the ANZECC Guidelines (Must not be exceeded)

Electrical conductivity targets are not described for each water quality zone of the Basin Plan. Instead, the Murray-Darling Basin End-of-Valley salinity targets are incorporated into the water quality targets. The NSW End-of-Valley targets are listed in Table 2-4.

Table 2-4 Salinity (electrical conductivity) End-of-Valley targets under the New South Wales Macquarie Castlereagh Water Resource Plan

Water quality zone	Salt load per year (t/yr)	End of valley targets (absolute value)	
		Median (50%) – EC, µS/cm	Peak (80%) – EC µS/cm
Macquarie – Castlereagh			
Macquarie River	25,760	504	744
Bogan River	34,830	456	581
Castlereagh River	8,910	368	

2.3.5 NSW Water Quality Objectives

The NSW Water Quality and River Flow Objectives (Office of Environment and Heritage, 2006) (NSW WQO) are the agreed community values and long-term goals for NSW's surface waters. The NSW WQO set out:

- the community's values and uses for rivers, creeks, estuaries and lakes (i.e. healthy aquatic life, water suitable for recreational activities like swimming and boating, and drinking water); and
- a range of water quality indicators to help assess the current condition of watercourses and whether they support those values and uses.

The project is in the Macquarie-Bogan and Hunter Catchments under the NSW WQO classifications, however the NSW WQO state that the Murray-Darling Basin Commission (and now the Basin Plan 2012) supersedes the NSW WQO for the hydrology and water quality study area for the Macquarie-Bogan catchment.

For the Hunter River catchment the NSW WQOs for the upper uncontrolled streams require protection of:

- aquatic ecosystems
- visual amenity
- secondary contact recreation
- primary contact recreation
- livestock water supply
- irrigation water supply
- homestead water supply
- drinking water at point of supply-Disinfection only
- drinking water at point of supply-Clarification and disinfection
- drinking water at point of supply-Groundwater
- aquatic foods (cooked).

More specifically, the NSW Water Quality and River Flow Objectives report notes that "People in the Hunter catchment said that they regarded the health of river ecosystems as very important; as was water that looked clean and pleasant. The most important uses of water in the catchment were for irrigation, homestead water supply, industrial supply, and for watering livestock." (Office of Environment and Heritage 2006).

2.3.6 NSW Natural Resource Access Regulator (NRAR) Guidelines for controlled activities on waterfront land, 2018

Provide guidance on development and activities on waterfront land in accordance with the WM Act, including specific guidelines for riparian corridors and vegetation management. The project would intersect a number of watercourses and would therefore need to comply with these guidelines at each land-water interface. NRAR is responsible for assessing and issuing approvals for controlled activities conducted in, on or beside rivers, lakes and estuaries.

2.3.7 NSW National Parks and Wildlife Service, Developments adjacent to National Parks and Wildlife Service lands, 2020

These guidelines have been developed by Department of Planning, Infrastructure and Environment (DPIE) to provide guidance on development applications that are adjacent to land managed by National Parks and Wildlife Service (NPWS). This advice aims to avoid any direct or indirect adverse impacts on NPWS parks. The project is located downstream of a national park, traverses the Durridgere State Conservation areas and adjacent to Wollar Creek where the riparian corridor is managed by NPWS.

2.3.8 NSW Guidelines for developments adjoining land and water, 2013

The administration of this guideline is managed by the Department of Planning and Environment – Water and it provides guidance on development and activities on waterfront land. The project would cross a number of high stream order watercourses as described below and would need to therefore appropriately manage the land-water interface during construction.

2.3.9 Landcom Managing Urban Stormwater – Soils and Construction, 2004

These are aimed at providing guidance for managing soils in a manner that protects the health, ecology and amenity of urban streams, rivers estuaries and beaches through better management of stormwater quality.

They provide best practice guidelines, principles, and recommended minimum design standards for good management practice in erosion and sediment control during construction works. Of particular relevance to the project is Volume 1, 4th Edition (commonly known as The Blue Book).

The clearing of land for construction would result in the potential for sediment movements and localised changes to surface water flow which would need to be managed in accordance with The Blue Book.

2.3.10 Hunter River Salinity Trading Scheme, 2018

The project is located in the upper Goulburn River which is a tributary of the Hunter River. The Hunter Salinity Trading Scheme covers the entire Hunter River catchment including the Goulburn River of which Wollar Creek (closest watercourse to the project) is a tributary. The scheme was introduced in 2002 to address salinity issues in the Hunter River (NSW Department of Industry, 2018). The scheme allows saline water accumulating in mines and Lake Liddell to be discharged at times of high river flows and low background salinity levels. This scheme is rarely used during drought periods due to a lack of high rainfall events. Water quality during drought periods can be generally expected to decline as the concentration levels of individual pollutants increases in water bodies in response to reduced dilution (NSW Department of Industry, 2018).

The scheme premise is to only discharge salty water when there is an abundance of low salinity, fresh water in the river. The Wollar Creek catchment is reported to contain naturally occurring sediments that are high in salt. This is relevant for the project because the cumulative changes to salinity levels in surface water runoff from this and nearby projects could impact the trading scheme meeting its salinity targets.

The aim of the scheme is to meet the environmental objectives as outlined in Section 2.3.1 and maintain the salinity levels. The total allowable discharge is calculated so that the salt concentration does not exceed 900 electrical conductivity (EC) (Electrical conductivity is measured in microsiemens per centimetre (μS/cm)) in the middle and lower sectors of the river, or above 600 EC in the upper sector. The project lies within the middle sector of the Hunter River and for the 2019–2020 recording period there were 13 opportunities to discharge into the river. The monitoring of levels of EC indicated that the salinity level of less than 900 EC was maintained for the 2019–2020 period.

3 Methodology

3.1 Overview

The proposed methodology for the hydrology and surface water quantity and quality impact assessment included considering all surface water resources within the study area, including permanent and intermittent resources; rivers, creeks, dams, lakes, and any other features that either store, transport or use surface water.

The methodology used to assess the potential impacts to hydrology and surface water quantity and quality from construction and operation of the project has been divided into the following aspects that can be considered separately but inform the complete understanding of surface water resource relevant to the project:

- hydrology, water supply and water resources impact assessment
- geomorphic impact assessment
- water quality impact assessment.

The surface hydrologic processes include consideration of flooding but are also inextricably linked to groundwater. Technical paper 15 – Flooding assess changes in flood behaviour due to the project and Technical paper 17 – Groundwater considers the existing groundwater environment and impacts to groundwater.

The proposed methodology for this hydrology and surface water quantity and quality impact assessment includes:

- determination of the study area for this assessment
- describing the existing environment relevant to the study area, through a review of existing publicly available information, and water quality data obtained as part of the project's Contamination Factual Report – Energy Hubs (Packages A and C) (WSP Golder, October 2022)
- conducting an assessment of the potential impacts of the project in relation to the surface water resources in the study area
- determining whether these impacts are significant
- development of appropriate mitigation measures for residual impacts.

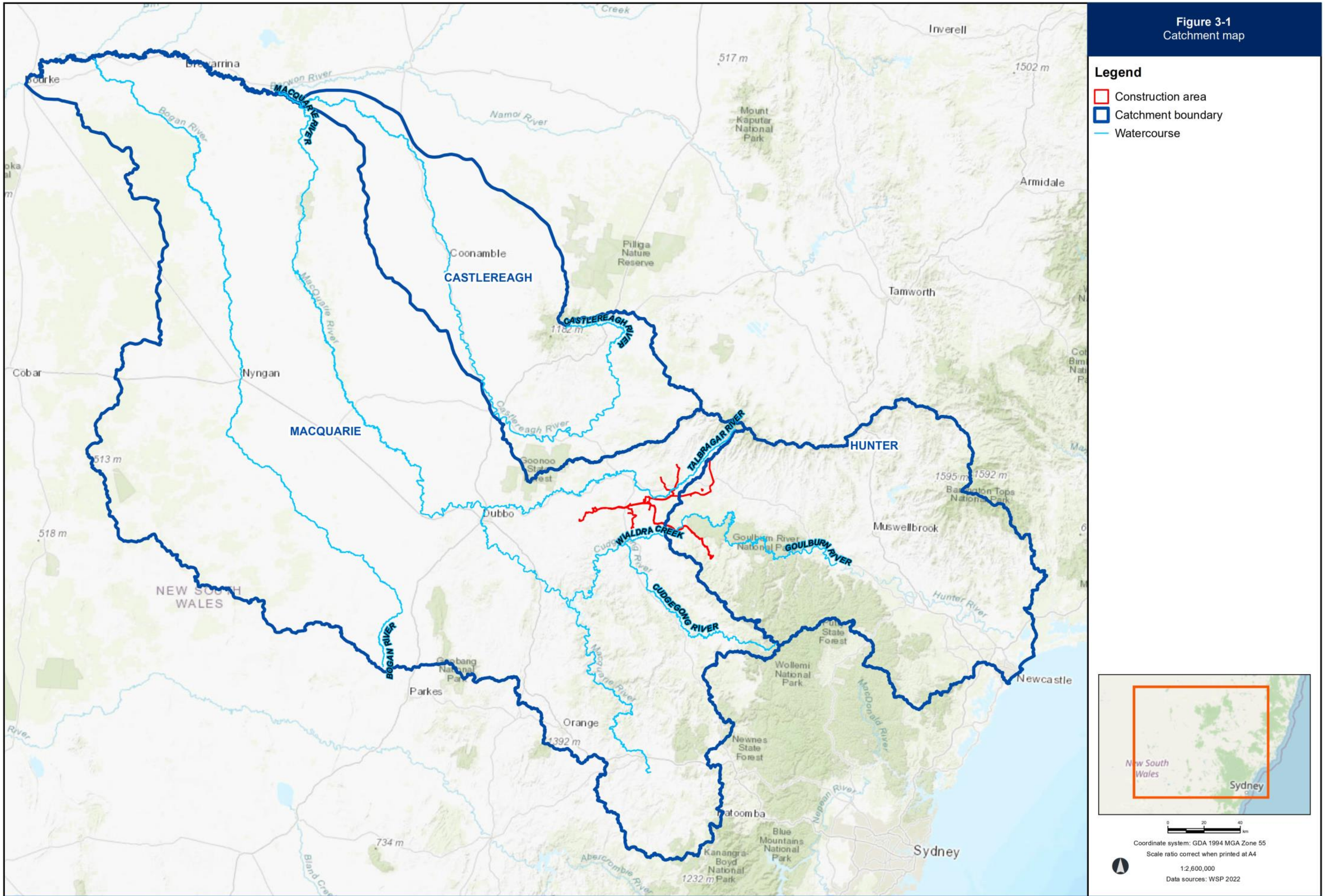
The proposed methodology for each aspect of the surface water environment is presented in Sections 3.2 to 3.5.

3.2 Study area

The hydrology and surface water quantity and quality study area for this assessment is defined as the catchment areas that the project is located within, being the Macquarie and Hunter Rivers including all major and minor tributaries within these catchments. Within the Macquarie River catchment the Talbragar River is the major tributary intersecting the project. The Cudgegong River, which is a tributary of the Macquarie River, does not intersect the project but a number of its tributaries intersect the project and drain into Wialdar Creek and then into the Cudgegong River. The Hunter River is made up of a number of large tributaries with the eastern portion of the project located within the Goulburn River and the project intersects Wollar Creek which is a tributary of the Goulburn River.

Figure 3-1 shows the location of the project and the catchment boundaries for the catchments Macquarie-Bogan Rivers, Castlereagh River and Hunter River. The Macquarie, Bogan and Castlereagh Rivers form one catchment downstream of the project and make up 7% of the Murray Darling Basin catchment area.

Figure 3-1
Catchment map



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3.3 Hydrology and geomorphology

To inform the hydrology and geomorphology assessment the following tasks have been undertaken.

3.3.1 Desktop review

A desktop review has been undertaken to define the existing hydrologic regime and watercourse health (geomorphology) of the study area. This has included:

- documenting the available rainfall from the Bureau of Meteorology
- reviewing and documenting the flow gauge data, from the Water NSW Real time data website (Real-time water data (waternsw.com.au))
- describing the existing catchments, geomorphic conditions, topography and land uses based on the NSW Department of Industry, spatial data for:
  - river styles, hydro line spatial data for the Strahler stream order information
  - topography
  - land uses zones
- identifying connections to groundwater through review of the NSW Water Sharing plans and NSW Department of Industry spatial data for Groundwater dependent ecosystems.

3.3.2 Hydrologic regime and geomorphic assessment

A qualitative (only) assessment of the potential hydrologic regime and geomorphic impacts from construction and operation of the project was undertaken. A qualitative assessment (rather than a modelling-based approach) is deemed to be adequate as the potential risks are anticipated to be low, and can be appropriately managed through the design.

Geomorphology relates to the form, shape, size and structure (slopes, presence of rocks, locations of ponds, soil types) of watercourses. The geomorphic condition of a watercourse is dependent on the flows, vegetation, soil types, aquatic biodiversity etc and these can be affected by human induced changes to catchments and watercourses. Watercourses in good geomorphic condition are important for overall catchment health.

The NSW River Styles mapping (NSW Department of Industry, 2019) has been used for this assessment.
The geomorphic assessment has focussed on locations where the project intersects watercourses as identified by the NSW River Styles mapping (NSW Department of Industry, 2019) for the operation and construction areas.

The geomorphology impact assessment has included:

- review of the existing fragility of the watercourses
- qualitative assessment of the potential changes to existing geomorphic dependent actions, including flows
- identification of mitigation and management measures to minimise impacts to the surface water features.

3.4 Water supply and water resources

The assessment of the hydrologic processes included consideration of the annual rainfall and stream flows for the project catchments. This informs the understanding of the volume of available surface water. The water supply, water storage and existing water entitlements within the water source, such as domestic, public utility and agricultural uses were assessed to determine the volume of surface water that could be available to meet the (primarily) construction water demands of the project. The hydrologic processes therefore impact the current available water supply, and water storage.

The assessment of potential surface water supply for the project has involved:

- a review of the available rainfall and flow gauge data
- a desktop review of existing water supply (including volumes), water access licences, water sharing plan water allocations and water allocation uses and conditions for each water source
- documentation of the potential surface water quantities available across the project and their sources and extraction conditions
- a review of proposed construction and operational water demands
- qualitative assessment of potential impacts to water availability for the construction and operation of the project
- identification of mitigation and management measures to minimise loss of available surface water.

3.5 Water quality

Water quality refers to the chemical and physical quality of the water in all surface water features within the study area. The assessment involved:

- a desktop review of available water quality studies (refer to Section 3.5.1) to determine the baseline water quality conditions
- a review of project surface water samples collected as part of the Contamination Factual Report – Energy Hubs (Packages A and C) (WSP Golder, October 2022)
- identification of the water quality assessment criteria
- a comparison of the baseline water quality to the Basin Plan and Hunter River quality objectives and targets
- a qualitative assessment of the potential pollutants and impacts to the water quality environment from construction and operation activities
- identification of water quality treatment measures for construction camp reuse to minimise discharge
- identification of mitigation and management measures to minimise impacts to water quality.

3.5.1 Desktop review

The desktop review considered the following documents and data sources:

- State of the Catchment (Office of Environment and Heritage, 2010)
- Hunter River Salinity Trading Scheme (NSW Department of Environment and Conservation, 2006)
- National Water Quality Assessment (Sinclair Knight Merz, 2011)
- State of the Environment (EPA, 2018)
- Basin Plan 2012 Annual report 2018–2019 (MDBA, 2020)
- WaterNSW monitoring data
- Contamination Factual Report Energy Hubs (packages A and C) (WSP Golder, October 2022).

As part of the project's geotechnical and contamination investigation program (WSP Golder 2022), surface water samples (grab samples) were collected at 5 locations across the project construction area in August 2022 as shown in Figure 3-2. These included Cassilis Road, the Talbragar River on the Golden Highway, Ross Crossing Bridge, Talbragar River on Blue Springs Road, Talbragar River on Merotherie Road and Cudgegong River on Goolmar (Twelve Mile) Road. The samples were tested for the following:

- calcium
- magnesium
- sodium
- potassium
- pH
- electrical conductivity
- chlorine
- sulfate
- alkalinity
- fluoride
- hardness
- total dissolved solids; and
- heavy metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc).

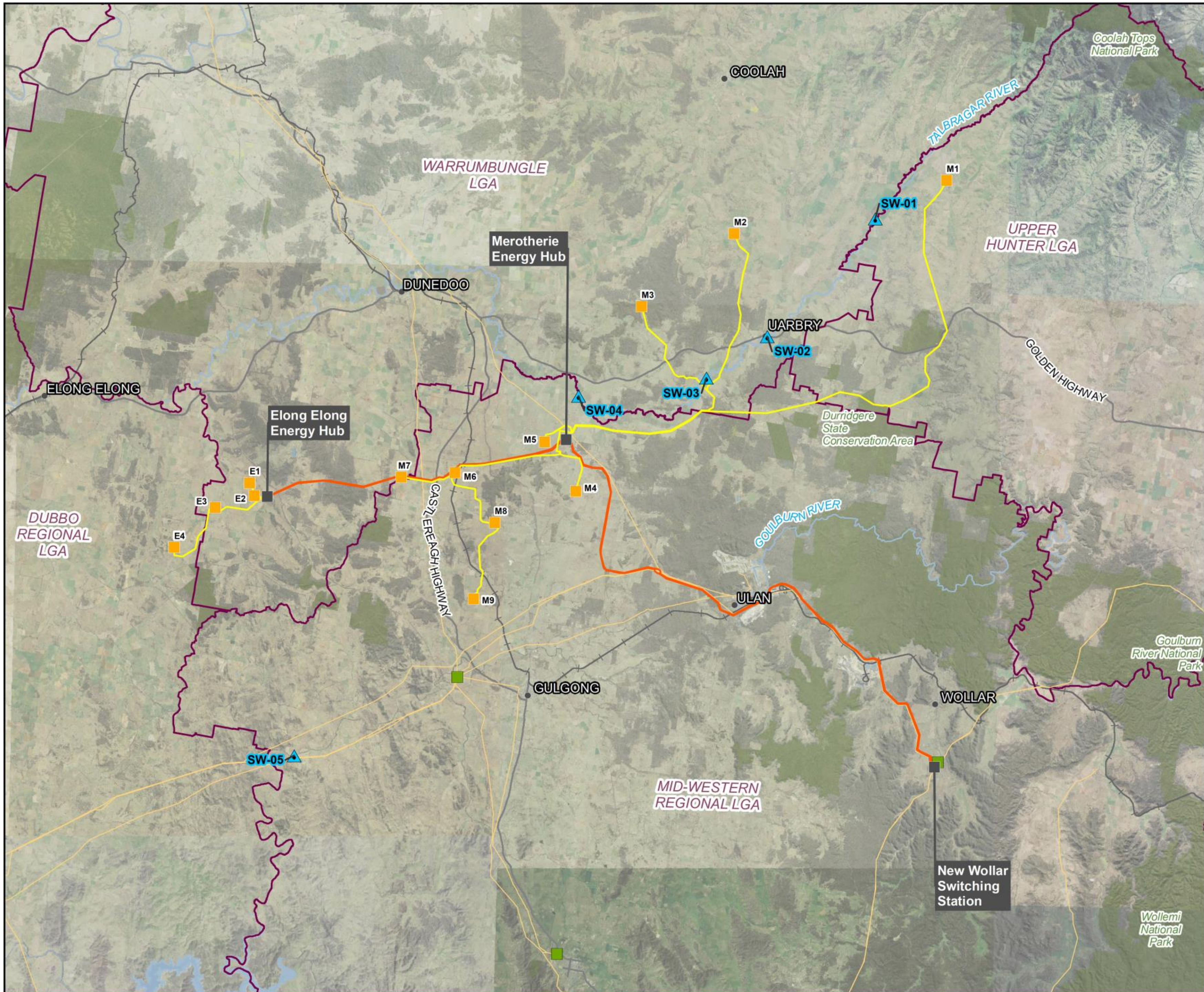

Figure 3-2
Surface Water Monitoring Locations

Legend

- Energy hub / 500 kV switching station
- 330 kV switching station
- 500 kV transmission line
- 330 kV transmission line
- Existing substation
- Existing transmission line
- Road
- Railway
- Watercourse
- Water body
- Local government area
- NPWS estate
- Surface Water Monitoring Location

0 5 10 km

Coordinate system: GDA 1994 MGA Zone 55

Scale ratio correct when printed at A4

1:500,000

Data sources: WSP 2022 / 2023

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3.5.2 Water quality assessment criteria

The Basin Plan 2012 provides the community values and the water quality target values to maintain the water quality objectives for the Macquarie-Castlereagh water source as listed in the water resource plan (refer to Section 2.3.4). ANZG guidelines provide the associated water quality indicators and default guideline values (refer to Section 2.3.3) for the Hunter River catchment. The Hunter River Salinity Trading Scheme (refer to Section 2.3.10) outlines the salt concentration of discharges into the river.

3.5.3 Impact assessment

The qualitative assessment of the potential surface water quality impacts from construction and operation of the project is deemed to be adequate as it is anticipated that the potential risks to be low and appropriately managed through the design. The approach has therefore included:

- identification of the potential pollutants and impacts to the surface water quality within the study area from construction and operation activities
- identification of any residual impacts post-mitigation and the likely performance against the water quality objectives.

3.5.4 Water quality mitigation measures

In addition to design guidelines and requirements, other mitigation measures are identified to minimise and manage potential impacts to watercourses. The mitigation measures focus on performance outcomes that should be used to inform future stages of the design.

3.5.5 Water quality monitoring

Chapter 7 outlines a monitoring program to assess the performance of the project design and mitigation measures to meet the project specific criteria. The monitoring program was developed to focus on the common pollutants and complement existing historic data and monitoring programs.

4 Existing environment

4.1 Sensitive receiving environments

Sensitive receiving environments for this hydrology and surface water quantity and quality impact assessment include the watercourses that intersect the operational and construction areas. Watercourses convey the surface runoff from the catchments and their shape, form and health is influenced by the quantity and quality of water that enters them. The surface water users who extract water from the water sources are also considered sensitive receivers for this assessment and therefore the quantity of surface water available is a key aspect assessed.

Other sensitive receives relevant to surface water quantity and quality include aquatic fauna and flora and groundwater dependent ecosystems. Refer to Technical paper 4 – Biodiversity Development Assessment Report and the Technical paper 17 – Groundwater for the assessment of these aspects.

4.2 Catchment overview

4.2.1 Watercourses

The project is located within the Macquarie and Hunter River Catchments, with other key catchments near the study area including the Castlereagh and Namoi River Catchments. Figure 4-1 shows the watercourses and catchments within the study area that are intersected by the project. The construction area would intersect up to 29 watercourse crossings, most of which are within the Macquarie Catchment, which covers an area of about 74,800 square kilometres (NSW DPE, 2020b). The Macquarie River is a 9th order stream at Burrendong Dam which means it is a large river and exists as a combination of many tributary streams.

The Macquarie River has a catchment area of 74,800 square kilometres to its junction with the Barwon River and the Talbragar River has a catchment area of 3050 square kilometres to Elong Elong and the project is estimated to cover approximately 0.36% of the total Macquarie River catchment cover a length of around 235 kilometres.

The Hunter River catchment is 37,000 square kilometres (NSW DPE, 2020a), and around 39 kilometres of the project is located within this catchment (around 0.2%). The Goulburn River is main sub-catchment that the project is located in, which is a Strahler 6th order stream.

The watercourses that would be intersected by either a transmission line alignment or access roads are presented in Table 4-1 below and the stream order is listed. The majority of these watercourses are ephemeral and therefore do not have permanent water but are dependent on rainfall events for flow.

Table 4-1 Watercourse names and Strahler stream order

Watercourse name	Strahler Stream order
Back Creek	3
Browns Creek	2
Cainbil Creek	5
Cockabutta Creek	5
Copes Creek	5
Cooyal Creek	3
Cumbo Creek	5
Curryall Creek	2
Four Mile Creek	4
Laheys Creek	2
Mona Creek	2
Moolarben Creek	6
Moreton Bay Creek	4
Murrumbline Creek	3
Planters Creek	2
Salty Creek	1
Sandy Creek	7
Sportsmans Hollow Creek	2
Spring Flat Creek	7
Stubbo Creek	4
Talbragar River	9
Tallawang Creek	4
Tucklan Creek	4
Turill Creek	2
Wagrobil Creek	2
White Creek	3
Wialdra Creek	8
Wilpinjong Creek	2
Yellow Waterholes Gully	1
Back Creek	3
Browns Creek	2

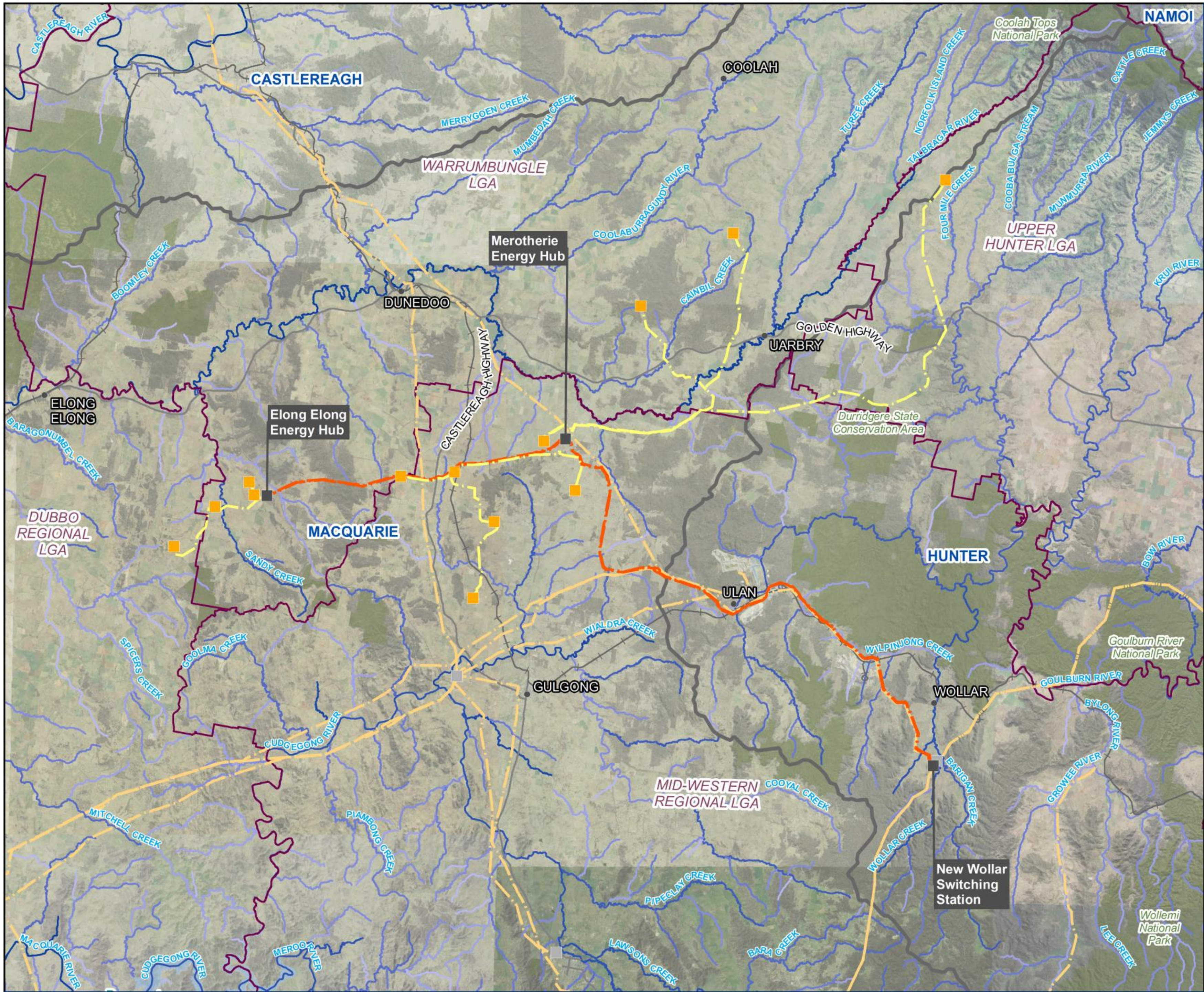

Figure 4-1
Watercourses and catchments

Legend

- Energy hub / 500 kV switching station
- 330 kV switching station
- 500 kV transmission line
- 330 kV transmission line
- Existing substation
- Existing transmission line
- State road
- Railway
- Watercourse
- Water body
- Local government area
- Catchment boundary
- NPWS estate

Watercourse (Strahler stream order)

1, 2, 3, 4, 5, 6, 7, 8, 9, 10

0 10 20 km

Coordinate system: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A4
1:500,000
Data sources: WSP 2023

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4.2.2 Geomorphology

The existing geomorphic conditions for the catchments in the study area documented in the NSW River Condition Index (RCI) tool which is a subset of the NSW River Styles mapping (NSW Department of Industry, 2019). The data in the tool includes indicators for geomorphic condition, and this data can be summarised as follows for the study area:

- Upper Talbragar River – has a very good geomorphic condition. This indicates little change to the hydrologic regime (including surface flows and sediment loads) and riparian vegetation generally intact.
- Talbragar River from Uarbry to Elong Elong – has a poor geomorphic condition, which are a result of watercourses having experienced direct human disturbance with irreversible change, including changes to surface water flows (hydrologic regime) and clearing of vegetation and evidence of erosion.
- Upper Goulburn River – poor to moderate geomorphic conditions. Moderate conditions include localised changes to hydrologic regime some clearing of vegetation and some evidence of erosion.

4.2.3 Climate and rainfall

The climate and rainfall for the project has been separated into two sections due to the expanse of the project. There are several weather stations located near and around the project that have been identified to inform an understanding of the prevailing climate for each section of the project.

Towards the central area of the project, near Elong Elong and Merotherie energy hubs, the closest weather stations are Gulgong (062013) and Dunedoo (064009). These stations have an annual (non-seasonal) mean maximum temperature 23.2 to 24.1°C and an annual (non-seasonal) mean minimum temperature of 9.6 to 9.7°C. The mean annual rainfall is 651.2 millimetres at Gulgong and 615.4 millimetres for Dunedoo (BoM, 2022). The stations are located at elevations of 475 metres and 388 mAHD respectively which is within the range of elevations that the project would traverse and therefore are suitable for providing an understanding of the prevailing climate for the project.

Towards the new Wollar switching station, the closest Weather Stations are Mudgee (062101) and Merriwa (061287). The recorded (non-seasonal) mean maximum temperature for Mudgee and Merriwa are 22.7 and 24°C with corresponding annual mean minimum temperatures of 8.3 and 9.2°C respectively. The recorded mean annual rainfall is 666.9 millimetres and 613.9 millimetres respectively (BoM, 2022). The weather and stream gauge locations are presented in Figure 4-3.

The data presented in Figure 4-2 indicates that the months of November to March are generally wetter with Autumn and Winter experiencing dryer conditions with less rainfall totals.

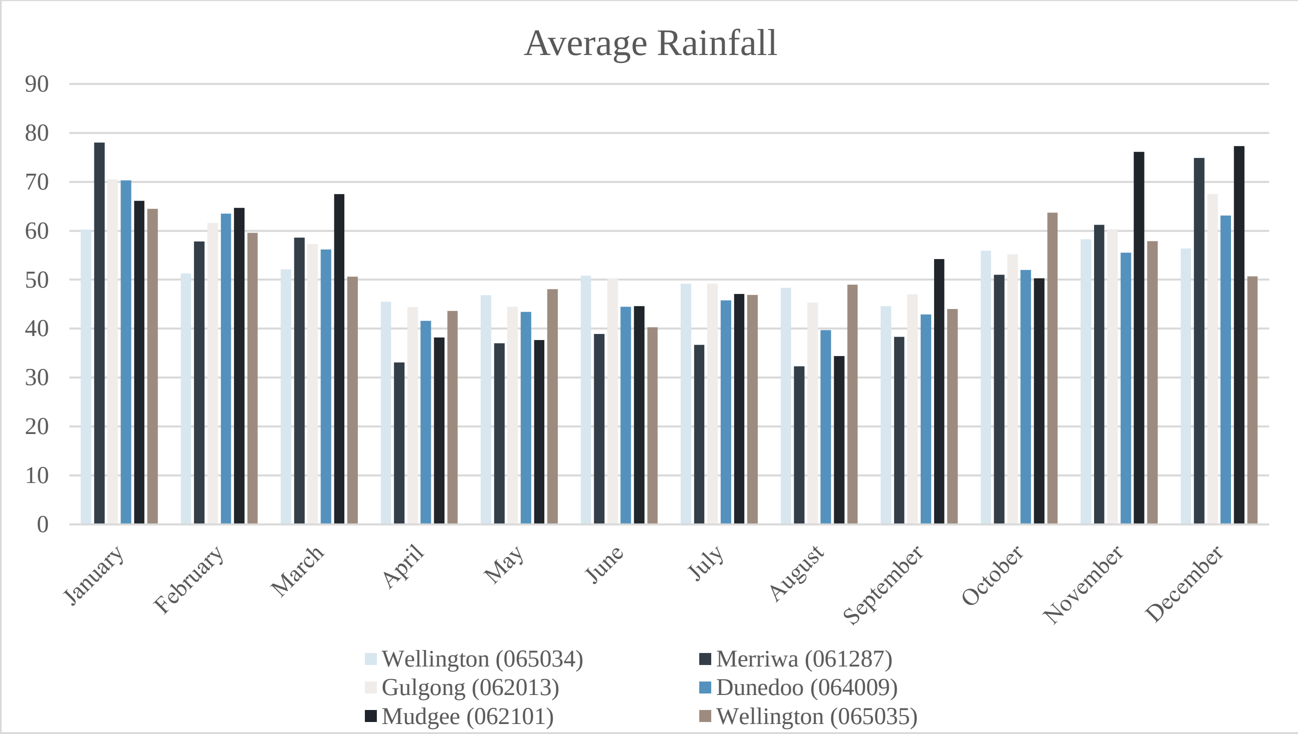

Figure 4-2 Mean rainfall depths

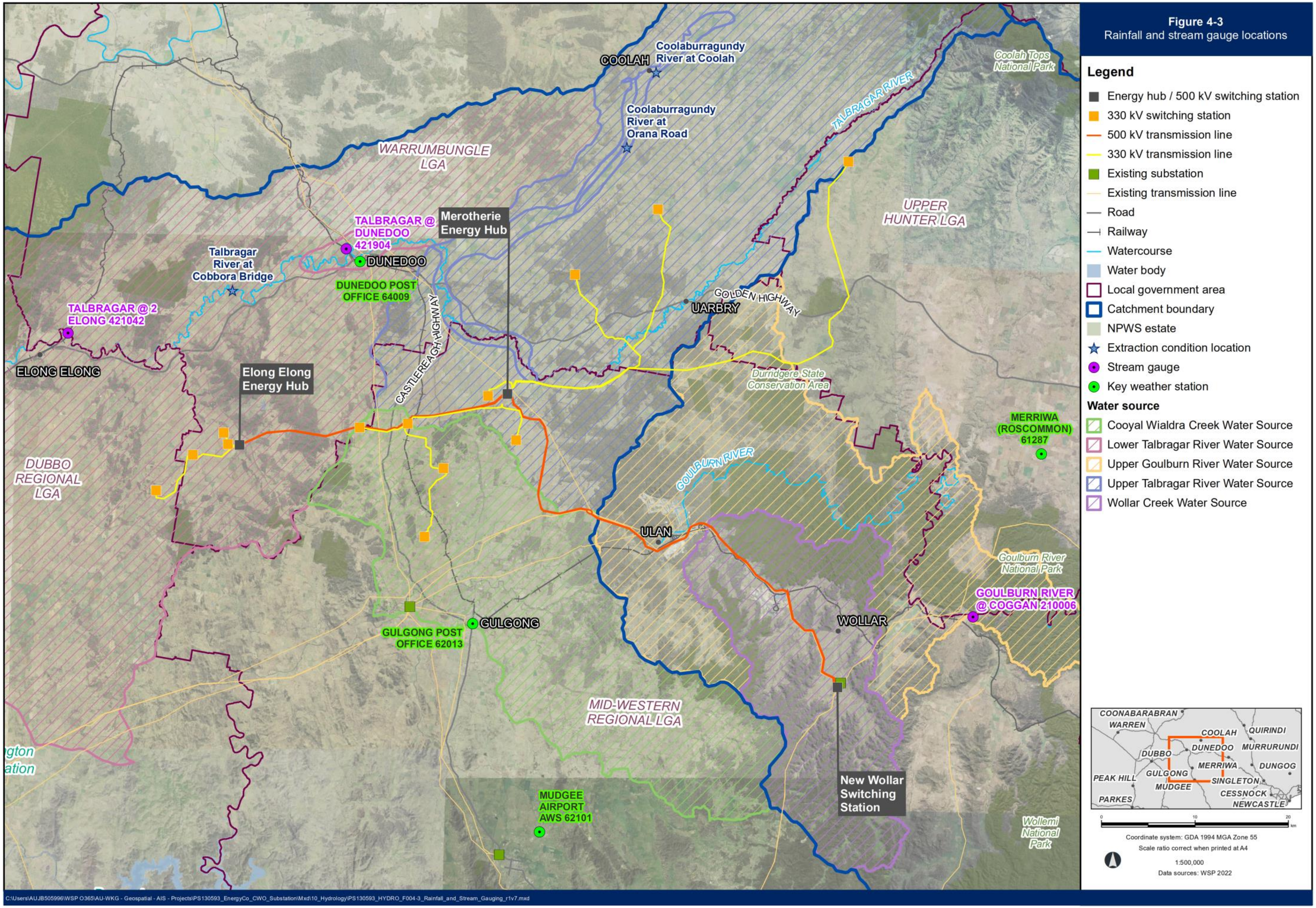

Figure 4-3
Rainfall and stream gauge locations

4.2.3.1 Climate change projections

NSW and ACT Regional Climate Modelling (NARCliM) project uses global climate model outputs and downscales these to provide finer, higher resolution climate projections for a range of meteorological variables across 12 different regions in NSW and ACT. The NARCliM Central West and Orana region predicts an increase of up to 0.2% in annual rainfall across the project, but this varies across the region as presented in Figure 4-4. However, the seasonal projections show a decrease in winter and spring rainfall but an increase in summer and autumn rainfall for the near future (2020–2039) period. For the far future (2060–2079) period the annual change is predicted to be an increase of up to 7.5%.

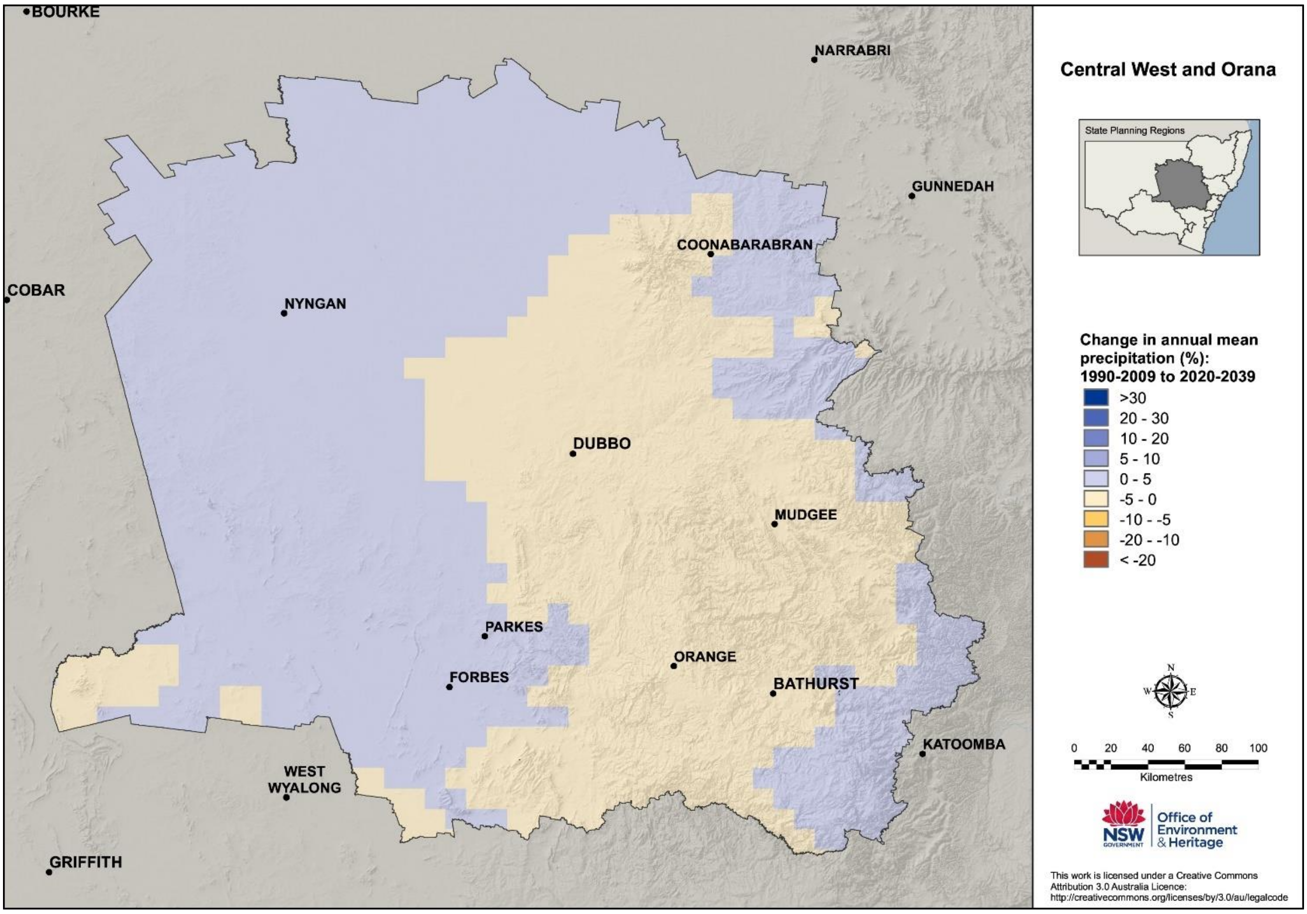

Figure 4-4 Central-West Orana change in annual mean rainfall near future time period

4.2.4 Topography

The project lies at the top of the Macquarie and Hunter River catchments with the catchment divide occurring between the new Wollar Switching station and the Merotherie Energy Hub. From the catchment divide the land slopes away to the west towards the Talbragar and Macquarie rivers and towards the east the land slopes towards the Goulburn and Hunter rivers. The slopes vary across the project due to it traversing several catchments as well as the catchment divide. The elevation across the project varies from a minimum of 350 metres to 700 mAHD. The topography surrounding the project is presented in Figure 4-5.

Figure 4-5
Topography

Legend

- Energy hub / 500 kV switching station
- 330 kV switching station
- 500 kV transmission line
- 330 kV transmission line
- Existing substation
- Existing transmission line
- State road
- Railway
- Watercourse
- Water body
- Local government area
- NPWS estate

Surface elevation (50m intervals)

- 180 - 350
- 350 - 400
- 400 - 450
- 450 - 500
- 500 - 550
- 550 - 600
- 600 - 650
- 650 - 700
- 700 - 800
- 800 - 850
- 850 - 900
- 900 - 950

0 8 16 km

Coordinate system: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A4
1:500,000
Data sources: WSP 2022

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4.2.5 Existing land uses

The land uses within the study area (as defined in Section 3.2) are predominately agricultural including dryland cropping and dryland grazing (as shown in Figure 4-6). Protected environments such as national parks and state conservation areas, biodiversity offset areas and forestry areas are also present. The Moolarben, Wilpinjong and Ulan mines are located within the south-eastern section of the study area. Existing electrical infrastructure include various substations, and transmission lines and several wind farms and solar farms that are either proposed or approved within or near the study area.

Figure 4-6
Land use
Page 1 of 4

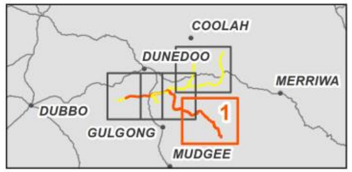
Legend

- Construction area
- Construction compound
- Energy hub / 500 kV switching station
- 500 kV transmission line
- Existing substation
- Existing transmission line
- Road
- Railway
- Watercourse
- Water body

Land use

- 1.1.0 Nature conservation
- 1.3.0 Other minimal use
- 2.1.0 Grazing native vegetation
- 2.2.0 Production native forestry
- 3.2.0 Grazing modified pastures
- 3.3.0 Cropping
- 3.4.0 Perennial horticulture
- 4.2.0 Grazing irrigated modified pastures
- 4.4.0 Irrigated perennial horticulture
- 5.2.0 Intensive animal production
- 5.3.0 Manufacturing and industrial
- 5.4.0 Residential and farm infrastructure
- 5.6.0 Utilities
- 5.7.0 Transport and communication
- 5.8.0 Mining
- 6.2.0 Reservoir/dam
- 6.3.0 River

Footprint



0 2 4 km

Coordinate system: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A4
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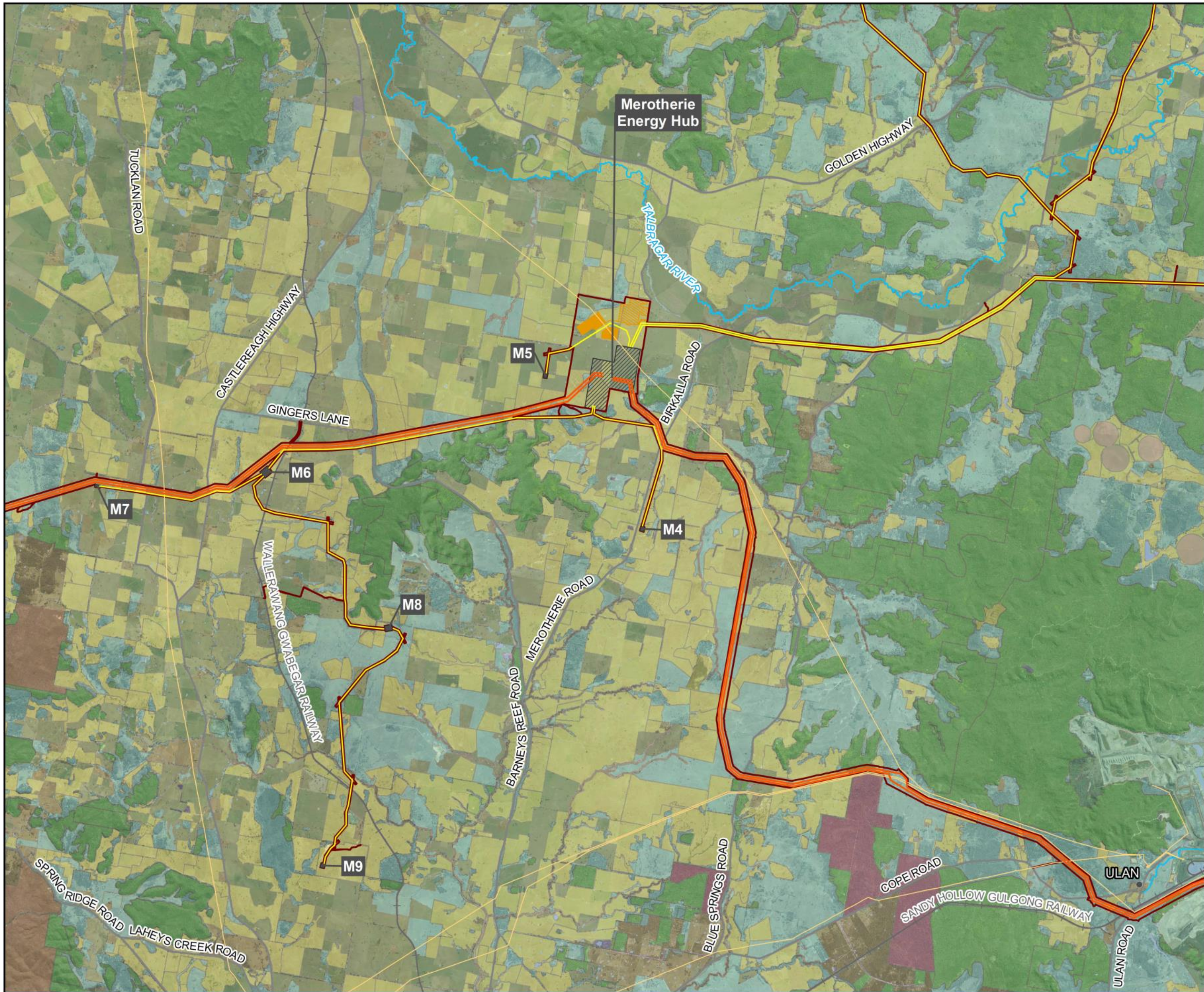
Data sources: WSP 2022

Figure 4-6
Land use
Page 2 of 4

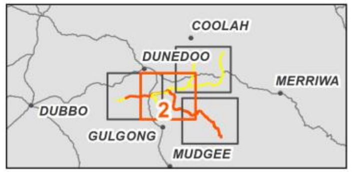


Legend

- Construction area
- Construction compound
- Workforce accommodation camp
- Energy hub / 500 kV switching station
- 330 kV switching station
- 500 kV transmission line
- 330 kV transmission line
- Existing transmission line
- Road
- Railway
- Watercourse
- Water body

Land use

- 1.1.0 Nature conservation
- 1.2.0 Managed resource protection
- 1.3.0 Other minimal use
- 2.1.0 Grazing native vegetation
- 2.2.0 Production native forestry
- 3.2.0 Grazing modified pastures
- 3.3.0 Cropping
- 3.4.0 Perennial horticulture
- 4.2.0 Grazing irrigated modified pastures
- 5.2.0 Intensive animal production
- 5.3.0 Manufacturing and industrial
- 5.4.0 Residential and farm infrastructure
- 5.5.0 Services
- 5.6.0 Utilities
- 5.7.0 Transport and communication
- 5.8.0 Mining
- 5.9.0 Waste treatment and disposal
- 6.2.0 Reservoir/dam
- 6.3.0 River
- 6.5.0 Marsh/wetland
- Footprint



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Data sources: WSP 2022

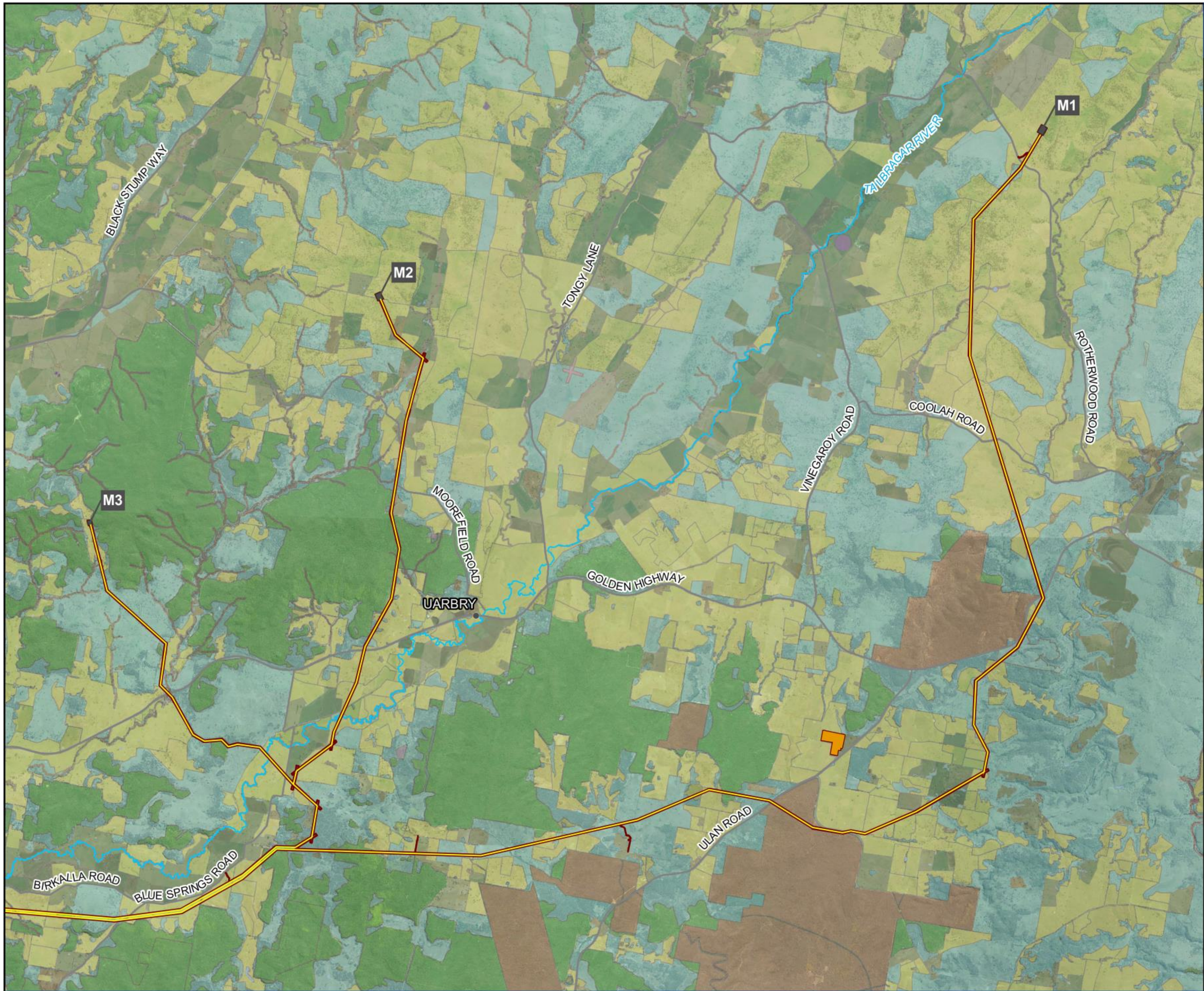


Figure 4-6
Land use
Page 3 of 4

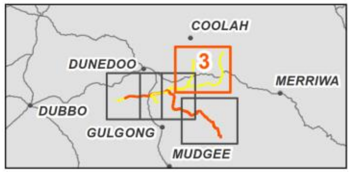
Legend

- Construction area
- Workforce accommodation camp
- 330 kV switching station
- 330 kV transmission line
- Road
- Watercourse
- Water body

Land use

- 1.1.0 Nature conservation
- 1.2.0 Managed resource protection
- 1.3.0 Other minimal use
- 2.1.0 Grazing native vegetation
- 3.2.0 Grazing modified pastures
- 3.3.0 Cropping
- 3.4.0 Perennial horticulture
- 4.2.0 Grazing irrigated modified pastures
- 4.3.0 Irrigated cropping
- 5.2.0 Intensive animal production
- 5.3.0 Manufacturing and industrial
- 5.4.0 Residential and farm infrastructure
- 5.5.0 Services
- 5.6.0 Utilities
- 5.7.0 Transport and communication
- 5.8.0 Mining
- 6.2.0 Reservoir/dam
- 6.3.0 River
- 6.5.0 Marsh/wetland

Footprint



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Coordinate system: GDA 1994 MGA Zone 55
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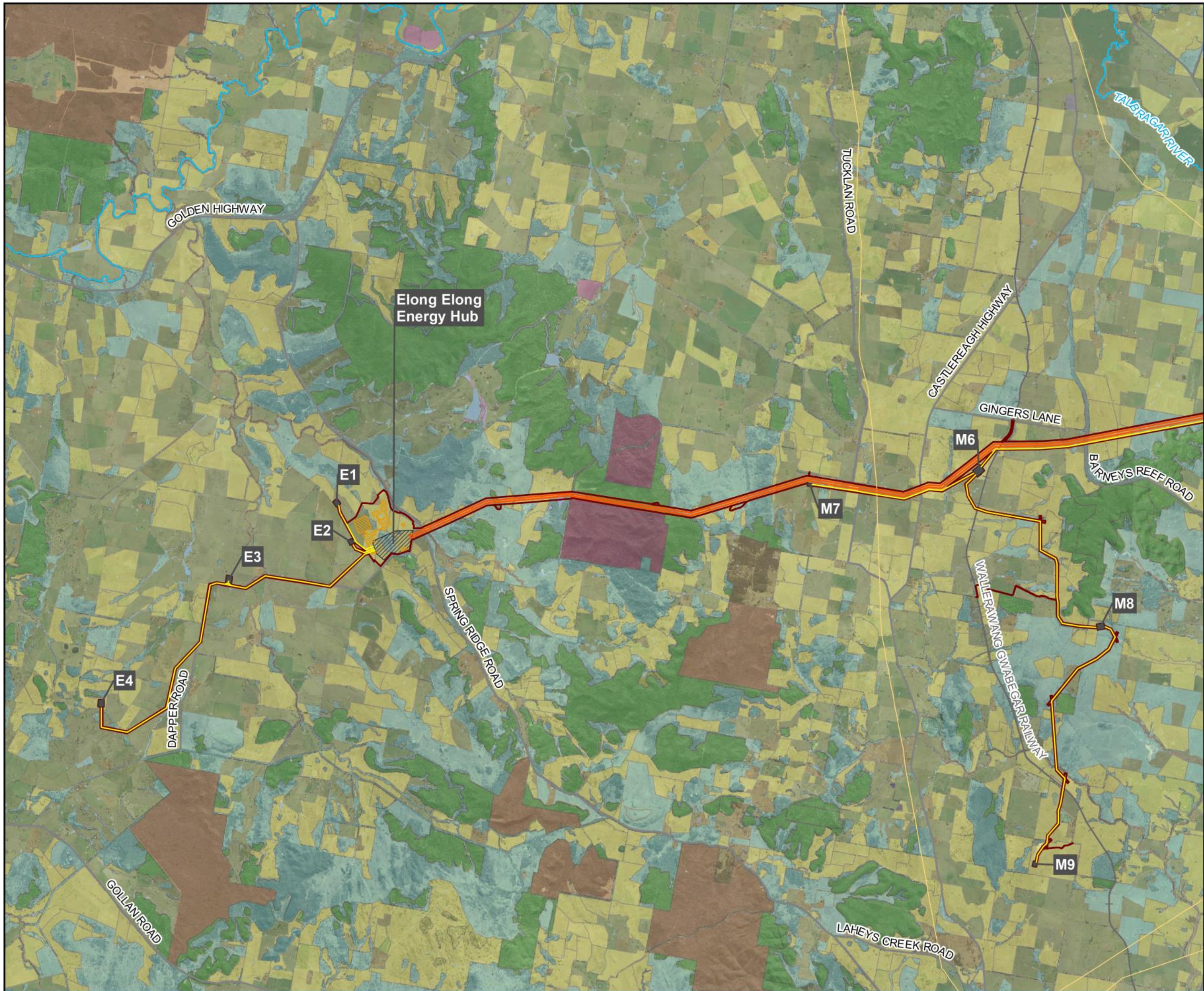
Data sources: WSP 2022



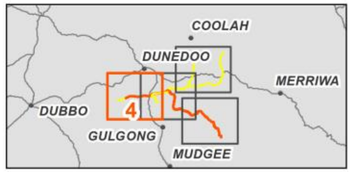
Legend

- Construction area
- Construction compound
- Energy hub / 500 kV switching station
- 330 kV switching station
- 500 kV transmission line
- 330 kV transmission line
- Existing transmission line
- Road
- Railway
- Watercourse
- Water body

Land use

- 1.1.0 Nature conservation
- 1.2.0 Managed resource protection
- 1.3.0 Other minimal use
- 2.1.0 Grazing native vegetation
- 2.2.0 Production native forestry
- 3.1.0 Plantation forests
- 3.2.0 Grazing modified pastures
- 3.3.0 Cropping
- 3.4.0 Perennial horticulture
- 4.3.0 Irrigated cropping
- 5.2.0 Intensive animal production
- 5.3.0 Manufacturing and industrial
- 5.4.0 Residential and farm infrastructure
- 5.7.0 Transport and communication
- 5.8.0 Mining
- 6.2.0 Reservoir/dam
- 6.3.0 River
- 6.5.0 Marsh/wetland

Footprint



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Coordinate system: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A4
1:160,000
Data sources: WSP 2022

4.2.6 Soil salinity and sodicity

Dryland salinity is the accumulation of salts in the soil surface and groundwater in non-irrigated areas. Salinity is commonly caused by the mobilisation of salts in the soil profile by surface water or groundwater. The broad processes for groundwater mobilisation include groundwater recharge (or deep drainage), groundwater movement or groundwater discharge.

Dryland salinity may also be caused by the exposure of naturally saline soils such as hypersaline clays. It can be associated with sodic soils (soils with an exchangeable sodium percentage (ESP) of more than six per cent). ESpade (DPIE, 2022) indicates that the soils in the vicinity of the construction area are sodic soils. Soil sodicity can lead to:

- reduced flow of water through soil—which limits leaching and can cause salt to accumulate over time and the development of saline subsoils
- dispersion in the soil surface, causing crusting and sealing, which then impedes water infiltration
- dispersion in the subsoil, accelerating erosion, which can cause the appearance of gullies and tunnels.

The study area is mapped as having a low salinity potential. The saline and sodic soil conditions mapped on DPIE, 2022 are presented in Figure 4-7.

The Hunter River Catchment has the Hunter River Salinity Trading Scheme which works to keep salinity levels within the catchment at an agreed EC level (refer to Section 2.3.10) by limiting discharges to only occur during high flow events and by balancing the salt discharge amounts from industry against background salt levels in the river.

4.2.7 Acid sulfate soils

Acid sulfate soils (ASS) and potential acid sulfate soils (PASS) are naturally occurring soils containing iron sulphides. On exposure to air, iron sulphides oxidise and create sulfuric acid. This increase in acidity can result in the mobilisation of aluminium, iron, and manganese from the soils.

Acid sulfate soil risk mapping is shown in Figure 4-8, which shows acid sulfate risk classifications for land within and in the vicinity of the study area. The risk classifications are based on the NSW Government acid sulfate soil risk mapping.

The published digital GIS and the CSIRO Australian Soil Resource Information System indicates that there is a low or extremely low probability of acid sulfate soils within the study area. There is a potential for localised areas of acid sulfate soils in low lying waterlogged areas i.e. surrounding creeks or dams.

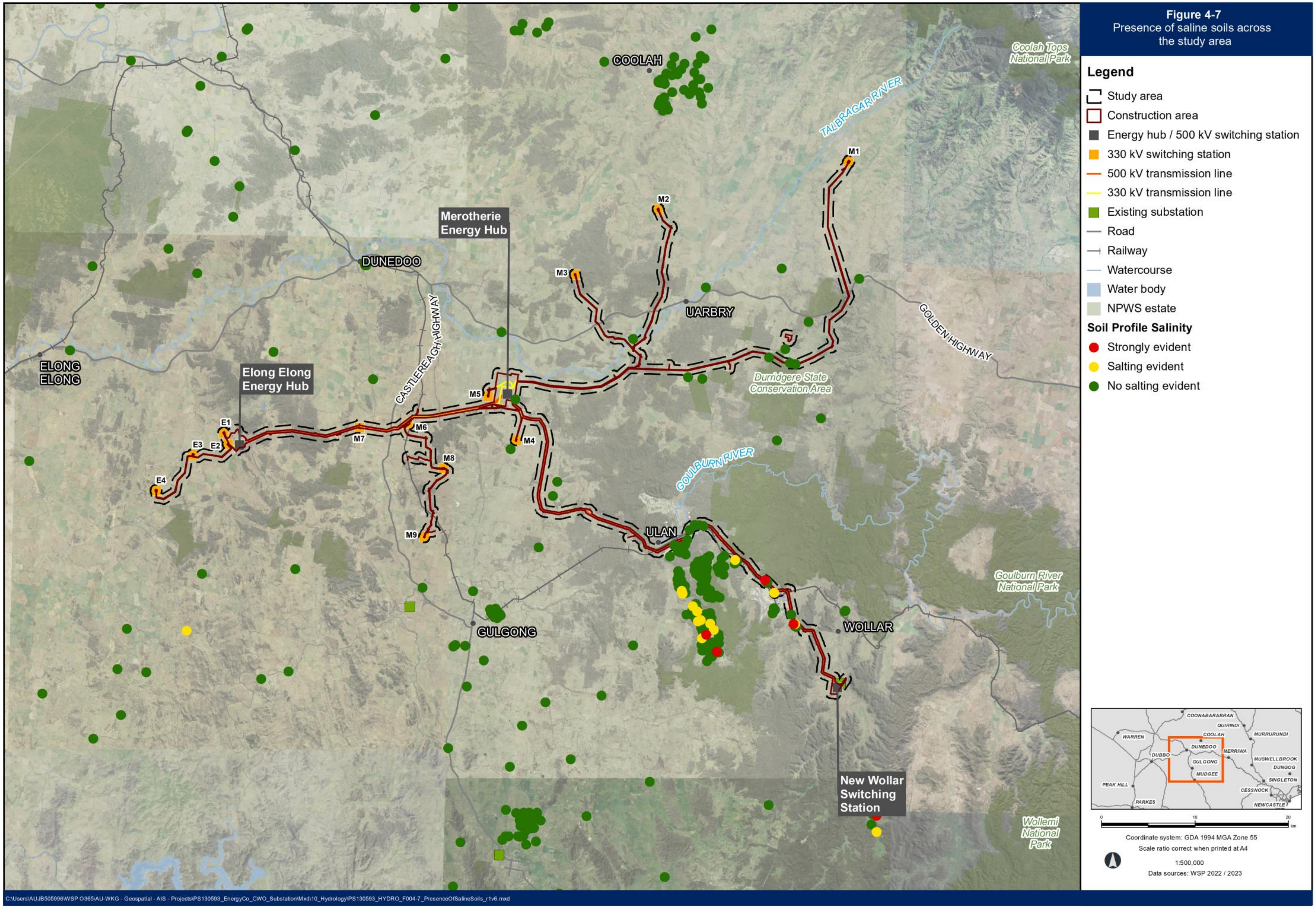
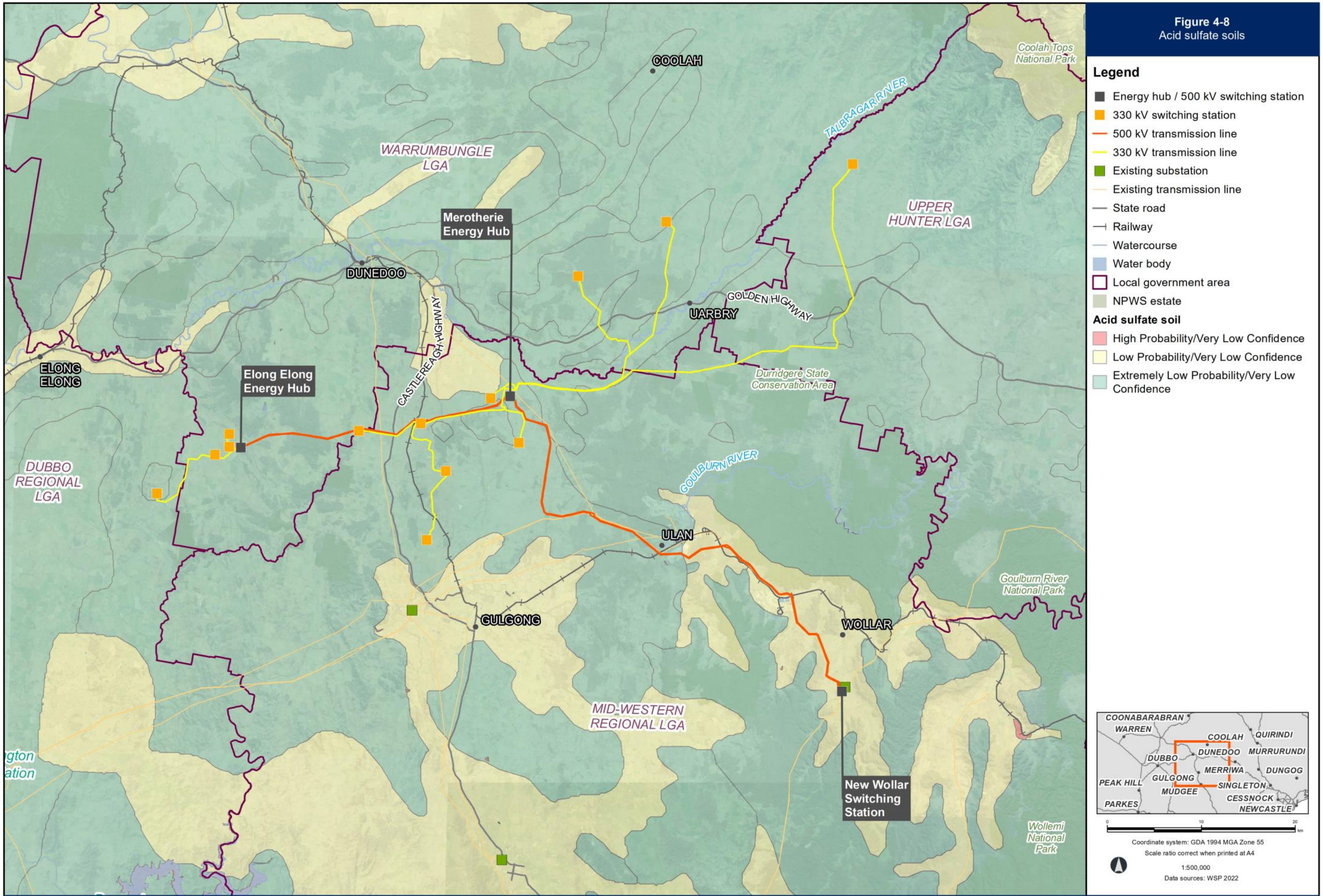


Figure 4-7
Presence of saline soils across the study area



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4.3 Water resources

4.3.1 Water supply

4.3.1.1 Existing water supply infrastructure

In the Warrumbungle LGA, there are Council owned potable water supplies in the villages of Dunedoo and Coolah both of which are north of the project. In the Mid-Western LGA there is a Council owned potable water supply in Gulgong which is located approximately 24 kilometres south of the Merotherie Energy Hub.

In addition, there are private companies in the region with the capability to supply potable drinking water and water for dust suppression.

Beyond these settlements, rural land holders rely on rainwater collected and stored on site, capture of surface flows and stored in dams, extractions from rivers and watercourses via Water Access Licences (WALs) and groundwater WALs for stock and domestic use.

4.3.1.2 Regional water supply

The project is located across the Macquarie Bogan, Hunter, and Castlereagh Unregulated and Alluvial Water Sharing plans (WSP). The project is located within the following surface water sources which are shown on Figure 4-3:

- Upper Talbragar Water Source
- Lower Talbragar Water Source
- Cooyal Wialdra Creek Water Source
- Wollar Creek Water Source
- Upper Goulburn River Water source.

According to the NSW Environment Water Register (Water NSW, 2022a) there are no environmental water licences across these water sources and as such all of these surface water sources are unregulated. Unregulated rivers have natural flows that depend entirely upon the weather and climate and therefore do not have dams which are able to capture, store and regulate the flows. Allocation for the 2022–2023 water year is presented in Table 4-2 to Table 4-6, providing an indication of water availability for that year.

Table 4-2 Upper Talbragar unregulated water source water licence information

Access licence category	No. of WAL(s)	Total share component (ML)	2022/2023 allocation
Domestic and Stock (rights)		245	100% of Share Component
Domestic and Stock (Domestic)		12	100% of Share Component
Unregulated River	8	370	100% of Share Component

Table 4-3 Lower Talbragar unregulated water source licence information

Access licence category	No. of WAL(s)	Total share component (ML)	2022/2023 allocation
Domestic and Stock (rights)		308	100% of Share Component
Domestic and Stock (Domestic)	2	24	100% of Share Component
Unregulated River	8	2227	100% of Share Component

Table 4-4 Wollar Creek unregulated water source water licence information

Access licence category	No. of WAL(s)	Total share component (ML)	2022/2023
Aquifer	3	782	1 ML per share
Domestic and Stock	1	11	100% of Share Component
Domestic and Stock (Domestic)	4	9	100% of Share Component
Unregulated river	5	78	1 ML per share

Table 4-5 Cooyal Wialdra Creek unregulated water source licence information

Access licence category	No. of WAL(s)	Total share component (ML)	2022/2023
Domestic and Stock	4	26	0
Domestic and Stock (Domestic)	1	11	0
Unregulated River	25	594	0

Table 4-6 Upper Goulburn unregulated water source licence information

Access licence category	No. of WAL(s)	Total share component	Share component unit
Aquifer	3	102	1 ML per share
Domestic and Stock	1	8	100% of Share Component
Unregulated River	16	1780	1 ML per share

The location of all the WALs across these water sources is not known.

4.3.1.3 Water supply availability

To understand the availability of surface water across the project, the water source data (refer to Section 4.3.1.2 has been analysed against recorded stream flow and rainfall data.

Water take from the unregulated water sources, as documented in Section 4.3.1.2, are based on the conditions listed in Table 4-7 below with the extraction locations presented on Figure 4-3. Table 4-7 only considers the Upper and Lower Talbragar and Upper Goulburn River as the other water sources have only small volumes of water available.

Table 4-7 Water source extraction conditions

Water source	Condition#	Condition
Upper Talbragar River	80SL026001	The authorised work shall not be used for the purpose unless there is a visible flow in the Coolaburragundy River at or near lot 133 DP 750744, parish of Collieblue, county of Bligh.
Upper Talbragar River	80SL026109	The licensed work shall not be used for irrigation unless there is a visible flow in the Coolaburragundy River at the Orana road crossing, within lot 8 DP 750745, parish of Collier, county of Bligh.
Upper Talbragar River	80SL031868	The pump shall not be used for the purpose of irrigation unless there is a visible flow in the Talbragar River at the flood warning gauging station located at the village of Uarbry.

Water source	Condition#	Condition
Upper Talbragar River	80SL035618	The authorised work shall not be used for irrigation unless there is a visible flow in the Coolaburragundy River at the Orana road crossing, within portion 8, parish of Collier, county of Bligh.
Lower Talbragar River	80SL095238	The licensed work shall not be used for the purpose of irrigation unless there is a clearly visible flow in the Talbragar River at Cobbora bridge adjacent to lot 48 DP 754301, parish of Cobbora, county of Lincoln.
Upper Goulburn River	NA[1]	Not permitted to take water: — if there is no visible flow at the location from which the water is taken (Division 4, part 35) — or, below the very low flow class, defined as less than or equal to 2 ML/day as measured at the Goulburn River at Coggan gauge (210006).

(1) Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2022, Part 6 Division 3 and Division 4 (part 35) Flow classes and Schedule 1

Across the project there are two stream gauges. These are located along the Talbragar River, at Elong Elong (Water NSW Gauge #421042) and at Dunedoo (Water NSW Gauge #421904) which are both located in the Lower Talbragar River water source. The Elong Elong gauge commenced recording values in 1964 and records water level, electrical conductivity and water temperature. The Dunedoo gauge commenced recording in 2017 and records water level only. Both gauges use the water level recordings to estimate water discharge based on site specific rating curves. The location of these gauges is presented on Figure 4-3.

To understand the reliability of the water extraction conditions being met, the Elong Elong recorded gauge data was reviewed. The Elong Elong gauge has a “cease to flow” level of 0.4 m, which was used to equate to “clearly visible” flow as per the conditions detailed in Table 4-7. From the data available (1970 through to 2022) the following can be deduced:

- median level is 0.6 m (which is 0.2 m above cease to flow level), which is exceeded 28% of the time over the period of record
- 90th percentile level is 1.118 m, which is exceeded 6% of time over period of record
- 10th percentile level is 0.414 m, which is exceeded 51% over period of record.

The data is presented in Figure 4-9 which includes the raw recorded mean daily levels, median water level, 90th and 10th percentile levels and drought years. The BOM (Previous droughts (bom.gov.au)) listed histroical droughts have occurred in 1997 to 2009 (known as The Millennium drought) and 2017–2019. The gauge data records indicate that the quality of the data recorded over these years cannot be relied upon but this is likey due to the fact that there was little to no water in the river to record.

The gauge data indicates that on average the river is above the cease to flow level for 28% of the time, which would mean that for approximately two thirds of the year there is unlikely to be visible flow in the river to allow extraction.

To further understand the relationship between surface water and climate, water usage data for the Cudgegong Regulated River Water Source has been compared against recorded rainfall. Figure 4-10 below shows the water usage data for the Cudgegong River across a range of water licences for the years 2004 to 2022. The Cudgegong Regulated River Water Source was chosen as a representative water source because of the data availability. The Cudgegong Regulated River Water Source assessment can be translated to the study area water sources because it has similar upstream catchment characteristics such as land uses and climate. The annual rainfall data for the BOM Mudgee (62101) is also plotted as is the drought years. When the regulated river (general security) licence data usage is compared against the rainfall data and drought years, it can be seen that it generally follows drought years and these equate to low usage.

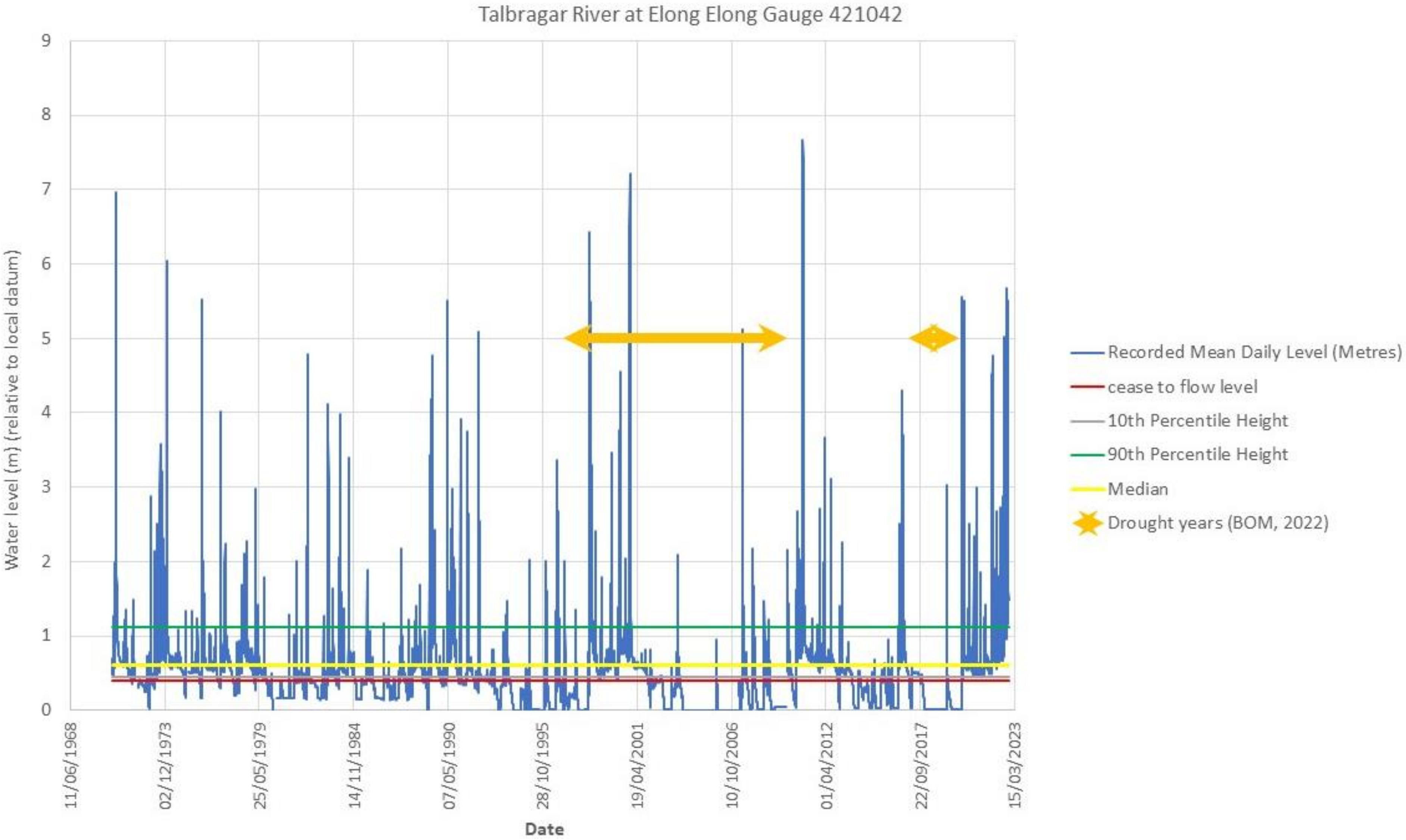


Figure 4-9 Talbragar River at Elong Elong recorded gauge data

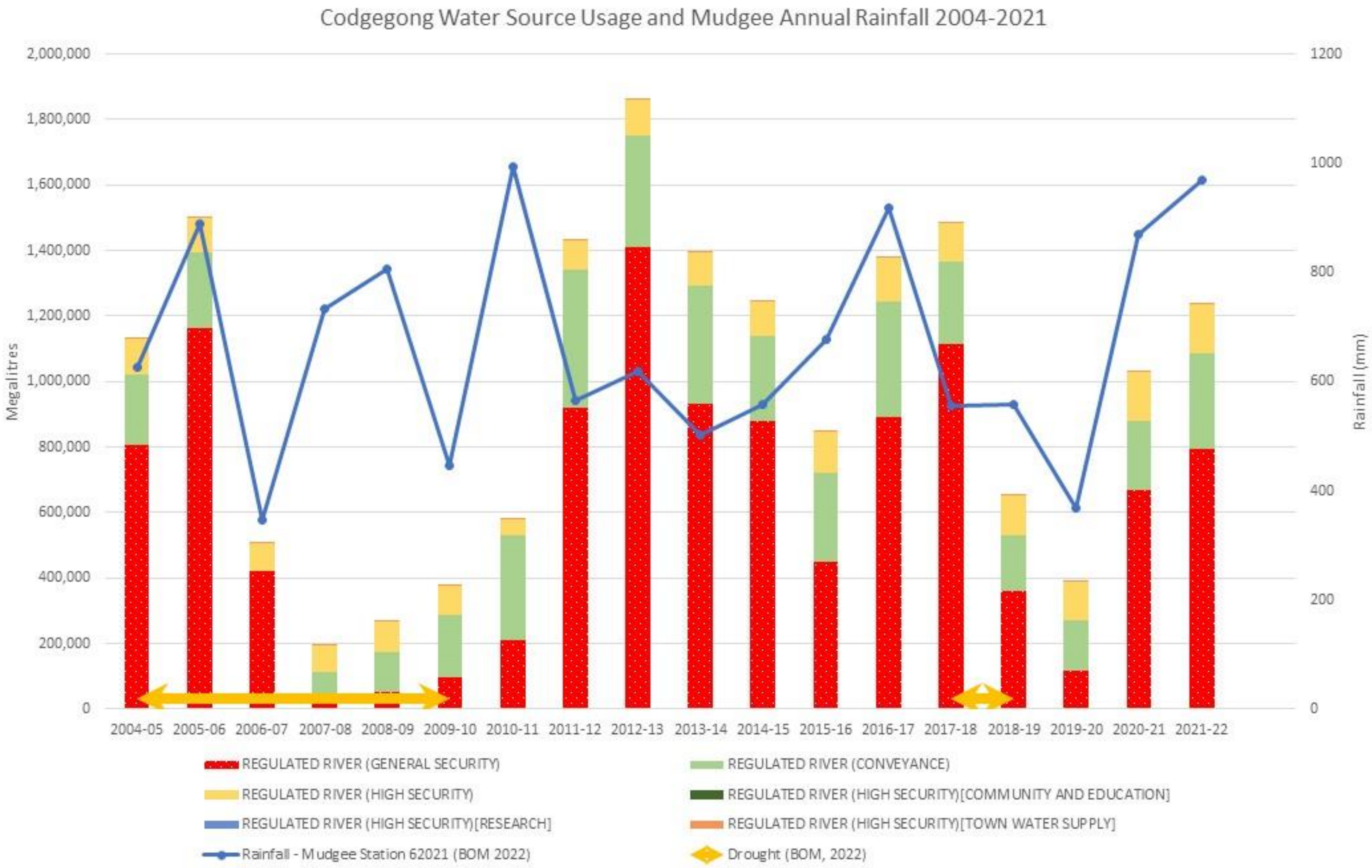


Figure 4-10 Water usage and annual rainfall depths

4.4 Hydrogeology

Details of the groundwater sources (and Water Sharing Plans) are listed in Table 4-8, including aquifer type, and productivity category.

Table 4-8 Groundwater sources within the project.

Groundwater source	Management zone	Aquifer type
Sydney Basin MDB Groundwater Source	Sydney Basin MDB (Other) Management Zone	Porous rock
Gunnedah-Oxley Basin MDB Groundwater Source	Gunnedah-Oxley Basin MDB (Other) Management Zone	Porous rock
Liverpool Ranges Basalt MDB Groundwater Source	N/A	Fractured rock
Lachlan Fold Belt MDB Groundwater Source	Lachlan Fold Belt MDB (Other) Management Zone	Fractured rock
Sydney Basin-North Coast Groundwater Source	N/A	Porous rock
Oxley Basin Coast Groundwater Source	N/A	Porous rock
Liverpool Ranges Basalt Coast Groundwater Source	N/A	Fractured rock
Talbragar Alluvial Groundwater Source	N/A	Alluvial

4.5 Groundwater dependent ecosystems

A review of the BoM Groundwater Dependent Ecosystems Atlas (GDE Atlas) (BoM 2022) high potential GDE's was completed as part of the groundwater assessment (Technical paper 17 – Groundwater), and consideration of the potential impacts of the project on GDE's is provided in Chapter 10 (Biodiversity) of the EIS. Technical paper 17 – Groundwater identified 17 unique high priority terrestrial GDE's (that occur in 320 locations) and 5 high priority aquatic GDE's (six in the Macquarie-Bogan river catchment and two in the Hunter river catchment).

The GDE Ecological Value (HEVAE) spatial database has been developed by NSW Department of Planning and Environment (DPE 2020) using recorded and predicted spatial data to provide weighted scores for each attribute associated with four HEVAE criteria (distinctiveness, diversity, naturalness and vital habitat). Within the project, the high priority GDE's are generally limited to small patches within remnant vegetation areas and along surface water drainages (see Figure 4-11).

Figure 4.11
Groundwater dependent ecosystems
Page 1 of 4

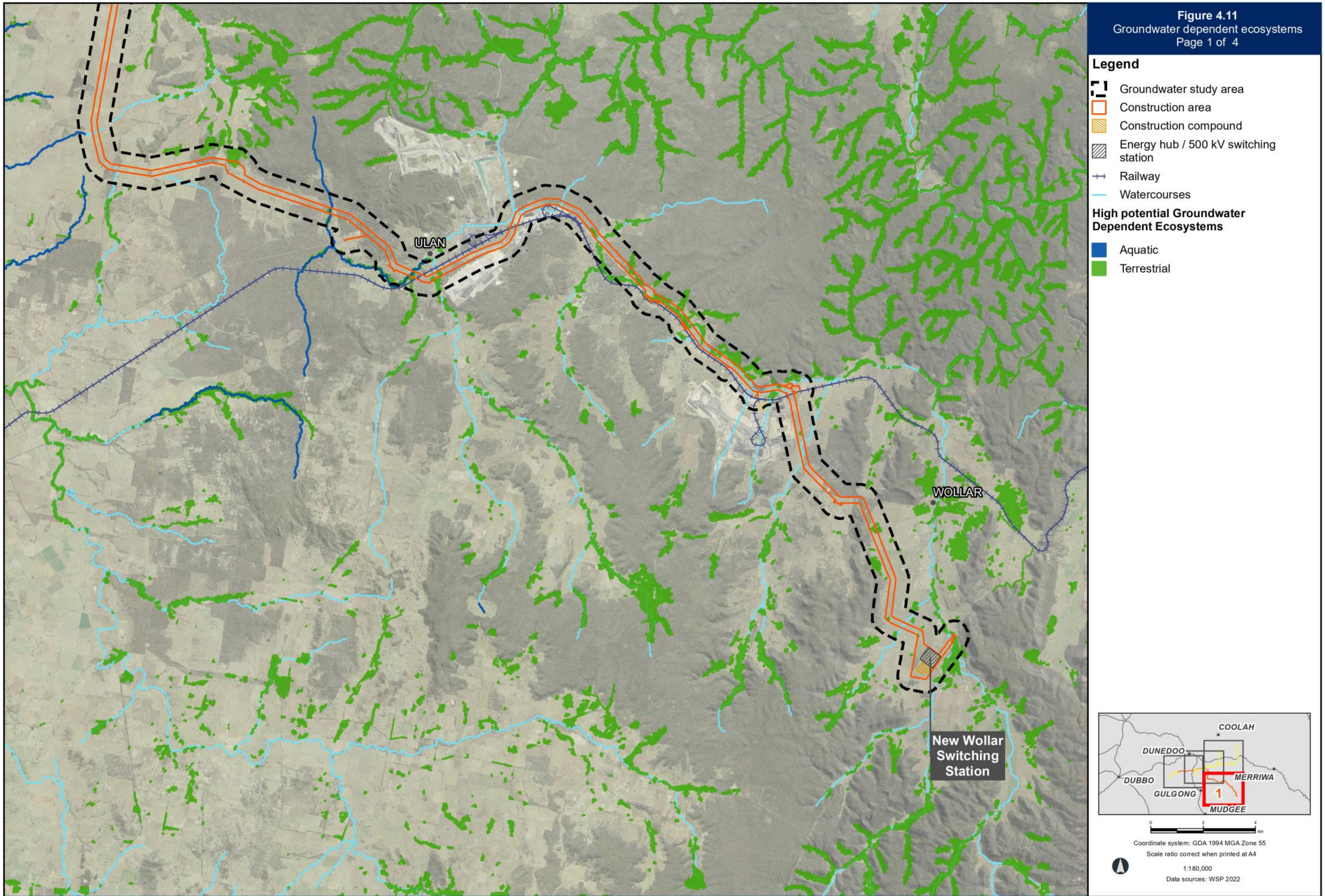
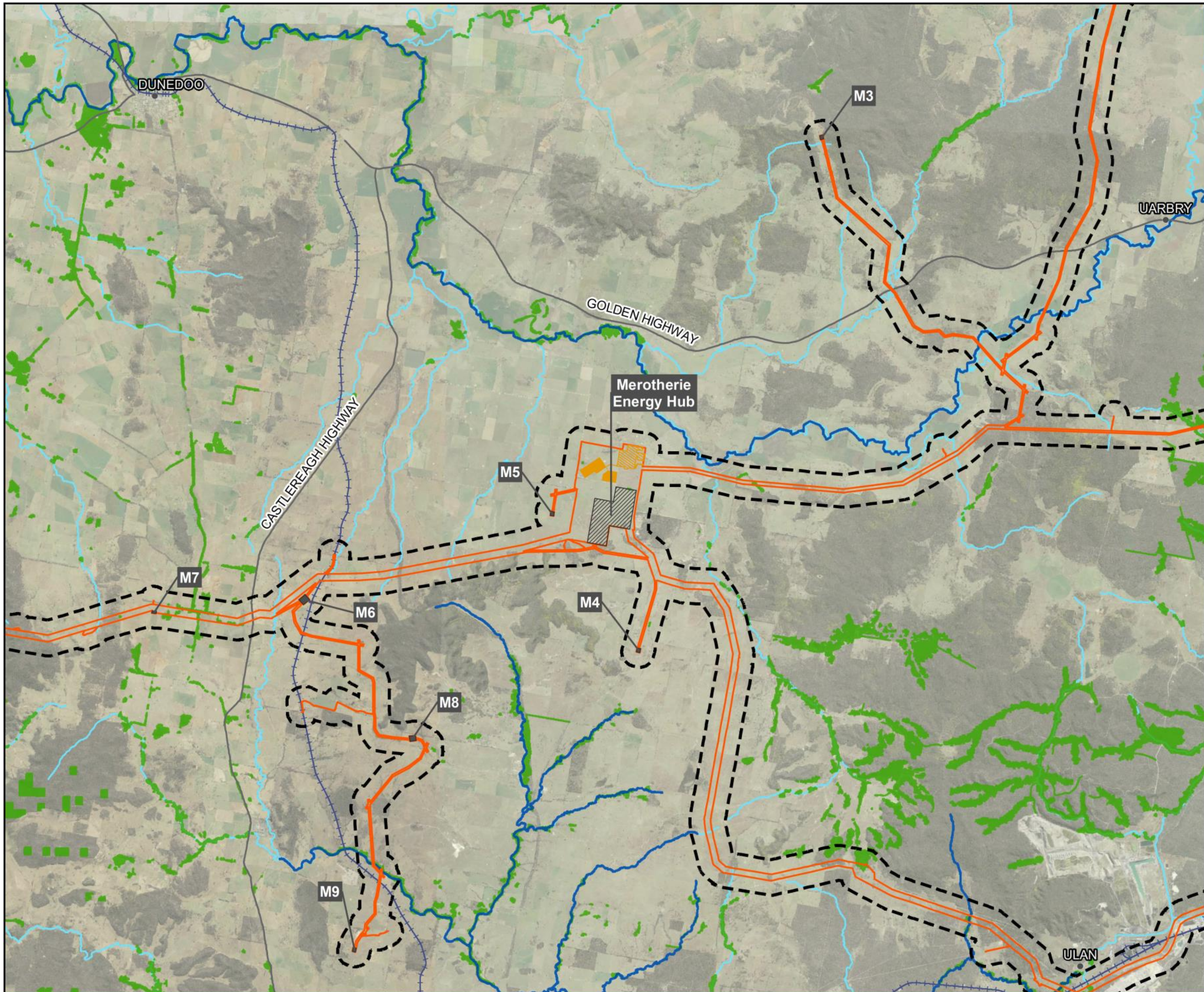


Figure 4.11
Groundwater dependent ecosystems
Page 2 of 4

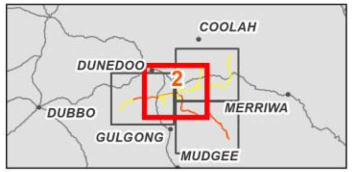


Legend

- Groundwater study area
- Construction area
- Construction compound
- Workforce accommodation camp
- Energy hub / 500 kV switching station
- 330 kV switching station
- Road
- Railway
- Watercourses

High potential Groundwater Dependent Ecosystems

- Aquatic
- Terrestrial



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Coordinate system: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A4

1:180,000

Data sources: WSP 2022

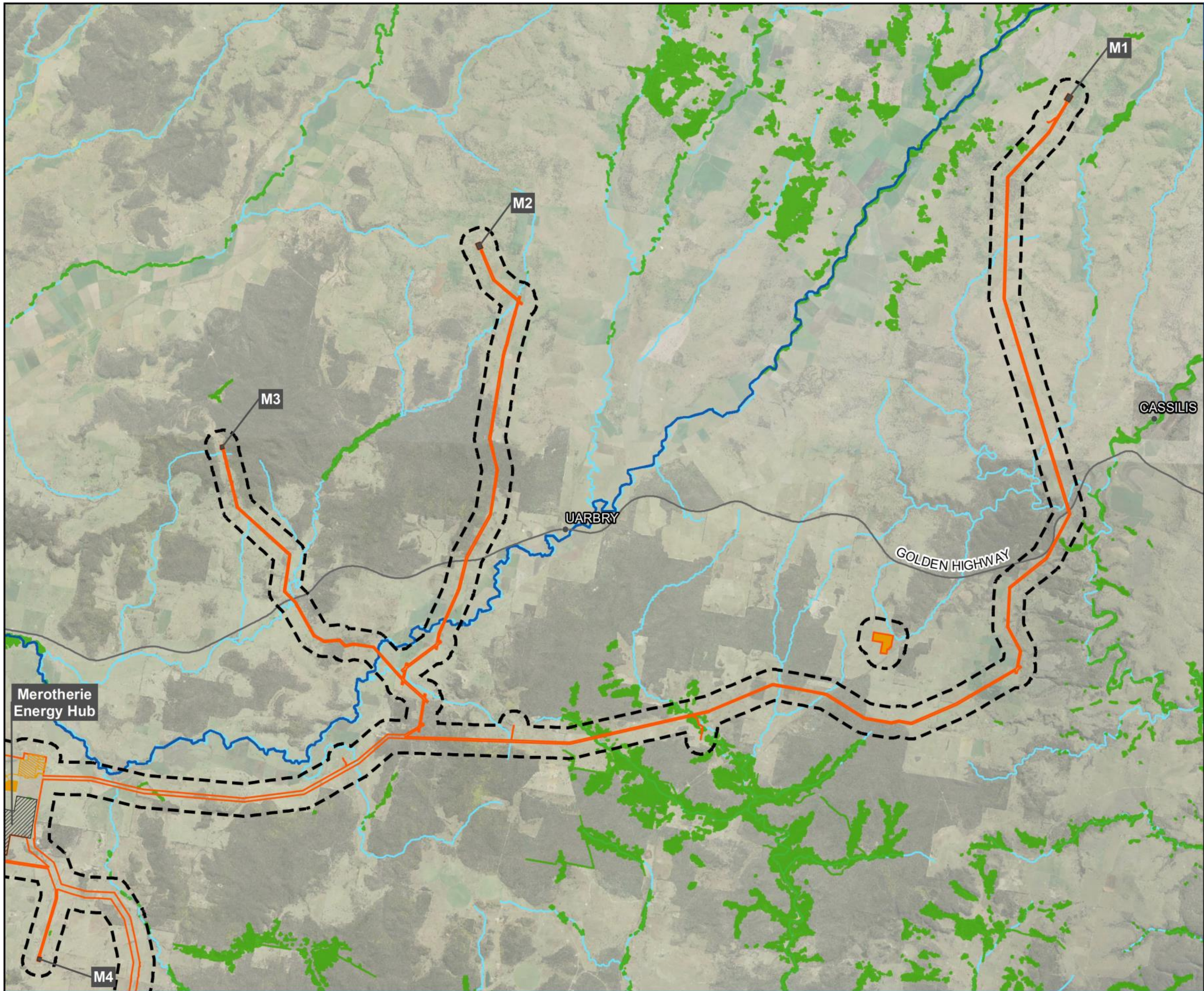

Figure 4.11
Groundwater dependent ecosystems
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Legend

- Groundwater study area
- Construction area
- Construction compound
- Workforce accommodation camp
- Energy hub / 500 kV switching station
- 330 kV switching station
- Road
- Watercourses

High potential Groundwater Dependent Ecosystems

- Aquatic
- Terrestrial

Coordinate system: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A4
1:180,000
Data sources: WSP 2022

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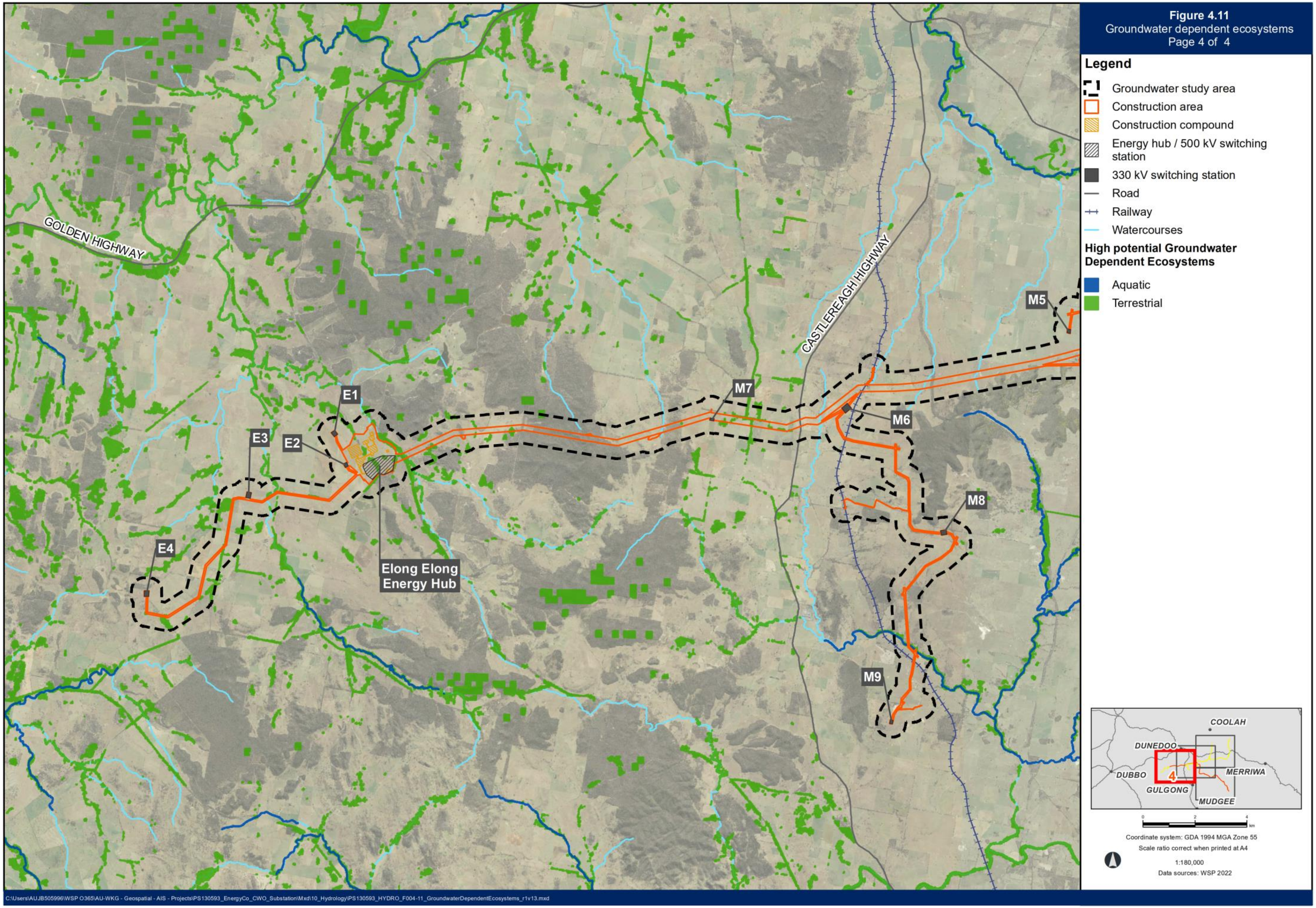

Figure 4.11
Groundwater dependent ecosystems
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4.6 Water quality

The existing water quality is based on a review of the available data for the catchment as no project specific information is available. The following documents provide an understanding of the quality of surface water for the larger catchments of the Macquarie and Hunter Rivers. This information provides insight into the key water quality parameters for the study area.

4.6.1 State of the Catchments (NSW Government, 2010)

The 2010 State of the Catchments reports (NSW Government, 2010) documented the condition of, and pressures on, 13 catchments under the NSW Monitoring Evaluation and Reporting program.

4.6.1.1 Hunter-Central Rivers region

The reports used turbidity and Total Phosphorus (TP) as indicators of water quality performance for all catchments for the period from 2005–2008. For the Hunter River catchment, water quality results were varied across the catchment. There were limited results to indicate a trend for phosphorus, but turbidity was trending upwards at the time of reporting. There were also varying electrical conductivity results but all sites on the Hunter River were concluded to have stable salinity.

4.6.1.2 Central West region

For the Central West region, the majority of the sample points had between 80–100% of TP samples exceeding guideline values. Exceedances in turbidity however, varied across the region from 0 to 56%. Due to data gaps in water quality data records, trend results could not be reported for majority of the region. Therefore, there are no overall data trends made for the region.

4.6.2 National Water Quality Assessment

The National Water Quality Assessment (Sinclair Knight Merz, 2011) was commissioned as a nationwide water quality assessment to provide a snapshot of water quality across inland waters of Australia. The assessment collated water quality data from a series of sources across Australia and compared them to the relevant ANZECC 2000 water quality objectives for the region. The water quality data examined in the assessment included turbidity, salinity, pH, nutrients, and algal blooms (specifically cyanobacterial blooms), and faecal contamination (microbial quality). The report classified water quality for each of these parameters between very poor to good based on the percentage of samples that were compliant with the ANZECC 2000 objectives. These classifications are shown in Table 4-9.

Table 4-9 National Water Quality Assessment 2011 – Water quality classifications against ANZECC 2000 guidelines

Classification	Percentage compliance with ANZECC 2000 Guidelines Values
Good	>75%
Fair	50–75%
Poor	25–50%
Very Poor	<25%

The Macquarie-Bogan River Basin received a score of very poor for both Total Nitrogen (TN) and TP, poor for salinity and fair for pH. Across the Basin there was a high degree of variability between sites for turbidity, but the basin was overall rated good, as 76% complied with ANZECC/ARMCANZ (2000) guidelines.

Salinity ranged from 92 to 1140 micro siemens per centimetre and was generally highest in the Talbragar River. The median concentrations for nutrients ranged from 370 to 1200 micrograms per litre for TN and 21 to 154 micrograms per litre for TP, in comparison to guideline values of 500 and 50 micrograms per litre respectively (ANZECC/ARMCANZ 2000).

The Castlereagh River basin was rated ‘very poor’ for salinity and had a median salinity of 821 micrograms per litre. While pH had a median of 8 pH units (n =31). Nutrients were rated poor and very poor, for TN and TP respectively. For TN the median concentration was 310 micrograms per litre, while for TP was 68.5 micrograms per litre.

4.6.3 NSW State of the Environment 2021 Report (EPA, 2021)

Prepared every three years, the NSW State of the Environment (SoE) Report provides information on the status of key environmental issues facing New South Wales including watercourse health. Figure 4-12 shows a summary of the monitoring sites used for the SoE 2021 and the percentage of samples from each site to exceed the ANZG 2018 water quality guidelines for the coastal river catchments, such as the Hunter River and against the Basin Plan (Section 2.3.3) and for the inland rivers such as the Macquarie-Castlereagh River. The SoE 2021 reported on only nutrients TN and TP.

Figure 4-12 shows that the sampling sites on the Goulburn, Macquarie, and Cudgegong Rivers, had fair to poor ratings for TN and TP, but the Talbragar River had very poor ratings for both TN and TP.

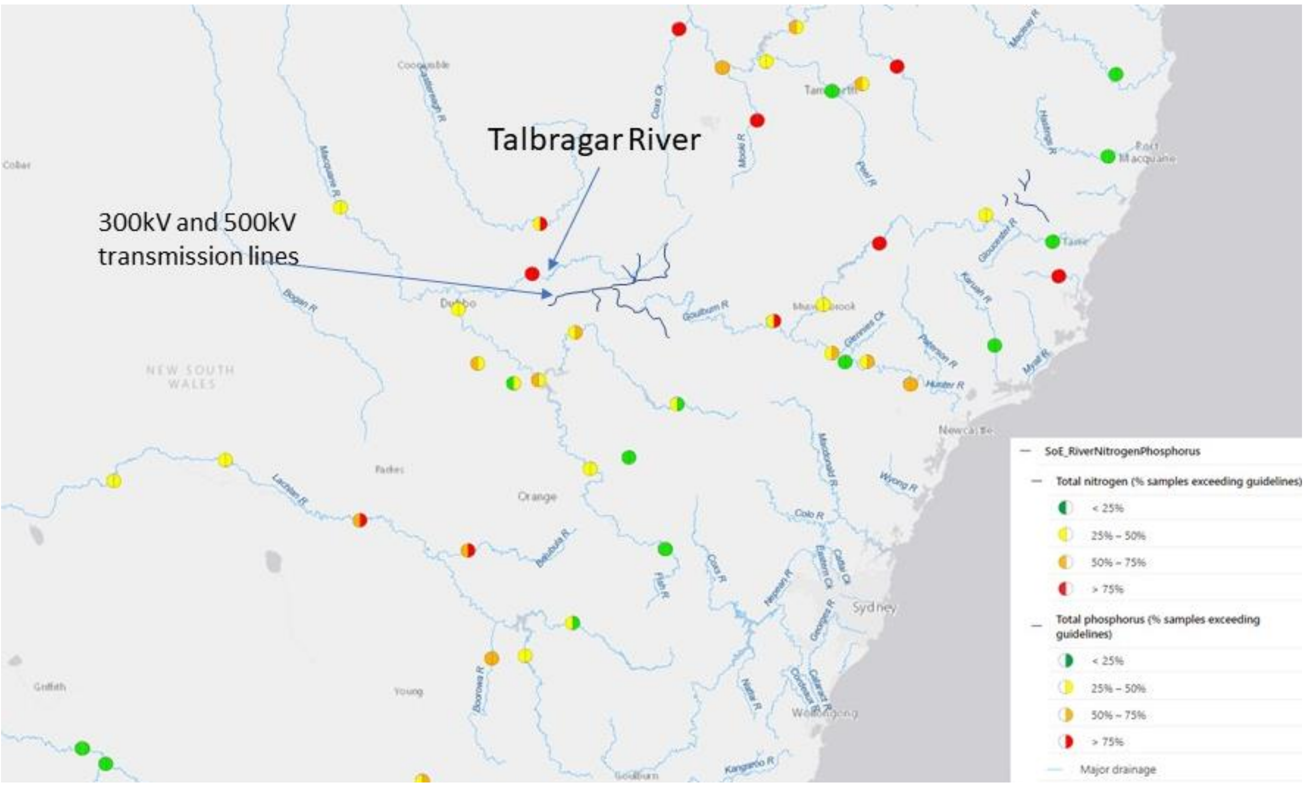


Figure 4-12 Percentages of samples exceeding guidelines for nutrient values as assessed by the 2021 State of the Environment report

4.6.4 Macquarie-Castlereagh Water Resource Plan

The Murray-Darling Basin Plan (2012) requires all basin water resource areas to have a water quality management plan. The Water Quality Technical Report for Macquarie-Castlereagh (NSW Department of Planning, Industry and Environment, 2020) surface water resource plan area (WRPA) gives an overview of the water quality condition. The report uses data collected between 2010–2015 to calculate results for a range of sites in the Macquarie Castlereagh Surface Water resource plan area. There are two sites relevant to the project and these are 421042 and 421019. Refer to Figure 4-13 for the location of these sites and Table 4-10 for a breakdown of the water quality index (WaQI) score for the two sites. The WaQI scales five years of data for a single parameter and as a combined WaQI into a single number between 1 and 100 which corresponds to four categories: Poor, Fair, Good and Excellent. The numerical value for the categories are:

- Poor 1–59
- Fair 60–79
- Good 80–94
- Excellent 95–100.

Table 4-10 Water quality index scores for the Macquarie Castlereagh WRPA 2010–2015 water quality data

Site name	Rating overall	WaQI	Total Nitrogen	Total Phosphorus	Turbidity	pH	DO
Talbragar River at Elong Elong (421042)	Poor	31	37	7	22	85	46
Cudgegong River at Yamble Bridge (421019)	Fair	73	77	54	85	94	52

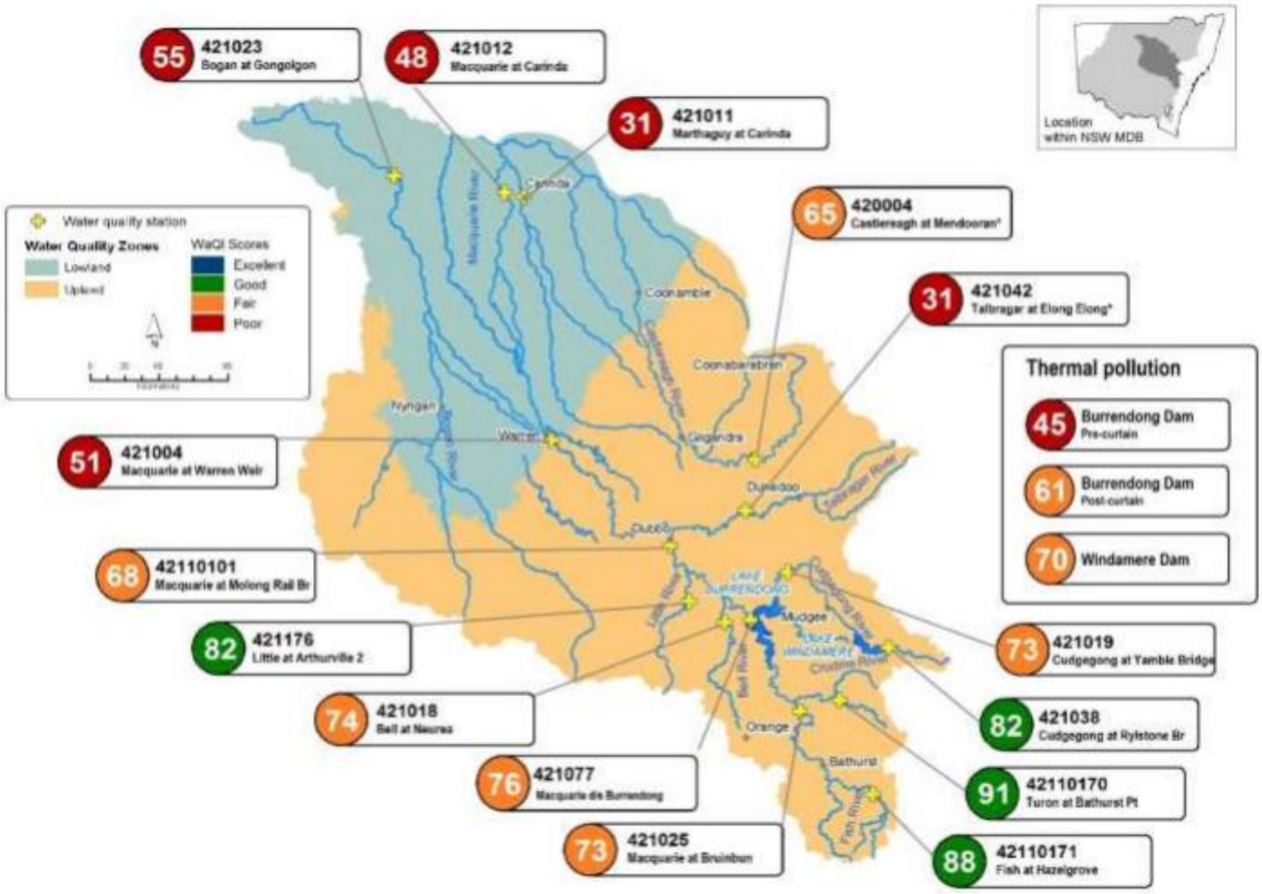


Figure 4-13 Macquarie Castlereagh WRPA water quality index scores (NSW Department of Planning, Industry and Environment, 2020

Table 4-11 provides a summary of the risk rating for water dependent ecosystems at water monitoring and stream gauges near the project. The data provides the consequence of the parameter having an impact on the water dependent ecosystem and the probability (likelihood) of the impact occurring, such that a low consequence and high likelihood has a medium risk for affecting the health of water dependent ecosystems.

Table 4-11 Sites with high and medium risk to the health of water dependent ecosystems

Site name	Parameter	Consequence	Likelihood	Level of risk
Talbragar River at Elong Elong (412042)	Turbidity	Low	High	Medium
	Total Phosphorus	Low	High	Medium
	Total Nitrogen	Low	High	Medium
	Dissolved Oxygen	Low	High	Medium
Cudgegong River at Yamble Bridge (421019)#	Total Phosphorus	High	High	High
	Turbidity	NA	NA	NA
	Total Nitrogen	NA	NA	NA
	Dissolved Oxygen	High	High	High

Source: NSW Department of Planning, Industry and Environment, 2020

Note: Cudgegong River data was limited to the information presented in the table and as available from the source document.

Water quality attributes in the Macquarie Castlereagh WRPA are strongly correlated to the flow, such that high river flow tends to result in high turbidity, nutrients, pesticides and pathogens, but lower electrical conductivity.

4.6.5 Hunter River Salinity Trading Scheme

The Scheme has been designed to balance the water quality objectives of the Hunter River with water quality needs of agricultural users and the discharge needs of mines and power stations within the Hunter River catchment. Overall, salinity is kept to an appropriate level by only allowing discharges during high flow or flood events and balancing the amount of salt that industry can discharge against the background salt levels in the river. The total allowable discharge is calculated so that the salt concentration does not go above 900 micro siemens per centimetre (µS/cm) in the middle and lower sectors of the river, or above 600 micro siemens per centimetre (µS/cm) in the upper sector. The project area lies within the middle sector of the Hunter River (refer to Figure 4-14) and for the 2020–2021 recording period there were 15 opportunities to discharge into the river.

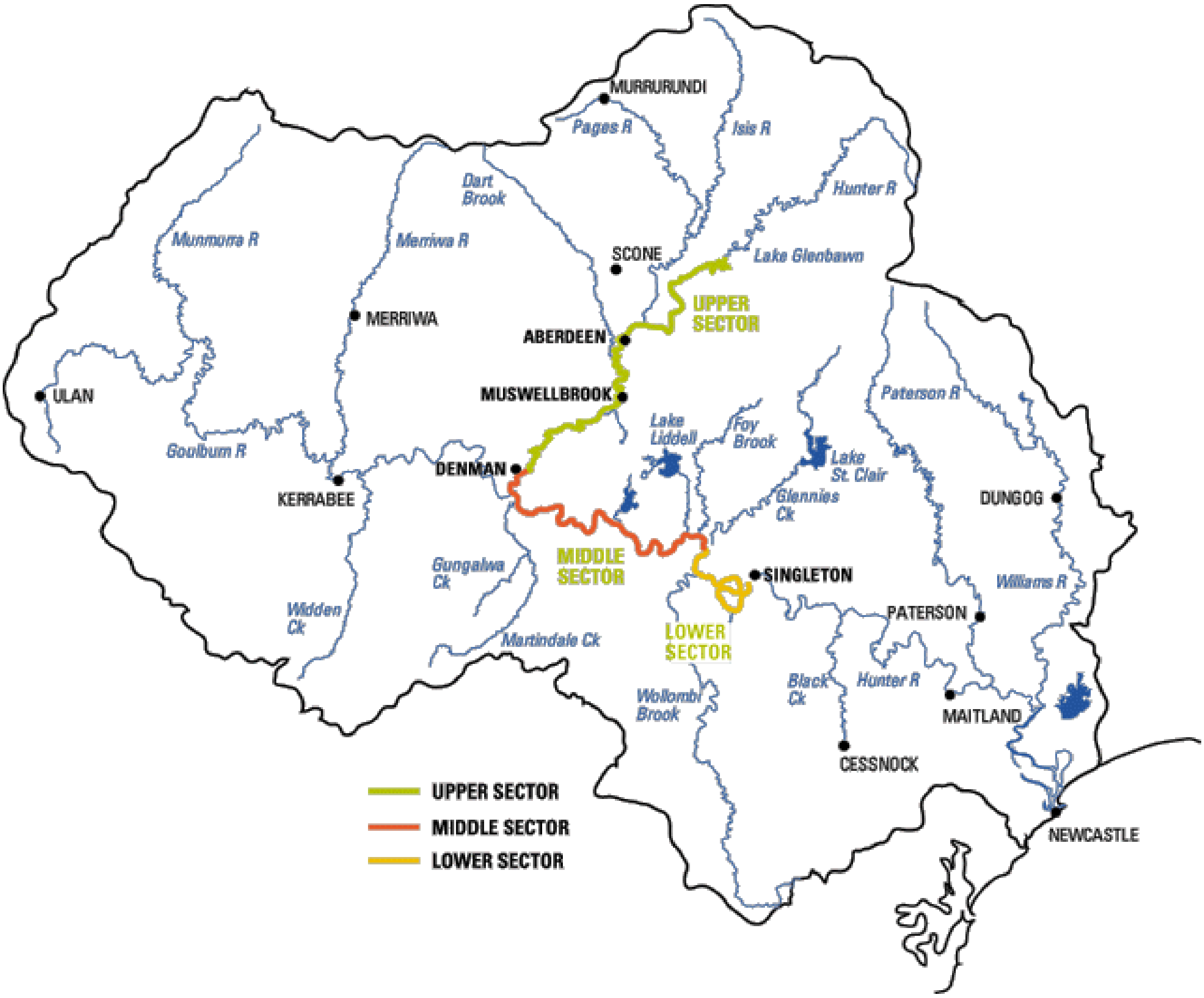


Figure 4-14 Hunter River salinity trading scheme map

Participants in the scheme are licensed by the Environmental Protection Authority (EPA). The Environment Protection Licence (EPL) defines the discharge points and the monitoring and reporting requirements. To understand the licence conditions, applicable for the Goulburn River, a review of the EPA licence register was completed. The licence conditions indicate discharge concentration limits of between 500 and 900 micro siemens per centimetre (µS/cm) are to be achieved at all discharge locations into the Goulburn River.

The salinity target for the Middle Sector is 900 micro siemens per centimetre (µS/cm) for both high flows and flood flows (refer to Figure 4-15). For the 2020–2021 period the average daily salinity level in the Hunter River at Denman was 855 micro siemens per centimetre (µS/cm). Spikes in electrical conductivity occurred when river flows in Denman dropped from 1000 ML per day to under 450 ML per day. The contributing factors included concentration of salt due to lower flows, potential inputs from surface water run-off and infiltration, and saline groundwater inflows.

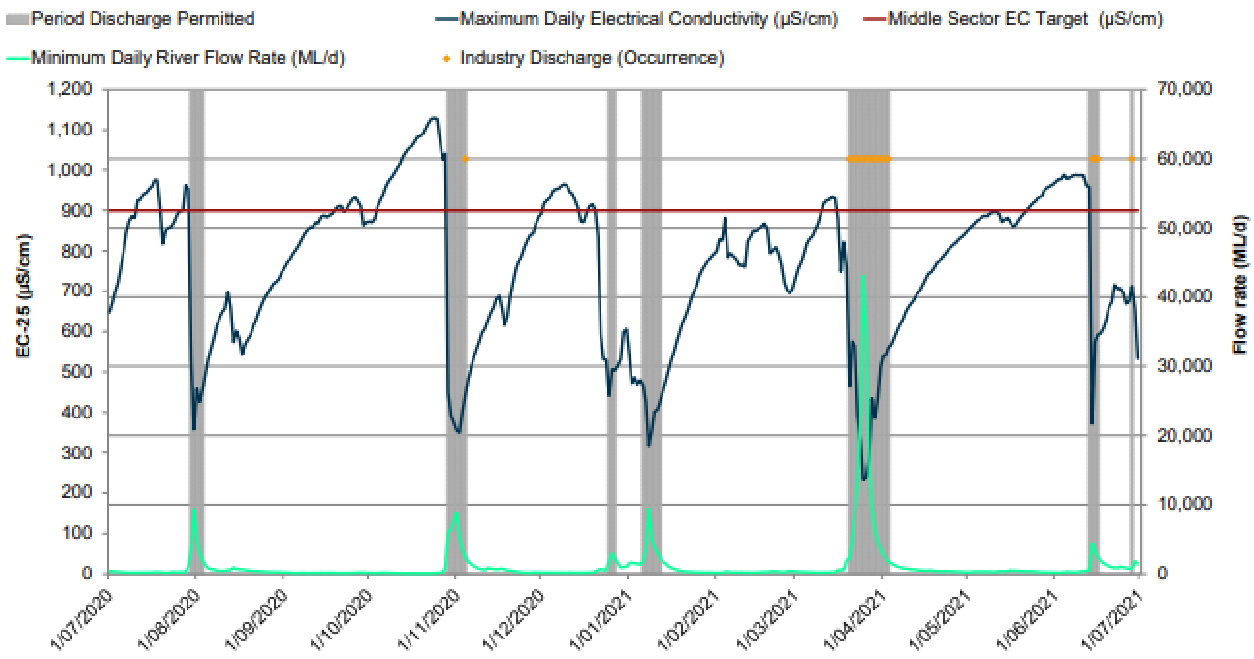


Figure 4-15 Maximum salinity and minimum flow: Hunter River upstream of Glenies Creek (2020–2021)

4.6.6 *Environmental Protection Licences Audit results*

The water quality discharge from Moolarben, Wilpinjong, and Ulan mines is subject to conditions as outlined in their respective Environmental Protection Licence (EPL) as regulated by the New South Wales Environment Protection Authority (EPA) in accordance with the Protection of the Environment Operations (POEO) Act 1997.

Each mine is required to have a license for their discharge of water into the environment, which includes specific limits and conditions to ensure that the water quality meets the relevant standards.

Each mine is required to regularly monitor a range of water quality parameters and report to the EPA via an Environmental Monitoring and Audit Report to ensure compliance with relevant water quality standards.

4.6.6.1 Moolarben Coal Mine

The 2020 Annual Review for Moolarben Coal Operations (Chase, 2020) documented water quality monitoring results for pH, electrical conductivity and turbidity for the water sampling locations in Goulburn River, Moolarben Creek, Lagoons Creek, Murragamba, Eastern and Wilpinjong Creeks. The results indicate:

- Goulburn River:
  - pH readings generally recorded within the 20%ile and 80%ile levels for all sites
  - the recorded EC values for Goulburn River are generally below the trigger level (900 µS/cm)
  - the turbidity readings for all three monitoring locations are generally below the trigger level (25 NTU).
- Moolarben Creek, Lagoons Creek
  - for pH some of the samples were above the trigger levels for Moolarben Creek but lower for Lagoon Creek
  - EC readings were generally within the 20%ile and 80%ile for each site
  - for turbidity there are several recordings that exceed the trigger level (25 NTU) during 2020.
- Murragamba, Eastern and Wilpinjong Creeks
  - pH readings generally recorded within the 20%ile and 80%ile levels for all sites
  - for EC, some high EC recordings were recorded but are associated with extended dry periods. Generally below trigger level of 900 µS/cm.

The turbidity readings for all three monitoring locations are generally below the trigger level (25 NTU).

4.6.6.2 Wilpinjong Coal Mine

At Wilpinjong coal mine there are three monitoring locations on Wilpinjong Creek and one downstream of Cumbo Creek. The 2021 Annual Report (March 2022) summarises the water quality monitoring results for 2021 and exceedances against the agreed trigger values. The results indicate the following:

- pH observations exceeding the lower trigger level at downstream Cumbo Creek are consistent with observations for the available monitoring record (from 2014). The observations indicate near-neutral pH, and are unlikely to pose a threat to the health of the aquatic ecosystem.
- pH observations exceeding the upper trigger level for downstream Wilpinjong Creek may be related to the pH of water discharged from the Reverse Osmosis (RO) Plant (LDP24). The RO plant was observed to discharge within defined EPL limits in 2021, but the upper bound of these limits is higher (pH 8.5) than the upper pH limit at downstream Wilpinjong Creek (pH 7.7).

Electrical conductivity and turbidity readings did not exceed trigger values for the period.

4.6.6.3 Ulan Coal Mine

Glencore 2021 Annual Review Surface Water Monitoring (attachment C) (Glenore, 2022) report for the Ulan Coal mine indicates that there are 15 surface water monitoring locations and 9 surface water discharge monitoring locations. As a minimum they measure for TSS but some locations include all the following pH, EC (µS/cm), TSS (mg/L) , Oil & Grease, (mg/L), BOD (mg/L), Nitrogen (mg/L), and Phosphorous (mg/L).

The results indicate that the recorded samples were generally within the ANZG trigger values for 2021, except for a few locations which were documented as follows:

- elevated EC for a site upstream of operations
- elevated EC and pH discharge in a small pool in Ulan Creek, upstream of a discharge point. When there is very limited flow from the pool, the EC increases. When there is rain and significant flow, the EC drops, indicating that EC rises as water from the pool evaporates. No exceedance of discharge flows was recorded. Increases in pH may have been a result from increased run off from increased rainfall
- elevated TSS – A maximum TSS recorded of 1,820 µS/cm following heavy rainfall on the 22 November 2021low pH – Historical data from Ulan Creek has low pH but the creek is ephemeral and has no mining activities in the area.

4.6.7 Grab sample results

The Contamination Factual Report Energy Hubs (packages A and C) (WSP Golder, October 2022) documents the collection of grab samples of surface water at five (5) locations (see Section 3.5.5 and Figure 3-2 for details of the locations). The results of the grab samples indicated:

- all heavy metals concentration levels were below the adopted site assessment criteria
- concentrations of inorganics (such as sulfate, bicarbonate, carbonate, hydroxide, chloride, fluoride and sodium) were below the adopted assessment criteria for all samples except for hardness. Hardness exceeded the aesthetic guidelines in four samples, SW1, SW2, SW3 and SW4.

The results of the grab sample water quality testing in comparison to the relevant ANZG indicators listed in Table 2-1 are presented in Table 4-12. Use of the grab samples results are limited as they represent the a single point in time analysis. Notwithstanding, the results indicate that at the time of sampling, salinity levels were above the ANZG default guidelines levels of 350 µS/cm and the pH was outside of the range 6.5–8 for lowland rivers in the Macquarie River catchment. The results are also above the pH (8 unit) water resource plan targets as presented in Table 2-3 but below the peak (80%) – salinity (744 µS/cm) as outlined in Table 2-4.

Table 4-12 Surface Water Grab sample results

Indicator	Unit	Grab samples range
Salinity (electrical conductivity)	µS/cm	496–715
pH	unit	7.99–8.39

4.6.8 Summary of water quality

The water quality for the study area can be separated into the Macquarie-Castlereagh Catchment and the Hunter Catchment. For the sections within the Macquarie-Castlereagh, water quality is rated mainly as ‘fair’, and then ‘poor’ at Elong Elong. The Macquarie-Bogan River Basin and the Castlereagh River Basin was rated ‘poor’ to ‘very poor’, for TN, TP, and salinity. The overall catchment area has ‘poor’ water quality with the highest salinity levels located at Elong Elong along the Talbragar River. For the Hunter River catchment, there nearest water quality data is at Denman. This site had a rating of ‘fair’ for TN and ‘very poor’ for TP, and then in 2020–2021 had an average daily salinity level of 855 micro siemens per centimetre which is within guidelines. The mining operations at Moolarben, Wilpinjong and Ulan report their water quality monitoring results as a requirement of the EPL which all reported to be largely compliant. However, the key parameters of EC and TSS were the common parameters where exceedances were reported.

The water quality across the study area is therefore not considered to be meeting the Basin Plan targets or the NSW WQO, except for salinity levels in the Hunter River catchment, which meet the targets for the middle section of the Hunter River trading scheme. The waterways across the study area could be considered slightly to moderately disturbed with the main influence being agricultural uses for the Macquarie-Castlereagh Catchment and mining for the Hunter Catchment. Turbidity and TP are the key indicators that rate the poorest for the environmental values of the waterways across the study area.

5 Construction assessment

This Chapter presents an assessment of the potential impacts that expected to occur during construction of the project. The key potential construction impacts relating to hydrology and water quality are discussed in detail below.

5.1 Geomorphology

The watercourses crossed by the project include the Talbragar River and several other smaller creek crossings. Transmission line towers would be constructed at least 50 metres from the edge of the major watercourses but are unlikely to avoid all first and second order streams.

There would be numerous crossings of minor streams by access tracks. The potential impacts to geomorphic conditions of these watercourses would include:

- changes in low flow channel shape due to temporary works (such as access tracks) changing local runoff behaviour (hydrologic regime)
- increased sediment load from runoff from construction areas.

The final siting of towers would avoid watercourse banks where practicable, and so no direct geomorphological impacts would be anticipated from construction work. Construction work associated with the installation of transmission line towers located within the flood plain may contribute to the above geomorphological impacts during flood events due to changes to overland flow paths. These impacts would be minor but could result in changes to erosion and channel shape due to the poor to moderate geomorphic conditions in the Talbragar River between Uarbry and Elong Elong and the Upper Goulburn River catchment. (refer to Section 4.2.2)

5.2 Water supply, water resources and wastewater

Water would be required for the construction of the project. The water demands for a range of construction activities have been estimated and presented in Table 5-1 and described as:

- dust suppression on construction work areas and access tracks through the use of a water spray attached to a tanker vehicle (including the possible use of water reduction polymers)
- general construction uses
- earthworks and pavement compaction
- on-site concrete batching
- wetting backfill material (if it is too dry for effective compaction)
- landscaping
- general worker facilities at the construction compounds and workforce accommodation camps.

Table 5-1 Construction water demand

Activity	Quality	Demand (ML) 2024	Demand (ML) 2025	Demand (ML) 2026	Demand (ML) 2027
Compaction (general)	Non-potable	0	43	25	3.5
Compaction (pavements)	Non-potable	4	21	17	0
Concrete	Potable	0	14.6	13	1.5
Dust suppression	Non-potable	5	87	31	0
Landscaping	Non-potable	0	0.5	6	2.6
Drinking water	Potable	1.5	13.5	13.5	1.5
Construction camp including personnel consumption	Potable	19	172	134	57.5

The non-potable water demand volumes are proposed to be sourced from existing surface water licences or potentially treated water sources. The available water sources and volumes are described in Section 4.3.1. The available water in each surface water source is dependent on conditions in each water source which are dependent on the climate.

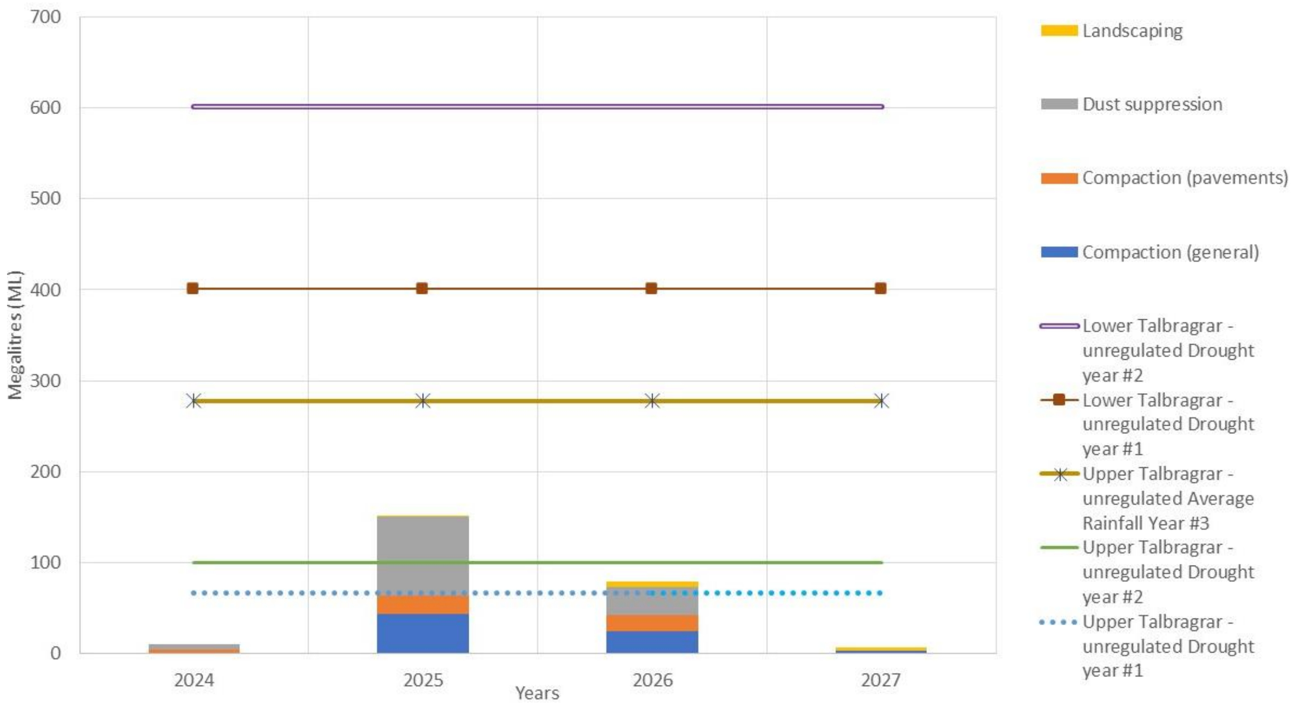
The project lies within the Upper and Lower Talbragar River water sources. Unfortunately however, no water usage data is available for these water sources. In order to provide a suitable representation of potential water usage impacts within the Talbragar River, water source data from the adjacent Cudgegong River catchment was used to assess the impacts due to its similar land uses and climatic conditions to the study area. For the Cudgegong River water usage (refer to Figure 4-10), three representative years were chosen to understand the potential water available to meet the non-potable water demands. The 2008–2009 year was considered a drought year (BOM, Previous droughts (bom.gov.au) 2022) for the Cudgegong River water source, with 18% of the total water usage being attributed to general security licences. The 2019–2020 was also considered a drought year, with 27% of the total water usage being attributed to general security licences.

These percentages were then transposed to the Upper and Lower Talbragar River water sources for the Upper Talbragar (refer to Table 4-2) the total water available is 370 ML per year and for the Lower Talbragar (refer to Table 4-3) the total is 2227 ML per year.

Figure 5-1 shows the total non-potable water demands for each year of construction, which indicates that the year 2025 would demand the largest volume of non-potable water. Figure 5-1 also shows the available water for the Upper and Lower Talbragar River water sources during drought years and an average rainfall year.

For all construction years, the available water for extraction would be limited by the preceding rainfall. As can be interpreted from the data, there is a high chance of water being available for all construction activities requiring non-potable water for the 2024 and 2027 construction years. The availability of water is also dependent on the condition of visible flow in the Talbragar River water source (refer to Table 4-7) and the long term data indicates that visible flow is only likely to occur 28% of the time. However, the impact to available water in the Upper and Lower Talbragar Rivers is considered to be low due to the low non-potable water demand volumes for the project during these construction years.

In an average year with a rainfall depth of 600 mm, 75% of the total water usage being attributed to general security licences would be potentially available and likely to meet the non-potable water demand for the project, subject to the condition of visible flow in Talbragar River water source (refer to Table 4-7). These construction years are estimated to have an impact on water source supply volumes in both the Upper and Lower Talbragar Rivers. However, the Lower Talbragar has a large volume of potential water available and therefore the impact would be less and could be the preferred source for non-potable water for the project during low rainfall periods.



#1 Drought year – based on Cudgegong water source usage 2008–2009, 18% of total was available for regulated river (general security)

#2 Drought year – based on Cudgegong water source usage 2019–2020, 27% of total was available for regulated river (general security)

#3 Average rainfall year – 600 mm – 2012–2013, 75% of total water was available for regulated fiver (general security)

Figure 5-1 Water demand against potential available water

5.3 Water quality

The construction of the project has the potential to degrade the water quality of the watercourses within study area and downstream areas , if not properly managed. The construction activities assessed with regard to water quality impacts included but are not limited to:

- vegetation clearing
- soil stripping, transportation and stockpiling for all construction, laydown, staging areas and access tracks
- earthworks and establishment of construction pads for each transmission line tower and for the proposed energy hubs and switching stations
- construction of footings and foundation works for the new transmission line towers including boring and/or excavation, steel fabrication works and concrete pours
- establishment and operation of concrete batching plant(s) during construction
- establishment and operation of water treatment plant (s) to treat and reuse water for construction activities as necessary
- establishment and construction works within the brake/winch sites
- upgrade of existing watercourse crossings or construction of new watercourse crossings where alternative access routes are impractical
- use of heavy and light machinery such as scrapers, excavators, dumpers, rollers, chainsaws and other equipment for all above activities (resulting potential spills or leaks of chemicals fuels or other waste materials)
- establishment and operation of construction compounds and workforce accommodation camps along the project.

Based on these activities, construction of the project may lead to increases of the following pollutants into watercourses:

- nutrients (nitrogen and phosphorus) – commonly present in agricultural areas that may become mobilised from disturbance of agricultural land for construction work
- sediment from vegetation and topsoil clearing, soil excavation, movement and storage and stormwater runoff through disturbed sites
- chemicals, fuels and hydrocarbons from use, refuelling and maintenance of equipment and construction machinery
- concrete slurry and wastewater – from two concrete batching plants
- potential contaminants of concern related to previous land uses – heavy metals, Total recoverable hydrocarbons (TRH), Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX), Polycyclic aromatic hydrocarbon (PAH), organochlorine pesticides (OCP) and organophosphorus pesticides (OPP)
- heavy metals such as zinc, lead, copper, nickel, cadmium and chromium from potential disturbance of contaminated land and the use and maintenance of vehicles and plants
- gross pollutants such as paper and plastic packaging and materials from material use on construction work areas and general construction staff litter.

The construction of the project may degrade water quality if not properly managed. Poor management, such as uncontrolled failures of site-specific soil and erosion controls, of locally generated surface water may subsequentially have impacts to surrounding ecology, sensitive receiving environments and other water uses. The risk of surface water quality discharges not meeting trigger values, would vary depending on the stage of construction, the area of disturbance and presence of high rainfall or wind weather events.

Potential construction water quality impacts associated with each of the key construction activities are discussed below.

5.3.1 Vegetation clearing

The construction of transmissions towers would require a disturbance footprint of about 80 m by 80 m at each location, which would laydown areas, and necessitate the removal of all vegetation within the subject areas. Vegetation removal would also be required for break and winch sites and access tracks. This vegetation would be removed using chainsaws and also by earthmoving equipment such as bulldozers being used above ground level.

Removal of vegetation increases risk of soils run-off and displacement. Removal of scrub and undergrowth would be minimised where possible.

5.3.2 Earthworks

Earthworks would be required for project elements such as construction of transmission line towers, construction of the proposed energy hubs, switching stations and for all general civil works required for access tracks, construction compound and workforce accommodation camps, and other ancillary facilities.

The risk of construction activities potentially impacting upon the quality of receiving waterways would be ongoing throughout the life of the construction phase and would be highest at locations with a slope of greater than 2.5 per cent, and where works are proximity to watercourses. Risks of sediment transport and erosion would also increase during high rainfall and wind weather events.

These potential impacts would be accounted for in the CEMP and SWMP. These would include requirements for progressive erosion and sediment control measures and on-site management protocols. Spoil from the excavations associated with the transmission line towers may be reused on site wherever possible, however in some instances spoil would be removed from site and disposed of at a facility authorised to accept such waste. Any such on site re-use would be within the construction area and would not substantially alter landform or drainage in the vicinity of the transmission line towers.

Implementation of appropriate soil and water construction management measures would be anticipated to minimise impacts to water quality impacts from construction of the project. Additionally, impacts would be limited to the duration of construction and would be a short term. As such construction of the project would not cause significant changes to the water quality environment.

5.3.3 Construction compounds and accommodation camps

Three construction compounds and two workforce accommodation camp sites would be required during the construction to provide staging/laydown, concrete batching facilities. Workforce accommodation camps would be established at Neeleys Lane and Merotherie. These would generally comprise a camp alongside a laydown area occupying typically 300 metres by up to 500 metres.

Establishment of these sites would include site clearing and additional impervious areas which may lead to increased run off and therefore increased sediment transport and erosion. There may be additional risks to water quality from release of gross pollutants and site litter from general site activities.

Wastewater treatment plants would be established at the workforce accommodation camps to manage the generation of wastewater. The water treatment plants would be appropriately sized according to the number of personnel to be housed at the respective workforce accommodation camps, including applicable redundancy for maintenance requirements. Wastewater would be treated, in accordance with the National Guidelines for Water Recycling (Environment Protection and Heritage Council, et al, 2006) to enable reuse for construction activities, such as dust suppression, with any waste by-product to be disposed offsite at a licenced premised that can lawfully accept the waste.

The water treatment plant would include testing and commission phase to ensure wastewater has been treated to the applicable criteria, prior to onsite reuse.

A SWMP would be prepared for the project which would include site-specific management measures to manage and mitigate release of additional sediments, litter and pollutants during use of these sites.

5.3.4 Watercourse crossings

The proposed transmission line would cross a series of major watercourses including the Talbragar River and several other smaller creek crossings.

Generally, the design of the transmission line would include a transmission line tower on either side of each major river crossing. A drone or helicopter may be used to take a lead wire over the watercourse to allow cables to then be pulled and strung tower to tower. In some circumstances it may be impractical to use a drone or helicopter, and in such cases alternative methods, such as the use of watercraft, might be required.

It is not envisaged that any access tracks or bridges would be required for these particular crossings due to the design and proposed construction method of the transmission line at these locations. There would likely be some temporary works at the transmission line tower on each side of the span to allow for the construction of the transmission line tower, however it is likely that these would be at least 50 metres from the bank of the watercourse. Where alternative access routes are impractical, a number of watercourse crossings and causeways would be required at some smaller watercourse locations along the length of the project. Where required, bed- level fords (i.e. construction of a good footing where a creek may be crossed) or causeways may be required to be constructed to provide temporary access. Where these crossings are required, they would typically be constructed using the following typical methodology:

- removing all loose material from the watercourse at the point to be crossed, forming a depression with firm base and sides
- the depression would then be filled with graded layers of rock. The rock layers would be placed so as to produce an interlocked bed of rock, sloped and dished, to allow water to drain freely through and flow over the causeway (minimum thickness of around 450 millimetres but not higher than the bed of the watercourse).

All watercourse crossing would be designed and installed in accordance with relevant Department of Primary Industries (DPI) guidelines for watercourse crossings including:

- Policy and Guidelines for Fish Friendly Waterway Crossings (DPI, 2004a)
- Why do fish need to cross the road? Fish Passage Requirements for Waterway Crossings (DPI, 2004b)
- Water Guidelines for Controlled Activities on Waterfront Land (DPI, 2012a).

If required as part of a water crossing, culverts may also be installed in accordance with required standards (such as AS/NZS 4058 Precast concrete pipes (pressure and non-pressure)).

With the correct implementation of pre-construction and construction measures, there would be limited residual risk to watercourses as a result of any watercourse crossings used during construction of the project.

5.3.5 Stockpiling and spoil handling

The construction of the project would generate spoil, vegetation waste and general construction and demolition waste that would be stored in stockpiles. Excavated material would be stockpiled to be used for backfill around the tower foundations and embankment filling at the tower site from which it was excavated. Topsoil would be kept separate from the excavated material to ensure placement at ground level during backfilling. Any excess excavated material would be spread evenly around the site after completion of the foundation backfilling (if suitable) or removed from the site and disposed of in accordance with the appropriate waste classification.

Stockpiling and screening of earthwork materials would pose a risk to the existing water quality in receiving environments through the increased likelihood of movement of sediment with the risk increasing if stockpiles are in proximity to the watercourse. Stockpiling of mulched vegetation from clearing of trees and shrubs would also pose a risk of tannins leaching into watercourses, and increased loads of organics in watercourses. The discharge of water that is high in tannins may increase the biological oxygen demand of the receiving environment, which may in turn result in a decrease in available dissolved oxygen. Once discharged to the environment, tannins may also reduce visibility and light penetration, and change the pH of receiving waters. These impacts may affect aquatic ecosystems in receiving environments.

Excess spoil would be reused where practicable. Excess spoil stockpiled in locations that are open to rainfall or runoff would include appropriate management measures such as sediment fences and diversion drains to mitigate the impact of sediment movement offsite. Correct implementation of stockpile management protocols would mitigate and manage impacts to the receiving environments water quality.

5.3.6 Potential for spills and litter

The following activities have the potential to result in release of contaminants, oils, fuels, grease, chemicals and gross pollutants into the watercourses in and surrounding the project:

- machinery and equipment operation, refuelling, maintenance and wash down
- spills and failure of machinery
- concrete batching, treatment and curing
- disturbance of contaminated soils
- inadequate management of chemicals, spoil, material stockpiles and litter from construction work areas
- wastewater generated during construction.

Pollutants from these activities may be picked up in runoff from the site and enter the watercourses and be transported downstream of the construction area. Water quality and ecological impacts may result from release of these contaminants into the catchment.

Temporary concrete batch plants would be constructed at each of the construction compounds.

Mitigation and management measures such as bunding, silt fences and other physical measures, would be implemented as part of the construction of the project. This would reduce the potential for release of chemicals from construction work areas and into watercourses.

5.3.7 Summary of water quality impacts

The key water quality objective for the project, is to appropriately manage water quality, including salinity, for environmental, social, cultural, and economic activity and therefore protect downstream environments from the potential impacts of surface runoff and discharge during construction and operation. The detailed water quality objectives for the project are defined in Section 1.1.1 and the existing water quality conditions indicate turbidity and TP to be the indicators affecting the watercourses. It is anticipated that through correct implementation of the standard mitigation measures, minimising soil loss during construction as described in Chapter 7, will minimise impacts to the existing water quality condition of the study area. As such construction of the project would not cause significant changes to the water quality environment against the identified water quality objectives and Basin Plan

Where there are sensitive receiving environments located along the project, water quality impacts from the construction of the project are anticipated to be short-term and limited in extent. Additionally, the progressive nature of construction would limit the work areas and duration within which impacts may occur. A water quality monitoring program would be developed to collect baseline data to characterise the existing water quality condition. The program would include water quality targets in line with the Basin Plan and ANZG guidelines. Monitoring as part of this program would assist in identifying any issues arising as part of the construction of the project and therefore minimising impacts to water quality as a result of the project.

6 Operational assessment

This Chapter presents an assessment of the potential impacts that are expected to occur during operation as a result of the project. The key potential construction impacts relating to hydrology and surface water quantity and quality are discussed in detail below.

6.1 Geomorphology

Potential impacts to geomorphology would include:

- changes in low flow channel shape due to placement of towers in low flow points which changes low flow runoff behaviour
- increased sediment load from runoff from permanent access tracks.

Transmission line towers located within the flood prone area of the watercourses may have minor, localised geomorphological impacts to the existing watercourses during flood events. The placement of the towers may be within minor low flow paths (1st and 2nd order streams) which would then result in changes in the position of these flow paths and movement of sediment locally within the flow path. However, this would not affect the main watercourse channels and regular flow regimes within the channels. Additionally it is recommended that no transmission towers should be located within the banks of watercourses with a stream order of 3 and above and therefore no geomorphological changes within the watercourses are expected that would affect the long term health of the watercourse (being the movement of sediment (including nutrients) and the presence of ponds or ripples that support aquatic fauna and flora).

Localised changes within flow paths may be experienced for the regular flood events but no significant impact is expected in large flood events, such as the 1% AEP. Where transmission line towers are located out of these minor watercourses, there would not be any geomorphological impacts.

6.2 Water supply and water resources

Water would be required during operation for maintenance activities and the operation. Section 4.3.1 outlines the available water for the surface water sources that intersect the project.

The long-term impacts of the expected operational water use on surface water available from the Upper and Lower Talbragar water sources would be minor but potentially be affected during dry periods when surface water availability could be low, and competition for water resources from existing irrigation suppliers in the region accessing the same water resources could be increased.

6.3 Water quality

There is potential for water quality impacts as a result of accidental spills or litter generated from operation and maintenance activities along the transmission easement near watercourses, however, these impacts would be minor and localised. Provided correct operation procedures and safeguards are implemented the residual likelihood of impacts would be very low. There would not be any impacts to water quality expected as a result of the presence of the transmission lines in the landscape.

There is potential for operational water quality impacts from any new impervious area at the switching stations and energy hubs. The new impervious areas have the potential to cause increased run off volumes and speeds, with potential for increased scour and sediment loads. The drainage system at the switching stations and energy hubs would collect and discharge surface and subsoil water to appropriate containment structures. Runoff within the switchyard would be intercepted by roadside kerb and guttering, V-drains and subsoil drains, and all associated pits and pipes, as appropriate would be diverted to natural watercourse using appropriate dispersion structures or drainage infrastructure.

Runoff outside the switchyard would be captured and diverted to natural watercourses using appropriate dispersion structures or drainage infrastructure. This would minimise potential scour and sediment movement from additional runoff from the new impervious areas introduced as part of the switching stations and energy hubs. The management of scour and capture of sediment will contribute to ensuring there are minimal impacts downstream and preventing triggering additional mitigation measures in relation to turbidity and TP which are key contributors to ‘poor’ water quality in the Macquarie Bogan catchment.

The drainage system would also separately drain oil and oil contaminated water to the appropriate containment structures. Potential impacts of oil and grease include films forming on the surface of the water and change the chemical oxygen demand within the watercourse or waterbody. The oil containment system would be provided in accordance with Substation Oil Containment Design Principles, to meeting the requirements of the Protection of Environment Operations Act and would therefore minimise the potential for water quality impacts from oils.

7 Recommended management and mitigation measures

7.1 Environmental management

Potential hydrology and water quality impacts during construction and operation of the project (in terms of both causing disturbance or creating impacts as a result of interrupting surface water sources) are expected to be limited, and would be further reduced with the implementation of the mitigation measures outlined below (Table 7-1) and within a CEMP and an erosion and sediment control plan (ESCP) sub-plan.

7.2 Construction Environmental Management Plan

The mitigation measures would be implemented and monitored for their effectiveness during construction. A Construction Environmental Management Plan (CEMP) and associated Soil and Water Management sub-plan (SWMP) would be prepared prior to construction of the project. The SWMP would identify the measures required to be implemented at construction work sites and this would limit the impact of the project (refer to the EIS for details). These would include soil and water measures which are commonly applied and well understood. Typical provisions within the CEMP would include:

- erosion and sediment control plan (ESCP) measures will be developed in accordance with the Managing Urban Stormwater: Soils & Construction series, including Volumes 1, 2A and 2C (Landcom). The proposed measures will be developed to suit the project conditions such that they consider the existing environment aspects as described in Chapter 4
- operational controls would need to be managed within an operational environmental management plan (OEMP).

To assist with specialising the ESCP measures, site specific project design inputs have been documented in Appendix A. This information would be used to inform the design of infiltration basins and trenches with a requirement to contain the 5 day 80^{th} percentile rainfall depth.

7.3 Mitigation measures

The identified impacts associated with the project are largely related to potential impacts on existing water quality. The following sections provide proposed mitigation measures which would be implemented for the project to mitigate the identified impacts. Table 7-1 details the proposed mitigation measures for the project.

Table 7-1 Mitigation measures – Surface water and hydrology

Reference	Impact	Mitigation measures	Timing	Applicable location(s)
WA1	Construction water supply	Construction water supply arrangements will be confirmed during continued design development and detailed construction planning, based on further investigations that include ongoing consultation with water suppliers to access the local reticulated network, use of treated mine water, and use of water tanks within construction compounds.	Detailed design and pre-construction	All locations
WA2	Construction water supply	Opportunities to minimise water demand will be further explored during detailed design and construction planning, including: — capture and use rainwater at construction compounds and/or workforce accommodation camps — use of treated mine water, subject to any onsite reuse requirements — re-use/recycling of construction water, for example, water could be reused onsite, for dust suppression, to assist with compaction — treated wastewater and/or groundwater inflows — the use of additives in concrete mixtures to reduce the amount of water required — identification of alternative construction techniques which will reduce water use (where practicable).	Detailed design and pre-construction	All locations
WA3	Watercourse geomorphology	Where relevant, permanent erosion control measures will be designed and implemented at relevant energy hubs, switching stations and transmission line towers to minimise potential scour and erosion risks associated with surface water runoff during operation.	Detailed design and construction	Energy hubs, switching stations and transmission line towers

Reference	Impact	Mitigation measures	Timing	Applicable location(s)
WA4	Dispersion of sediment into the environment	Areas disturbed as a result of construction activities will be managed in accordance with the requirements of *Managing Urban Stormwater Soils and Construction 4th Edition* (Landcom 2004). This will include the implementation of a range of erosion and sediment control measures which may include: — Drainage control measures, e.g. flow diversion banks, straw bale berms and rock-lined chutes — Sediment control measures, e.g. sediment fences, traps and basins and impervious covers — Erosion control measures, e.g. covering of stockpiles, erosion control blankets, dust suppression measures (e.g. water trucks) and revegetation.	Construction	All locations
WA5	Water quality	A water quality monitoring program for construction will be prepared and implemented to monitor water quality conditions at perennial watercourses that the transmission lines will cross, and to facilitate monitoring of any changes in water quality that could be attributable to the project during construction. The program will detail: — water quality objectives and criteria for the project, in accordance with the *Murray–Darling Basin Plan 2012* (Murray–Darling Basin Authority, 2012) and *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000* (ANZECC/ARMCANZ, 2000) — frequency, location and duration of sampling, as minimum will include at least two monitoring locations located downstream and upstream of the project on the Talbragar River, Talbragar River at Elong Elong (412042), Cudgegong River at Yamble Bridge (421019) and Wollar Creek	Pre-construction and construction	Relevant locations

Reference	Impact	Mitigation measures	Timing	Applicable location(s)
		— monitoring for total dissolved solids, dissolved oxygen, electrical conductivity, total suspended solids, total nitrogen and total phosphorus. In the event if exceedances of the project water quality criteria, soil and water management measures adopted as part of the Construction Environmental Management Plan would be reviewed and revised accordingly.		

It is anticipated that the implementation of appropriate soil and water construction management measures as discussed above would mitigate and minimise the potential impacts to the hydrologic environment and water quality. As such construction and operation of the project is not anticipated to cause significant changes to the hydrologic environment or water quality environment against applicable water quality objectives across the project.

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– Water NSW, 2022b, Real Time Data – Rivers and Streams, https://realtimedata.waternsw.com.au/, accessed: 22/08/2022.

9 Limitations

The preparation of this technical paper has involved a desktop exercise that has relied upon information from the proponent, together with freely available reports, data, figures and existing investigations. Freely available data and reports included the available background water sharing plan documents published by DPE, water resource plans and supporting documents published by DPE, river gauge data published by WaterNSW and collated by the Bureau of Meteorology.

The impact assessment is limited to a qualitative assessment based on the reference design and proposed construction methodology at the time of preparation of this report.

This assessment is adequate to assess typical environmental impacts and provide recommendations for mitigation measures. Recommendations would be subject to refinement as the design of the project is finalised and validation is undertaken during construction.

Appendix A

Erosion and Sediment Control Plan project environmental design inputs

Table A.1 ESCP project environmental design inputs

Environmental aspect	Blue Book clause	Project design input	Comment
Design rainfall			
5 day rainfall depth 80th percentile	Section 6.3.4 – Table 6.3a	Varies across the project Dubbo – 22.8 Bathurst – 20.6 Gunnedah – 30.2	Infiltration trenches and basins to be designed to infiltrate rainfall up to a site specific depth based on the information in this table.
Design storm AEP	Section 6.3.3	Sediment basins and their outlets should be designed to be stable in the peak flow from at least the 10-year ARI time of concentration event	To inform design of bypass channels and overflow weirs.
	Section 6.3.4	Sediment retention basins for Type D and Type F soils are wet basins. Their design criteria are the same.	
	Section 6.3.5	The design storm event for basins on Type C soils is taken as the 3-month ARI flow, unless specified differently in the local Council's "Stormwater Management Plan".	
Soil Type	Technical paper 16 – Contamination	Chromosols – CH Ferrosols – FE Kurosols, Natric – Kun Rudosols – RU Sodosols – SO Rudosols and Tenosols – RU_TE Vertosols – VE Kurosols – KU Kandosols – KA Site crosses over all soil hydrologic groups; A, B, C, D	To inform infiltration rates for minimal runoff following the design rainfall event.
Infiltration Rate	Appendix F	A – Saturated Steady State: 25 – Dry Soil: >250 B – Saturated Steady State: 13 – Dry Soil: 200 C – Saturated Steady State: 6 – Dry Soil: 125 D – Saturated Steady State: 3 – Dry Soil: 75	To inform design of infiltration basin and trenches to minimise runoff.

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