APPENDIX G

DUNGOWAN DAM AND PIPELINE EIS

Groundwater Impact Assessment

NSW GOVERNMENT | EMM creating opportunities

Dungowan Dam and pipeline project

Groundwater Impact Assessment

Prepared for Water Infrastructure NSW

September 2022

Dungowan Dam and pipeline project

Groundwater Impact Assessment

Water Infrastructure NSW

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Version	Date	Prepared by	Approved by	Comments
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Executive Summary

EMM Consulting Pty Limited (EMM) has been engaged by Water Infrastructure NSW to undertake a Groundwater Impact Assessment (GIA) to accompany an application and supporting environmental impact statement (EIS) for the Dungowan Dam and pipeline project (the project). The project includes a new dam at Dungowan (new Dungowan Dam) approximately 3.5 km downstream of the existing Dungowan Dam and a new section of pipeline about 32 km long between the proposed Dam outlet and the tie in point to an existing pipeline from Dungowan Showground to the Calala Water Treatment Plant (WTP).

The project is in the Tamworth region of NSW, within the southern New England Fold Belt. A large portion of the project area is mapped as Carboniferous aged marine sedimentary rocks (Sandon Association), while the valley fill areas are mapped as Quaternary aged alluvial deposits up to 4.6 m in thickness.

ES1 Hydrogeology

The main groundwater systems within the project area are:

- a localised highly permeable shallow groundwater system associated with the Quaternary-aged alluvium. For the purposes of this assessment, this unit is divided into:
  - the Peel River Alluvium (PRA): located downstream of Dungowan Creek and Chaffey Dam; and
  - the Dungowan Creek Alluvium (DCA): located within the Dungowan Creek floodplain.
- a low permeability regional fractured rock groundwater system associated with the metasedimentary rock which occupies the uplifted, mountainous portion of the project area. This unit is formally termed the Peel Fractured Rock (PFR).

Direct rainfall infiltration is the primary recharge mechanism across the project area, while groundwater discharge occurs via baseflow, seepage/springs, leakage to underlying groundwater systems and evapotranspiration.

Groundwater flow in the alluvium is down gradient, while regional groundwater flow in the fractured rock displays a muted reflection of topography, flowing from catchment highs to valley floors, or southeast to northwest, toward Tamworth.

ES2 Sensitive receivers

Private landowner bores near the project generally target the alluvial groundwater system. Private groundwater use is mostly licenced for water supply, irrigation, stock and domestic purposes.

Within a 1 km radius of the proposed pipeline and the Peel River downstream of Chaffey Dam to the Calala WTP, there are:

- nine registered groundwater bores used for domestic water supply within 10 km of the new Dungowan Dam,
- 236 domestic water supply bores;
- 119 irrigation supply bores; and
- 22 stock and domestic supply bores.

Terrestrial and aquatic ecosystems associated with creeks, rivers and riparian habitats receive groundwater baseflow contributions from both the alluvial and fractured rock aquifers. A review of the Bureau of Meteorology (BoM) groundwater dependent ecosystem (GDE) Atlas (BoM 2022) identified three plant community types (PCTs) that may have groundwater dependence. Ecosystem dependence associated with these PCTs are characterised as having a facultative-opportunistic reliance on groundwater, accessing temporary groundwater within the shallow alluvial sediments of the DCA following flooding events or extended wetting periods.

There are four 'high priority' GDEs listed in the *Water Sharing Plan for the NSW Murray Darling Basin Fractured Rock Groundwater Sources 2020*. However only the Black Spring site is relevant to the project. The Black Spring site is:

- located on Black Spring Creek approximately 9km north of Ogunbil;
- a tributary to Dungowan Creek; and
- located downstream of the new Dungowan Dam.

ES3 Impact assessment

The assessment of project-related impacts to groundwater resources and sensitive receivers considers the requirements of the *Water Management Act 2000* (WMA), the *Water Sharing Plan for the Namoi Alluvial Groundwater Sources 2020*, the *Water Sharing Plan for the NSW Murray Darling Basin Fractured Rock Groundwater Sources 2020* and the *NSW Aquifer Interference Policy* (AIP). In addition, the licensing requirements of the project have also been assessed against the WMA, the relevant water sharing plan (WSPs) and the AIP.

ES3.1 Construction impact pathways

The following components of the project construction were considered to have the potential to affect groundwater:

- Dam excavation area: groundwater is likely to be intercepted in the lower levels of Dungowan Creek when excavating the dam foundation. The assessment considered this interception and the potential for temporary impacts to nearby GDEs.
- Spillway excavation area: groundwater is likely to be intercepted when excavating the spillway chute and stilling basin foundation. The assessment considered this interception and the potential for temporary impacts to nearby GDEs.
- Quarry and borrow areas: groundwater may be intercepted when quarrying for construction materials. The assessment considered this interception and the potential for temporary impacts to nearby GDEs.
- Pipeline trenching works: groundwater would be intercepted when trenching through Dungowan Creek and could be intercepted when trenching through shallow alluvial sediments. The assessment considered this interception and the potential for temporary impacts to nearby GDEs and groundwater users (ie bores).

ES3.2 Operation impact pathways

The following components of the new Dungowan Dam and project operation were considered to have the potential to affect groundwater:

- the presence of the dam embankment has the potential to increase recharge to groundwater, as well as disrupt the hydraulic gradient and flow path of the groundwater.

- the applied load from the dam embankment on the Dungowan Creek Alluvium (DCA) and Peel Fractured Rock (PFR) groundwater sources has the potential to cause the water pressure (groundwater level) to rise, altering the local groundwater flow regime near the inundation area and dam embankment.
- due to the prioritisation of the new Dungowan Dam for Tamworth town water supply, run-of-river water transfers from Chaffey Dam to Calala WTP would reduce during the operation of the Dungowan Dam and pipeline project. It is possible that the Peel River Alluvial (PRA) groundwater regime may change due to the reduction of run-of-river water transfers.

The following is considered a cumulative operational impact:

- Chaffey Dam pipeline operation: run-of-river water transfers from Chaffey Dam to Calala WTP would reduce when Chaffey dam is at 20% capacity. At 20% capacity, the Chaffey Dam pipeline would be used in conjunction with the new Dungowan Dam to reduce transmission loses to the PRA. It is possible that the PRA groundwater regime may change due to the reduction in run-of-river transfers and environmental flows and GDEs and groundwater users (ie bores) on the Peel River may be affected.

ES3.3 Predicted impacts

ES3.3.1 Construction

Drawdown near the excavations is expected to be localised and temporary due to the sequential nature of the works, which would reduce the need for ongoing dewatering during construction. There are no groundwater users within the vicinity of the new Dungowan Dam and spillway excavation areas, and the terrestrial and aquatic ecosystems present do not have a dependent relationship with groundwater. The potential impact to GDEs and groundwater users due to these construction works is negligible to low.

During the construction of the pipeline, groundwater seepage to trenched excavation works is not expected to intercept groundwater. If groundwater is intercepted during trenching the implementation of management and engineering measures would minimise the need to dewater, reducing the likelihood of impact to GDEs and other groundwater users. Trenches would be left open for the minimal amount of time possible limiting dewatering if groundwater is intercepted.

ES3.3.2 Operation

During the operation of the project there would be a reduction in the run-of-river water transfers in the Peel River from Chaffey Dam to Calala WTP. Despite the reduced release of water from Chaffey Dam, environmental flows would remain the same. Despite these reduction in surface water flows, there would be a negligible impact on the PRA's groundwater regime and subsequently negligible impact for GDEs and groundwater users to access groundwater in the Peel River.

Analysis of the overall depth regime changes due to the operation of the project indicates that the minor changes to stream flow would result in negligible changes to stream depth in Dungowan Creek and the Peel River. By inference, the project is not expected to affect recharge rates to the DCA (below the new Dungowan Dam) and PRA (below Chaffey Dam), or effect groundwater access to GDEs or other users.

ES3.4 AIP minimal impact considerations

The project has potential to impact on local and regional groundwater sources and sensitive receivers. Potential impacts have been assessed in accordance with the AIP minimal impact considerations and the following has been determined:

- Potential impacts on private bores: no water supply works are predicted to be impacted by the project during construction or operation.

- Potential impacts on GDEs: GDEs are predicted to be negligibly impacted during the construction and operation of the project.

- Changes to groundwater quality: with regard to the AIPs' groundwater quality requirements, the project is not anticipated to result in a lowering of the beneficial use (ie environmental value) category of the local groundwater sources.

ES4 Groundwater licencing requirements

Based on the results of a steady state analytical model, the maximum volume required for licensing of groundwater during construction is:

- 24.9 ML/yr from the Dungowan Creek Management Zone within the Peel Alluvium Groundwater Source; and

- 3.9 ML/yr from the Peel Fractured Rock Groundwater Source.

The licencing pathway for groundwater entitlement during construction is via the water market. No groundwater take is expected during operation of the project and hence no licensing is required.

ES5 Management and monitoring

The design of the project and the associated environmental management requirements would be developed further during detailed design and prior to construction to minimise physical groundwater interception and inflow, conserve and reuse water, and minimise seepage. These designs would be combined with a water management strategy incorporating plans and mitigation measures, as well as a monitoring regime to minimise impacts to the groundwater systems and sensitive receivers.

Monitoring of the project's groundwater network would continue, and the network would be expanded to target the identification of potential impacts. Monitoring each component of the water management system (including groundwater seepage) underpins if, how, and when management responses are required. Triggers and thresholds would be developed in a project Groundwater Management Plan to provide context on if, how, and when management measures are required as part of the water management strategy for the project.

Abbreviations and units

ABS	Australian Bureau of Statistics
AIP	NSW Aquifer Interference Policy
AMD	Acid mine drainage
AWD	Available Water Determination
BLR	Basic landholder right
BoM	Bureau of Meteorology
$CaCO_3$	Calcium carbonate
CoT	Certificate of Title
CSSI	Critical State significant infrastructure
DCA	Dungowan Creek Alluvium
DPE	NSW Department of Planning and Environment
DPIE	NSW Department of Planning, Industry and Environment
EC	Electrical conductivity
EIS	Environmental Impact Statement
EMM	EMM Consulting Pty Limited
EP&A Act	NSW *Environmental Planning and Assessment Act 1979*
EPA	NSW Environment Protection Authority
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
EPL	Environment protection licence
FSL	Full supply level
GDE	Groundwater dependent ecosystem
GIA	Groundwater Impact Assessment (this report)
GL/yr	Gigalitres per year
GWMP	Groundwater Management Plan
HDD	Horizontal Directional Drilling
HDPE	High-density polyethylene
K	Hydraulic conductivity
kL/day	Kilolitres per day
km	Kilometre
kV	Kilovolt
LRS	NSW Land Registry Services
LTAAEL	Long term average annual extraction limit
L/s	Litre per second

L/s/km	Litres per second per kilometre
m	Metre
m/day	Metres per day
mAHD	Metres above height datum
mbgl	Metres below ground level
MGA	Map Grid of Australia
ML	Megalitre
ML/yr	Megalitres per year
MNES	Matters of national environmental significance
µS/cm	MicroSiemens per centimetre
NATA	National Association of Testing Authorities
NEFB	New England Fold Belt
NOW	NSW Office of Water
NRAR	NSW Natural Resources Access Regulator
NSW	New South Wales
NWC	National Water Commission
PAF	Potential acid forming
PCT	Plant community types
PFR	Peel Fractured Rock
PMF	Probable maximum flood
POEO Act	NSW *Protection of the Environment Operations Act 1997*
PRA	Peel River Alluvium
QA/QC	Quality Assurance/Quality Control
Redox	Oxygen reduction potential
SEARs	Secretary's Environmental Impact Assessment Requirements
SILO	Scientific Information for Land Owners
SMEC	SMEC Australia Pty Ltd
SSI	State significant infrastructure
TDS	Total dissolved solids
WAL	Water access licence
Water Act	NSW *Water Act 1912*
WMA	NSW *Water Management Act 2000*
WSP	Water sharing plan
WTP	Water treatment plant

Glossary

Term	Definition
Abstraction	The removal of water from a water store.
Allocation	The specific volume of water allocated to water access entitlements in a given water year or allocated as specified within a water resource plan.
Alluvium	Loose, unconsolidated (not cemented together into a solid rock), soil or sediments (including clay, silt, sand, gravel, cobbles and boulders), eroded, deposited and reshaped by water in some form in a non-marine setting.
Aquifer	A geological formation or group of formations; able to receive, store and transmit significant quantities of water. Means a geological structure or formation, or an artificial landfill, that is permeated with water or is capable of being permeated with water (NSW Water Management Act 2000 definition).
Aquifer, confined	An aquifer overlain by a confining bed. The confining bed has a significantly lower hydraulic conductivity than the aquifer. Typically, groundwater in a confined aquifer is under pressure significantly greater than atmospheric pressure.
Aquifer, fractured rock	An aquifer that occurs in sedimentary, igneous and metamorphosed rocks which have been subjected to disturbance, deformation, or weathering, and which allow water to move through joints, bedding planes, fractures and faults.
Aquifer interference activity	Means an activity involving any of the following: (a) the penetration of an aquifer, (b) the interference with water in an aquifer, (c) the obstruction of the flow of water in an aquifer, (d) the taking of water from an aquifer in the course of carrying out mining, or any other activity prescribed by the regulations, (e) the disposal of water taken from an aquifer as referred to in paragraph (d). (NSW Water Management Act 2000 definition).
Aquifer, unconfined	An aquifer in which there is no confining bed between the zone of saturation and the surface. The water table is the upper boundary of an unconfined aquifer and is at atmospheric pressure.
Aquitard	A geological formation that may contain groundwater but is not capable of transmitting significant quantities of it under normal hydraulic gradients. May function as a confining bed.
Available water determination	The water made available from time to time to water access licence holders in NSW. Expressed as ML/unit share (but still publicised to users as percentage allocations).
Baseflow	The component of streamflow supplied by groundwater discharge. Baseflow is characterised by an exponential decay curve following the cessation of surface runoff.
Beneficial use	Referenced in the NSW Aquifer Interference Policy relating to assessment of water quality impacts. The term “beneficial use” is interchangeable with the term “environmental value” (NWQMS 2013) (see below for definition).
Bore	A hole drilled in the ground, a well or any other excavation used to access groundwater. May be used for observation of groundwater (including water level, pressure or quality).
Catchment	The land area draining to a point of interest, such as a water storage or monitoring site on a watercourse.
Colluvium	Unconsolidated sediments that have been deposited at the base of hillslopes or depressions in the landscape by either runoff, sheet wash, slow continuous downslope creep, or a variable combination of these processes.

Term	Definition
Conceptual model	Documentation or schematic of the conceptual understanding of groundwater recharge and discharge processes, flow within a groundwater system, and the interaction of groundwater with surface water and GDEs.
Consumptive use	Use of water for private benefit consumptive purposes including irrigation, industry, urban and stock and domestic use.
Dewatering	Removal of water from an aquifer as part of the construction phase of a development or part of ongoing activities to maintain access, serviceability and/or safe operating conditions. (NSW AIP).
Drawdown	The lowering of water levels in a surface water or groundwater storage resulting from the loss or take of water from the storage.
Ecosystem	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.
Electrical conductivity (EC)	Electrical conductivity (EC) measures dissolved salt in water. The standard EC unit is microSiemens per centimetre (µS/cm) at 25 °C.
Environmental flow	The streamflow required to maintain appropriate environmental conditions in a waterway or water body.
Environmental value	Environmental values are particular values, or uses, of the water resource that are important for a healthy ecosystem or for public benefit, welfare, safety or health, and which require protection from the effects of contamination, waste discharges and deposits (NWQMS 2013). They reflect the ecological, social and economic values and uses of a water resource. The term "environmental value" replaces the term "beneficial use", which was used in previous guidelines (NWQMS 2013) and also in the NSW Aquifer Interference Policy.
Ephemeral	Something which only lasts for a short time. Typically used to describe rivers, lakes and wetlands that are intermittently dry.
Evaporation	A process that occurs at a liquid surface, resulting in a change of state from liquid to vapour. In relation to water resource assessment and water accounting, evaporation refers to the movement of water from the land surface (predominantly liquid) to the atmosphere (water vapour). The liquid water at the land surface that may be available for evaporation includes surface water, soil water, shallow groundwater, water within vegetation, and water on vegetation and paved surfaces.
Evapotranspiration	The combined loss of water from a given area during a specified period of time by evaporation from the soil or water surface and by transpiration from plants.
Extraction	Synonymous with abstraction in the case where water is removed from a groundwater store.
Gaining stream	A stream where groundwater discharge contributes to streamflow.
Groundwater	Water contained within rocks and sediments below the ground surface in the saturated zone, including perched systems above the regional watertable.
Groundwater entitlement	Water access entitlement granted on the groundwater resource. In NSW, equivalent to an aquifer access licence.
Groundwater Dependent Ecosystem (GDE)	Natural ecosystems that require access to groundwater to meet all or some of their water requirements on a permanent or intermittent basis, so as to maintain their communities of plants and animals, ecosystem processes and ecosystem services.
Groundwater discharge	The process by which groundwater is released into the environment usually either via baseflow or evapotranspiration.
Groundwater flow	Water that flows in aquifers and aquitards.
Groundwater level	The level of groundwater in an aquifer, typically measured in a groundwater bore. In the case of an unconfined aquifer, the groundwater level is equal to the water table level.
Groundwater, regional	A collective term for shallow and deep groundwater.

Term	Definition
Groundwater recharge	The process which replenishes groundwater, usually by rainfall infiltrating from the ground surface to the water table and/or by surface water infiltrating to the water table from a stream. Other forms of recharge include flooding and irrigation, and artificial recharge can also occur through various means, including bore injection.
Groundwater, shallow	Groundwater below the regional water table in the weathered fractured rock groundwater system that has a short circulation flowpath and discharges to local features (generally in upper and mid catchment landscape areas) such as springs and permanent creeks.
Groundwater system	Multiple aquifers that are overlying or adjacent but not necessarily connected, and are hydrogeologically similar regarding geological province, hydraulic characteristics and water quality. A system may consist of groundwater in one or more geological formations.
Hydraulic conductivity	A property of soil or rock, which describes the ease with which water can move through pore spaces or fractures. It depends on the intrinsic permeability of the material and on the degree of saturation. Saturated hydraulic conductivity describes water movement through saturated media.
Hydraulic gradient	Calculated as the difference between two hydraulic head measurements divided by the distance between the two measurements. Hydraulic gradient is used in the calculation of water flow.
Hydrogeologic unit	One or more geologic units which have similar hydrogeological characteristics and behaviour.
Hydrograph	A graph showing the surface level, discharge, velocity, or some other feature of water, with respect to time.
Incidental water	Water that is taken by an aquifer interference activity that is incidental to the activity; including water that is encountered within and extracted from mine workings, tunnels, basements or other aquifer interference structures that must be dewatered to maintain access, serviceability and/or safe operating conditions. (NSW AIP).
Infiltration	The process by which water on the ground surface enters the soil profile.
Losing stream	A stream from which water is lost to the surrounding and underlying substrate via infiltration through the streambed and banks.
Monitoring site	A place where observations of the environment are made; typically a physical location where sensors are used to measure the properties of one or more features of the environment (eg depth of a river, water level in a bore, surface or groundwater quality).
Overland flow	Surface runoff, which is caused when either, the ground surface is impervious, the underlying soil is saturated and cannot accommodate any more water, or because the intensity of rainfall is greater than the soil's capacity to infiltrate it.
Parameter	A measurable characteristic of a physical entity (feature); for example, the temperature of water in a river.
Permeability	The measure of the ability of a rock, soil or sediment to transmit a fluid. The magnitude of the permeability depends largely on the porosity and the connectedness of pores spaces. Synonymous with hydraulic conductivity when water is the fluid involved.
pH	Value that represents the acidity or alkalinity of an aqueous solution. It is defined as the negative logarithm of the hydrogen ion concentration of the solution.
Piezometric surface	A surface representing the hydraulic head of groundwater; represented by the water table altitude in an unconfined aquifer or by the altitude to which water would rise in a properly constructed bore in a confined aquifer.
Precipitation	All forms in which water falls on the land surface and open water bodies as rain, sleet, snow, hail, or drizzle.
Regulated river	River on which a licensed entitlement regime exists with centralised allocation, and from which orders may be placed for upstream release of a licensed allocation. A necessary, but not sufficient condition for a river to be regulated is that it is located downstream of a surface water storage.

Term	Definition
Riparian	An area or zone within or along the banks of a stream or adjacent to a watercourse or wetland; relating to a riverbank and its environment, particularly to the vegetation.
Saturated zone	The soil and geological layers below the land surface where all spaces between soil/sediment/rock particles are filled with water. It encompasses all the soil and geological layers below the water table.
Seepage	The infiltration of water from streams, irrigation channels, water storages, farm dams, natural surface water features and septic tanks into the groundwater system. It is a form of surface water–groundwater interaction and groundwater recharge. The term can also apply to low volumes of groundwater discharge.
Storage	A pond, lake or basin, whether natural or artificial, for the storage, regulation and control of water.
Stream	A watercourse and its tributaries. A stream can be permanent or ephemeral.
Streamflow	The flow of water in streams, rivers and other channels.
Stygofauna	Aquatic animals found in groundwater; sometimes used as a synonym of stygobite.
Surface runoff	Water from precipitation or other sources that flows over the land surface.
Surface water	Water that flows over or is stored on the surface of the earth that includes: (a) water in a watercourse, lake or wetland and (b) any water flowing over or lying on land: (i) after having precipitated naturally or (ii) after having risen to the surface naturally from underground.
Take	Take water from a water resource means to remove water from, or to reduce the flow of water in or into, the water resource including by any of the following means: (a) pumping or siphoning water from the water resource; (b) stopping, impeding or diverting the flow of water in or into the water resource; (c) releasing water from the water resource if the water resource is a wetland or lake; (d) permitting water to flow from the water resource if the water resource is a well or watercourse; and includes storing water as part of, or in a way that is ancillary to, any of the processes or activities referred to in paragraphs (a) to (d). (Commonwealth Water Act 2007 definition).
Total dissolved solids (TDS)	The sum of all particulate material dissolved in water. Usually expressed in terms of milligrams per litre (mg/L).
Turbidity	Means the measure of the light scattering properties of water and is an indicator of the presence of suspended solids.
Uncertainty	A state of lack of confidence to exactly describe the current or future condition of a system when limited knowledge of that system is available. Uncertainty is often categorised into two main types (Barnett et al. 2012): • deficiency in our knowledge of the natural world (including the effects of error in measurements); • failure to capture the complexity of the natural world (or what we know about it) in a model. Formal definition from AS/NZS ISO 310000:2009: Uncertainty is the state, even partial, of deficiency of information related to the understanding or knowledge of an event, its consequence, or its likelihood.
Unregulated river	A river where there is no entitlement system at all or where there is an entitlement system that does not allow orders to be placed for upstream release of a licensed allocation.
Water access entitlement	A perpetual or ongoing entitlement to exclusive access to a share of water from a specified consumptive pool as defined in the relevant water plan. In NSW, equivalent to a water access licence (ie an access licence referred to in section 56 of the Water Management Act 2000).
Water balance	The flow of water into and out of, and changes in the storage volume of, a surface water system, groundwater system, catchment or specified area over a defined period of time.

Term	Definition
Water quality	The physical, chemical and biological characteristics of water. Water-quality compliance is usually assessed by comparing these characteristics with a set of reference standards. Common standards used are those for drinking water, safety of human contact and the health of ecosystems.
Water resource	All natural water (surface water or groundwater) and alternative water sources, such as recycled or desalinated water, that has not yet been abstracted or used.
Water sharing plan	A legislated plan that establishes rules for managing and sharing water between ecological processes and environmental needs of the respective water source (river/aquifer). It manages water access licences, water allocation and trading, water extraction, operation of dams, management of water flows, and use and rights of different water users.
Water source	In NSW, water source means the whole or any part of: (a) one or more rivers, lakes or estuaries, or (b) one or more places where water occurs on or below the surface of the ground (including overland flow water flowing over or lying there for the time being), and includes the coastal waters of the State. (NSW Water Management Act 2000 definition).
Water table	The top of an unconfined aquifer which can be either perched or regional. It is at atmospheric pressure and, in a regional context, indicates the level below which soil and rock are saturated with water.
Water year	A continuous twelve-month period starting from a specified month for water accounting purposes. In NSW this is 1 July to 30 June each year.
Wetland	An area of land whose soil is saturated with moisture either permanently or intermittently. Wetlands are typically highly productive ecosystems. They include areas of marsh, fen, parkland and open water. Open water can be natural or artificial; permanent or temporary; static or flowing; and fresh, brackish or salty.

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1 Introduction

1.1 The project

The Peel River, part of the Namoi River catchment, provides water for irrigation as well as being the primary water supply for the city of Tamworth. Prompted by the millennium drought, investigations into the future water supply and demand for bulk water were undertaken for the regional city of Tamworth and the Peel Valley water users. The Dungowan Dam and pipeline project (the project) is a critical project to improving long-term water security for the region. The project includes a new dam at Dungowan (new Dungowan Dam) approximately 3.5 km downstream of the existing Dungowan Dam and a new section of pipeline about 32 km long between the proposed Dam outlet and the tie in point to an existing pipeline from Dungowan Showground to the Calala Water Treatment Plant (WTP).

In September 2022, the Minister for Planning and Homes declared the project to be Critical State Significant Infrastructure (CSSI) as it is a development that is essential for the State for economic and social reasons. This requires Schedule 5 of the *State Environmental Planning Policy (Planning Systems) 2021* to be updated to reflect the CSSI status of the project. As CSSI, the project is subject to Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* (EP&A Act), which requires the preparation of an environmental impact statement (EIS) and the approval of the NSW Minister for Planning and Homes.

The EIS has been prepared for the planning approval application for the project. This Groundwater Impact Assessment (GIA) has been prepared to support the EIS.

In addition to requiring approval from the NSW Minister for Planning and Homes, the project has been deemed a controlled action under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and requires approval from the Commonwealth Minister for the Environment and Water. The Minister for the Environment and Water has accredited the NSW planning process for the assessment of the project. Therefore, a single EIS has been prepared to address the requirements set out by the NSW Department of Planning and Environment (DPE) and the Commonwealth Department of Climate Change, Energy, the Environment and Water.

1.2 Project location

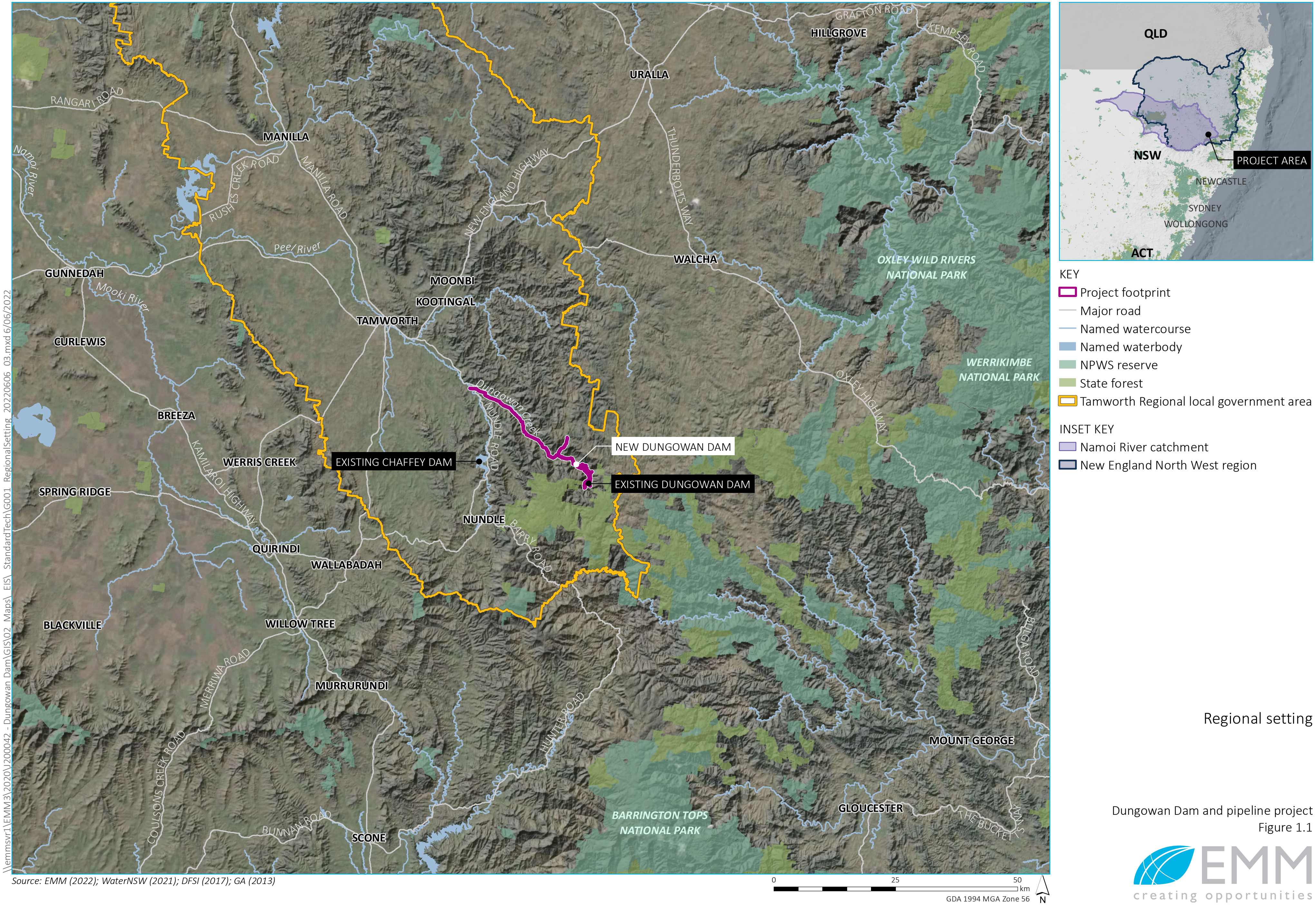
The project is located in the Tamworth Regional local government area (LGA), the New England Tablelands bioregion and part of the New England and North West region of NSW, west of the Great Dividing Range (DPE 2017). The New England and North West region is home to approximately 186,900 people and has a total area of around 99,100 km^2 (ABS 2018).

The city of Tamworth is the nearest (and largest) town to the project with over 40,000 residents. Other nearby regional towns include Quirindi (70 km west), Manilla (90 km north-west), Gloucester (90 km south-east), Armidale (100 km north) and Gunnedah (110 km west of the project).

The existing Dungowan Dam is in the Namoi River catchment approximately 50 km south-east of Tamworth in NSW. The Namoi catchment covers 4,700 km^2 and borders the Gwydir and Castlereagh catchments and is bounded by the Great Dividing Range in the east, the Liverpool Ranges and Warrumbungle Ranges in the south, and the Nandewar Ranges and Mount Kaputar to the north.

The existing Dungowan Dam is on Dungowan Creek, which is a tributary of the Peel River. Dungowan Creek is confined by the existing Dungowan Dam, while the Peel River system is regulated by Chaffey Dam, located in the upper catchment near the town of Woolomin, approximately 45 km from Tamworth.

The project's regional setting is shown in Figure 1.1.



Source: EMM (2022); WaterNSW (2021); DFSI (2017); GA (2013)

Regional setting

Dungowan Dam and pipeline project
Figure 1.1

EMM creating opportunities

1.2.1 Project impact areas

In outlining the project, a project footprint has been defined to facilitate the assessment of direct impacts from the project:

- Project footprint: all areas where direct impacts may be experienced during construction and/or operation.

The project footprint has an area of 315 ha and is comprised of the construction and operational footprints, of which there is some overlap:

- Construction footprint: areas where vegetation clearing and/or ground disturbance is required for construction of the dam, pipeline and ancillary facilities, including the area needed to decommission and rehabilitate the existing dam.

- Operational footprint: areas where there would be permanent operational elements or easements, including infrastructure needed to operate the new Dungowan Dam and pipeline. The operation footprint includes the inundation area, being the area defined by the proposed full supply level (FSL) for the project.

The project construction and operational footprints are shown in Figure 1.2.

Additional areas outside the project footprint have also been considered where relevant to the assessment of project impacts and include:

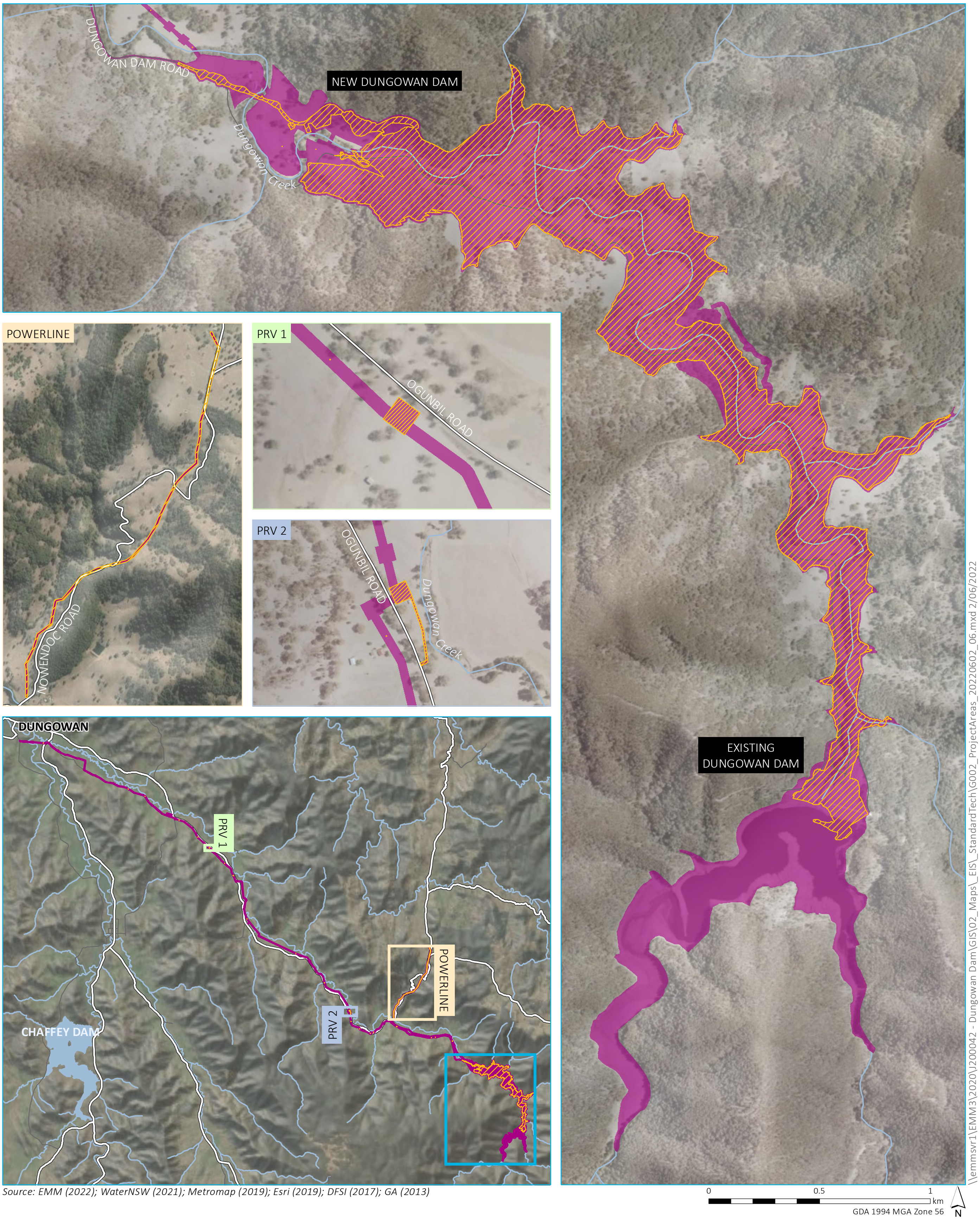
- Upstream flood extent: An area above the FSL to the level of a probable maximum flood (PMF) event that would be inundated for relatively short periods during operation associated with extreme rainfall events.

- Project area: A 10 km buffer around the project footprint defined to allow for assessment of potential indirect impacts.

- Downstream impact area: the area where hydrological changes may occur due to the project. This area is discussed in detail in the Surface Water Assessment (EMM 2022e) as well as other technical reports subject to changed flow regimes as a result of the new Dungowan Dam operation. The downstream impact area includes Dungowan Creek and also the Peel River downstream of Chaffey Dam.

1.2.2 Groundwater study area

This GIA has considered potential impacts from the project on watercourse hydrology within Dungowan Creek downstream of the existing Dungowan Dam to the confluence with the Peel River, and within the Peel River downstream from Chaffey Dam to Carroll Gap (nominally the end of the Peel River).



Source: EMM (2022); WaterNSW (2021); Metromap (2019); Esri (2019); DFSI (2017); GA (2013)

KEY

Construction footprint

Operational footprint

Existing environment

Major road

Minor road

Named watercourse

Named waterbody

Project footprint

Dungowan Dam and pipeline project

Figure 1.2

creating opportunities

1.3 Purpose of this report

This GIA supports the EIS for the Dungowan Dam and pipeline project. It documents the existing groundwater environment, methods used to assess changes to the groundwater environment, the initiatives built into the project design to avoid and minimise associated impacts, and the mitigation, and management measures proposed to address any unavoidable residual impacts.

Aspects of the groundwater environment discussed within this report include:

- the existing groundwater related environments and baseline conditions within the project and surrounding areas;
- the regulatory environment (with respect to water resources) within which the project would operate;
- the requirements of the project for water access licences to satisfy project demands, and specify arrangements for acquiring them;
- identify and quantify the potential impacts of the project on the current groundwater resources, and on water users both environmental and extractive in accordance with the Aquifer Interference Policy (AIP);
- specify mitigation and management measure, and monitoring requirements for groundwater;
- satisfy the Secretary’s Environmental Assessment Requirements (SEARs) relevant to groundwater impacts; and
- inform the wider community about the project and its potential impacts on the local and regional water environments.

1.4 Assessment guidelines and requirements

This GIA has been prepared in accordance with the SEARs for the Dungowan Dam and pipeline project as well as relevant governmental assessment requirements, guidelines and policies, and in consultation with the relevant government agencies.

The SEARs must be addressed in the EIS. Table 1.1 lists the matters relevant to the GIA and where they are addressed in this report.

Table 1.1 Relevant matters raised in SEARs

Requirement	Section addressed
1. A description and mapping, of the existing hydrological and hydrogeological regimes upstream and downstream to the proposed end of system flow point for surface and groundwater resources likely to be impacted by the project including: a) Rivers, streams, wetlands, groundwater resources, groundwater dependent ecosystems, drainage patterns, watercourses and riparian land. c) Highly connected alluvial aquifers and their responses to river flows. d) Groundwater systems including alluvial aquifers and recharge rates.	Chapter 3 and 4

Table 1.1 Relevant matters raised in SEARs

Requirement	Section addressed
2. An assessment and mapping of the predicted impacts of construction and operation of the project on water quality and hydrological, hydrogeological regimes, impacts of regulated river operations and any required contingency arrangements on flow characteristics at the project footprint, upstream and downstream for all surface and groundwater resources likely to be impact by the project, including: a) A detailed water balance for ground and surface water. b) Comparison to baseline data. j) Identification of water take volumes from relevant surface water and groundwater sources due to construction and operation of the project. k) Any impacts to existing water users. p) Changes to groundwater recharge and levels.	Chapter 8 and 9 (Surface water balance is provided in the Surface Water Assessment, appended to the EIS)
3. Identification of mitigation measures for any impacts to hydrology, water quality and geomorphology resulting from the construction and operation of the project, including details of any monitoring programs proposed to measure the performance of the mitigation measures.	Chapter 10
6. An assessment of the project's consistency with legislation and relevant consents, licences or permissions or any form of authorisation that govern the use or impacts of water, or affect water users, including: a) identification of legislative and regulatory context and relationships between these. b) identification of whether potential legal or administrative changes are required to carry out the project. c) assessment of the impact on all existing water entitlements, approvals, or relevant exemptions required for the construction or operation of the project, including an assessment of the current market depth where water entitlement would be purchased. d) details of how Basin Plan requirements for protection of planned environmental water and sustainable diversion limits would be considered. e) details of any impacts on existing Water Sharing Plans (WSP) or Water Resource Plans, including any changes to meet WSP and Basin Plan objectives and requirements. f) impacts to groundwater in accordance with the NSW Aquifer Inference Policy.	Chapter 7, 10 and 11

1.4.1 Other relevant reports

This GIA has been prepared with reference to other technical reports that were compiled as part of the EIS. The other relevant reports referenced in this GIA are listed below.

- Aquatic Ecology Assessment (EMM 2022a) – appended to the EIS
- Biodiversity Development Assessment Report (EMM 2022b) – appended to the EIS
- Contamination Preliminary Site Investigation (EMM 2022c) – appended to the EIS
- Land, Soils and Erosion Assessment (EMM 2022d) – appended to the EIS
- Surface Water Assessment (EMM 2022e) – appended to the EIS
- Waste Management Assessment (EMM 2022f) – appended to the EIS

2 Description of the project

This chapter provides a summary of the Dungowan Dam and pipeline project. It outlines the permanent infrastructure required to operate the project, as well as the key construction elements and activities required to construct the project. A comprehensive and detailed description of the project is provided as Appendix B1 of the EIS, which has been relied upon for the basis of this technical assessment.

2.1 Project overview

Water Infrastructure NSW proposes to build a new dam at Dungowan (new Dungowan Dam) about 3.5 km downstream of the existing Dungowan Dam and an enlarged delivery pipeline from the new Dungowan Dam outlet to the tie in point to the existing pipeline from Dungowan Showground to the Calala WTP. The existing pipeline from Dungowan Showground to the Calala WTP is not part of the Dungowan Dam and pipeline project. A summary of project elements is provided in Table 2.1. An overview of the project is provided in Figure 2.1.

Table 2.1 Overview of the project

Project element	Summary of the project
New Dungowan Dam infrastructure	Earth and rockfill embankment dam with height of ~58 m and a dam crest length of ~270 m.
	Storage capacity of 22.5 GL at full supply level (FSL) of RL 660.2 m AHD.
	The new Dungowan Dam on Dungowan Creek has a catchment size of 175 km^2 and is part of the Peel Valley and Namoi River catchment.
	Inundation extent (to FSL) of 130 ha (1.3 km^2)
	Spillway to the south of the dam wall including an approach channel, uncontrolled concrete ogee crest, chute and stilling basin. Free standing multiple-level intake tower connected with a bridge to the embankment, diversion tunnel with outlet conduit, valve house and associated pipework and valves.
	A permanent access road over the Dam crest to the valve house for operation and maintenance.
	Water diversion works including a diversion tunnel and temporary pipeline and upstream and downstream cofferdams to facilitate construction of the dam wall embankment.
Pipeline infrastructure	31.6 km of buried high density polyethylene (HDPE) pipe between 710 mm to 900 mm nominal diameter.
	Maximum 71 ML/day from the proposed dam to the junction with the pipeline from Chaffey Dam to the Calala Water Treatment Plant, to replace the existing 22 ML/day pipeline. The pipeline would connect to the valve house on the left abutment of the embankment. Valve infrastructure would include control valves installed in two above ground buildings along the pipeline.
	10 m wide easement for the 31.6 km length of the pipeline. The replacement pipeline extends from the new Dungowan Dam to a connection point with the existing pipeline between Dungowan Showground and Calala WTP.
Ancillary infrastructure and works	Road works to improve existing roads to provide construction access, temporary establishment and use of a construction compound, an accommodation camp, two upstream quarries and four borrow areas within the inundation area.
	A new 4.2 km long 11 kV overhead powerline (including a new easement and access track) connecting to an existing overhead line approximately 6 km north west of the dam. The existing overhead line that extends approximately 13.2 km to the Niangala area would also require minor upgrades, including re-stringing of new overhead wiring and replacement of some poles.

Table 2.1 Overview of the project

Project element	Summary of the project
Decommissioning of existing Dungowan Dam	Dewatering of existing dam, removal of existing Dungowan Dam infrastructure and full height breach of the existing Dungowan Dam wall. Rehabilitation of inundation area of the existing Dungowan Dam.
Disturbance	Areas of disturbance have been identified based on the direct impacts of the project. There is some overlap in the areas disturbed during construction and operation, with a resulting total disturbance area proposed for the project of 315 ha (project footprint). Disturbance would occur in a staged manner, with construction requiring disturbance of approximately 315 ha (construction footprint). Following construction and once rehabilitation is completed, there would be a permanent disturbance of approximately 158 ha comprising the inundation area and permanent infrastructure (operational footprint).
Construction	Construction duration of approximately 6 years.
	Construction workforce of approximately 125 workers at construction peak.
Operation	WaterNSW would be responsible for management, operation and general maintenance of the new dam. Tamworth Regional Council would be responsible for the management, operation and general maintenance of the pipeline. Public use and access to the dam would not be permitted and there would be no public facilities available during operation.
	One to two new full time workers plus part time work for existing WaterNSW operations team. Due to the new Dungowan Dam being prioritised over Chaffey Dam for Tamworth's future water supply, the water reserved for town water in Chaffey Dam would increase from 14.3 GL to 30 GL to ensure that water is set aside to meet Tamworth's town water supply water demand in years when rainfall is low.
Design life	100 years for zoned earthen embankment, structural concrete elements of the dam and the pipeline. 15 to 50 years for other non-structural project elements and pavements.
Assessment period (operational)	The assessment end point is when the water system performance reaches a level when an additional water supply option or change to the Water Sharing Plan is required. This has been estimated to be when the mean average annual water demand from Tamworth increases to 11 GL/year.

2.2 Project elements affecting groundwater

The following components of the Dungowan Dam and pipeline project have the potential to affect groundwater:

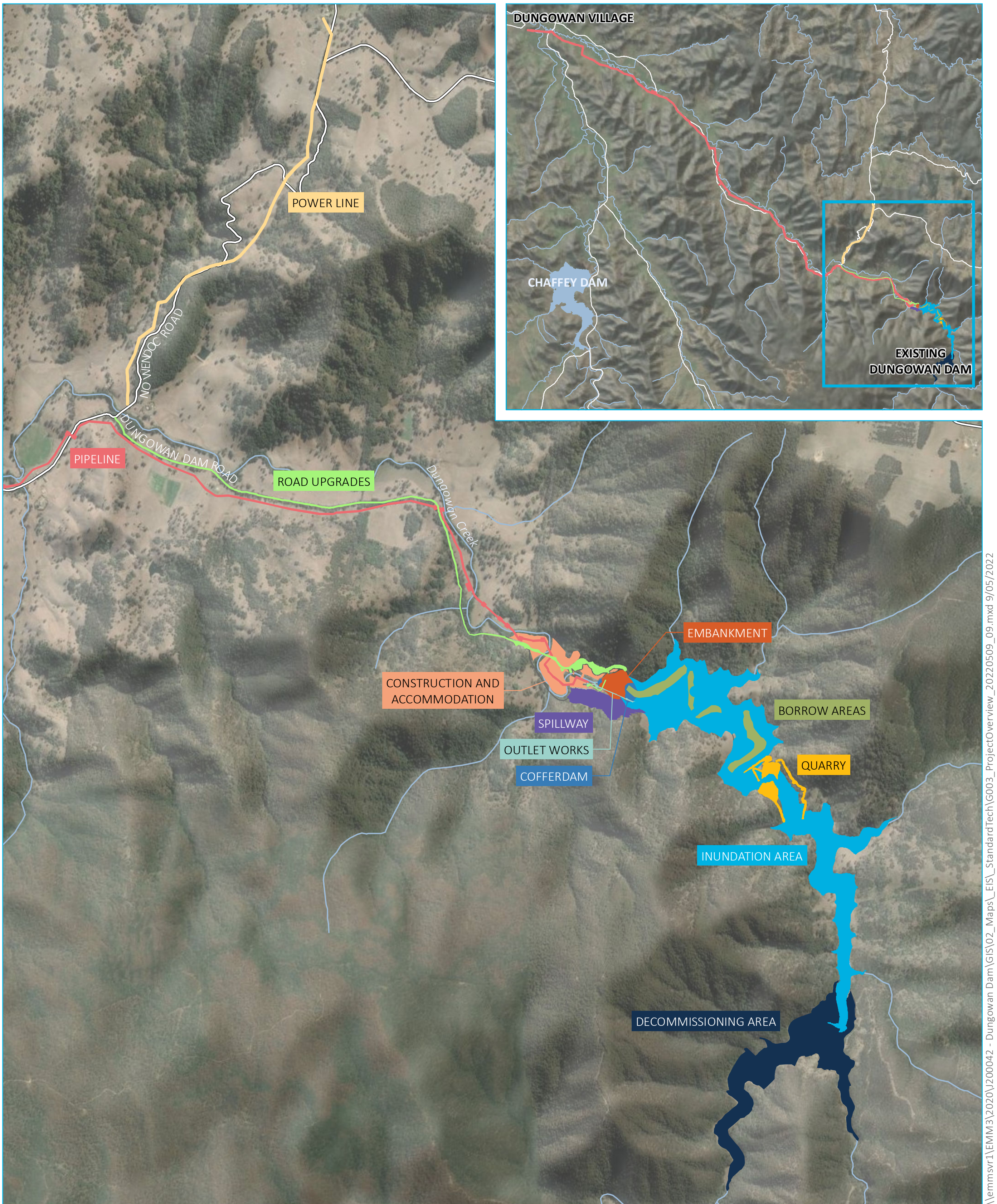
Construction

- Dam excavation area: groundwater is likely to be intercepted in the lower levels of Dungowan Creek when excavating the dam foundation.
- Spillway excavation area: groundwater is likely to be intercepted when excavating the spillway chute and stilling basin foundation.
- Quarry and borrow areas: groundwater could be intercepted when quarrying for construction materials.
- Pipeline trenching works: groundwater would be intercepted when trenching through Dungowan Creek and could be intercepted when trenching through alluvial sediments.
- Dungowan Dam operation

- the presence of the dam embankment has the potential to increase recharge to groundwater, as well as disrupt the hydraulic gradient and flow path of the groundwater.
- the applied load from the dam embankment on the Dungowan Creek Alluvium (DCA) and Peel Fractured Rock (PFR) groundwater sources has the potential to cause the water pressure (groundwater level) to rise, altering the local groundwater flow regime near the inundation area and dam embankment.
- due to the prioritisation of the new Dungowan Dam for Tamworth town water supply, run-of-river water transfers from Chaffey Dam to Calala WTP would reduce during the operation of the project. It is possible that the Peel River Alluvial (PRA) groundwater regime may change due to the reduction of run-of-river water transfers.

Other components of the Dungowan Dam and pipeline project are not considered aquifer interfering activities and have not been assessed further. These activities are:

- the construction and upgrades to the powerline: works are not anticipated to penetrate or take water from the local aquifer;
- existing dam decommissioning works: the inundation area upgradient of the existing Dungowan Dam is likely to return to pre-existing groundwater conditions. The decommissioning works will not be penetrating or taking water from the local aquifer; and
- the construction of ancillary facilities and road upgrades: works are not anticipated to intercept to penetrate or take water from the local aquifer.



Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013)

0 0.5 1 km
GDA 1994 MGA Zone 56
N

KEY

- Inundation area
- Borrow areas
- Construction and accommodation camp
- Outlet works
- Cofferdams
- Embankment
- Quarries
- Spillway
- Road upgrade
- Decommissioning area
- Power line footprint
- Pipeline construction footprint

Existing environment

- Major road
- Minor road
- Named watercourse
- Named waterbody

Project overview

Dungowan Dam and pipeline project
Figure 2.1

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3 Existing environment

3.1 Topography and land use

The project area is located within the New England Tablelands region in north-eastern NSW, centred on Dungowan Creek. The nearest town, being Tamworth, is located approximately 50 km north-west of the project. The project area comprises a flat valley-floor terrain which is used for agricultural purposes, mainly livestock grazing. Within the project area, the existing Dungowan Dam and associated infrastructure are located approximately 3.5 km upstream of the new Dungowan Dam site.

Vegetation within the project area has been impacted by previous land use, including agriculture and the existing dam. As a result, the landscape is partially cleared, comprising remnant vegetation, particularly along the creek and on lower slopes, and subject to moderate to high levels of weed invasion and agricultural activities.

The topographic relief of the project area is undulating, reflecting the uplift and valley fill environment of the New England Tablelands region. At the new Dungowan Dam site, located within the margins of Dungowan Creek and within the valley floor, the elevation is 617 metres Australian Height Datum (mAHD). The topography steeply rises to the north and south of Dungowan Creek to an elevation of 777 mAHD and 905 mAHD, respectively. Downstream and to the north-west of the proposed dam, along the Dungowan Creek floodplain and adjacent to the town of Ogunbil, the elevation drops to approximately 580 mAHD.

3.2 Climate

The climate in the project region is subtropical, with average summer maximum temperatures above 30°C and winter maximums of around 16°C. Rainfall occurs year-round, with slightly more rainfall in summer months on average. The sections below describe rainfall, evaporation and historic climate drivers for periodic drought and flooding.

3.2.1 Rainfall

At the dam site, Bureau of Meteorology (BoM) station 55193 recorded average rainfall of 1,000 mm/year over the period 1959 – 1997. Available records at this site, post 1997, are missing data for some months during the period 1998 – 2004, including almost all of 2002. Rainfall data are not available at this site after 2004, and the site was closed in 2010. A replacement site 55262 approximately 4 km north west (downstream) began recording rainfall in 2001 and recorded average rainfall of 750 mm/year over the period 2001-2019. The difference in average annual rainfall between the two sites may be attributed to:

- the millennium drought and the 2018-2019 drought were included within the 2001-2019 period for Station 55262, resulting in a lower average annual rainfall; and
- the 1950s were a particularly wet period across eastern Australia and are included in the 1959 – 1997 period for Station 55193.

Gauges 55262 and 55193 recorded March – September as drier months, and October – February as wetter months (Figure 3.1), consistent with the effects of seasonal movement of the subtropical ridge (refer EMM 2022e).

For comparison, WaterNSW recorded an average of 596 mm/year rainfall at the nearby Chaffy Dam over 2001-2019 period while Tamworth Airport Automatic Weather Station (AWS) 55325 recorded a median rainfall of 640 mm/year, with similar seasonal patterns to those recorded at the gauges located near Dungowan Dam.

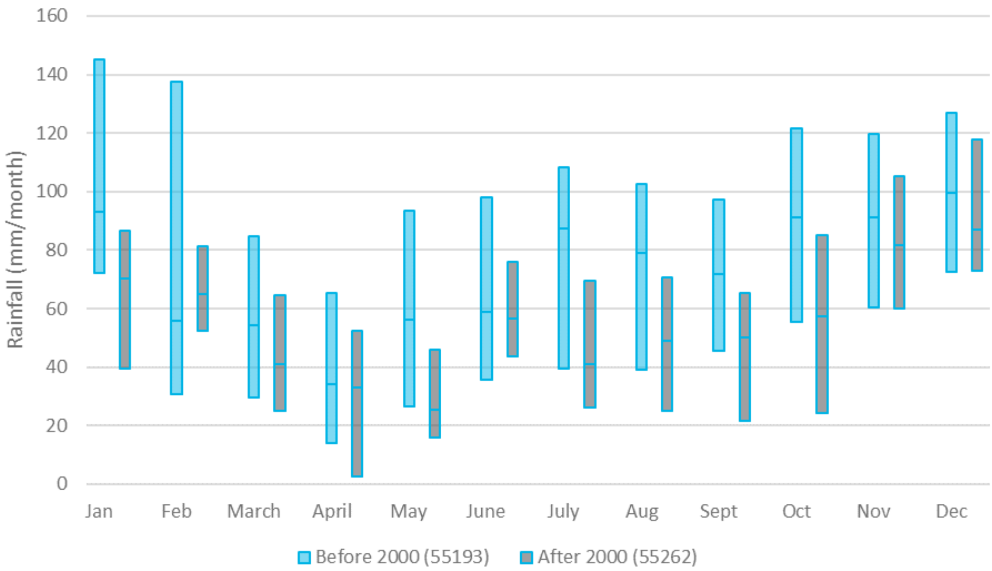


Figure 3.1 Dungowan dam monthly rainfall totals (25% to 75% quartiles)

3.2.2 Evaporation

The median yearly pan evaporation estimated for the Dungowan Dam site using SILO data, prepared by the Queensland Government (2022) which uses mathematical interpolation techniques to construct spatial grids and infill gaps in time series datasets, since 2000 is 1,185 mm/year. At the nearby Chaffey Dam site, WaterNSW have recorded average pan evaporation rates of 1,625 mm/year over the period 2009-2019 (WaterNSW, 2022a). Evaporation is estimated to exceed rainfall at Dungowan Dam during spring, summer and autumn months (Figure 3.2).

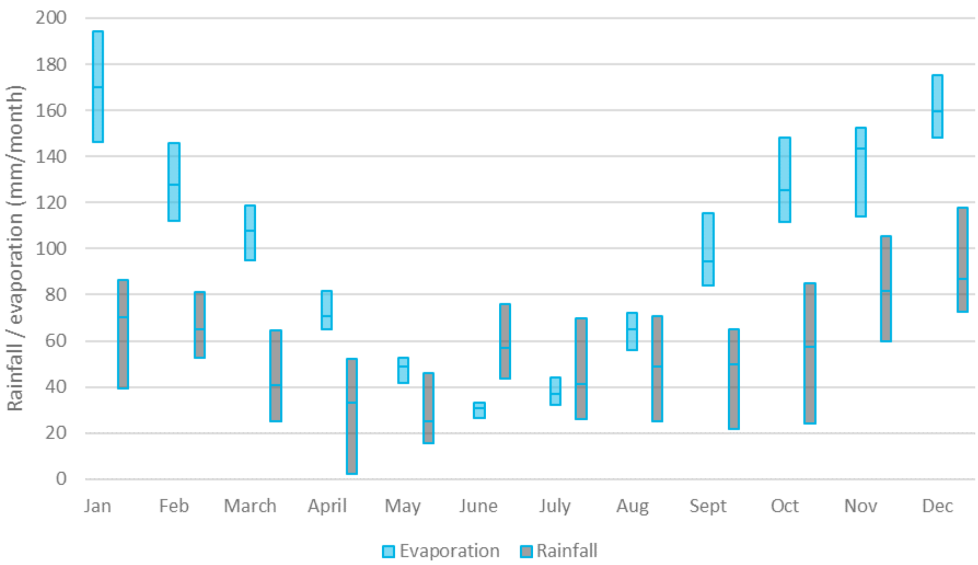


Figure 3.2 2001-2019 evaporation (SILO) and rainfall (station 55262) monthly totals (25% to 75% quartiles) at Dungowan Dam

3.2.3 Cumulative rainfall deviation

The project area has experienced long term climate cycles due to effects such as the El Niño / La Niña Southern Oscillation (ENSO) and the Southern Annular Mode (SAM) climatic processes. This has resulted in wet periods and droughts, as illustrated in the long-term rainfall trend shown in Figure 3.3. Prior to 1950 there was a trend of increasing rainfall at the Dungowan Dam site, while since 1950 there has been a trend of decreasing rainfall.

Regional droughts have occurred with regularity, with approximately one drought each decade through recorded history (ABS 2012). Floods have also occurred with regularity through the period of stream flow records (post-1950) (BoM 2020) with the last notable flood within the Namoi River occurring in 2016 (BoM 2017).

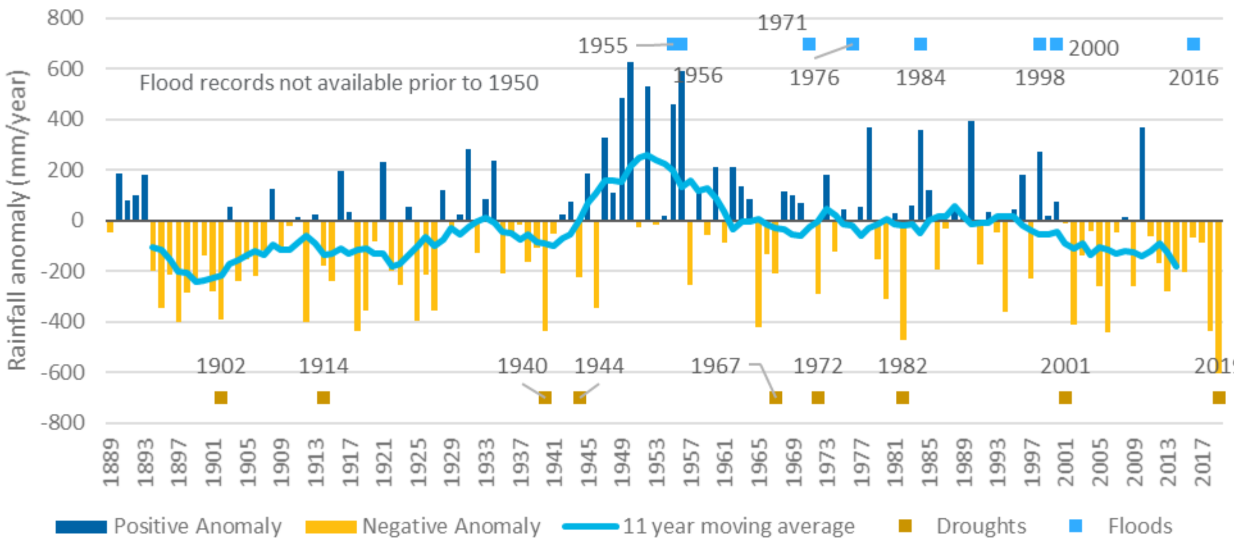


Figure 3.3 Historical rainfall trend at Dungowan Dam, and regional flood and drought markers

3.3 Hydrology

The new Dungowan Dam is located on Dungowan Creek, with a 126 km^2 native forest catchment. There are no population centres or privately owned land within the existing dam catchment. The new Dungowan Dam would capture runoff from the existing dam catchment, plus an additional 49 km^2, for a total catchment area of 175 km^2, an increase of 39%. These creeks originate from forested hills and gullies, other than Terrible Billy Creek and Swamp Gully, which originate from a farmed plateau, which forms the eastern watershed divide.

Approximately 30 km downstream of the new Dungowan Dam, Dungowan Creek joins the Peel River. At this confluence, Dungowan Creek contributes a catchment of 390 km^2, while the Peel River has a catchment of 590 km^2, giving a total combined catchment of 980 km^2 at the junction. Within the Peel River catchment lies Chaffey Dam. Downstream from the confluence of Dungowan Creek and the Peel River, Goonoo Goonoo Creek and Cockburn River meet the Peel River immediately upstream of Tamworth. At this confluence:

- Peel River (including Dungowan Creek), has a catchment area of 1,270 km^2;
- Goonoo Goonoo Creek has a catchment area of 660 km^2; and
- Cockburn River has a catchment area of 1,130 km^2.

The Peel River flows into the Namoi River approximately 60 km downstream from Tamworth. At this confluence, flow in the Namoi River is heavily influenced by the operations of Lake Keepit. The hydrology of the project area is shown on Figure 3.4.

3.4 Geology

The project area is located in the southern portion of the New England Fold Belt (NEFB). The geology of the NEFB comprises an eroded mountain range bounded to the south and west by border thrust fault systems. In the southern portion of the NEFB metasedimentary rocks dominate the basement rocks and include phyllites, cherts, jaspers and greywackes with interbedded basic volcanics. These are overlain by Carboniferous aged marine sedimentary rocks (DPI Water 2012a). Stratigraphic units relevant to the project are shown on Table 3.1 and project geology is shown in Figure 3.5. A large portion of the project area, centred across areas of uplift, is mapped as Sandon Association, whilst the valley fill areas are mapped as alluvial deposits. The Sandon Association at the project area is observed to be predominantly comprised of silicified mudstone, chert, metamudstone and phyllite (SMEC 2020). The Quaternary aged alluvium in an undifferentiated unit, comprising of interbedded clays, silts, sands and gravels of up to 4.6 m in thickness, with an average thickness of 2.6 m (EMM 2021 & SMEC 2020).

A review of available data indicates the thickness of the weathered rock within the Sandon Association ranges from 0 to 5 m, with an average thickness of 2.4 m (GHD 2017), while SMEC (2020) report the thickness of the weathered rock in the valley floor to be between 3.1 to 6.3 m, noting the thicker sections of weathered rock were encountered in valley floors, with 'fresh' rock often outcropping on steep slopes.

There are no mapped major geological structures in the project area (Figure 3.5). GHD (2017) and SMEC (2020) observed minor tectonic joints (defects) and possible sheet joints formed because of valley erosion and stress relief effects in the project area. SMEC 2020 observed a diverse range of open (non-lithified) defects throughout the rock mass in the project area. This includes sheared seams/zones, faulted zones, crushed seams and weathered seams.

Table 3.1 Geological units applicable to the project

Stratigraphic unit	Code	Age	Description
Quaternary Alluvium	Qa	Quaternary	Quaternary Alluvium, comprising undifferentiated alluvial deposits of sand, silt, clay and gravel
Sandon Association	Csa	Carboniferous – Devonian	Lithic (meta)wake, slate, phyllite, chert, jasper, amphibolite, metabasalt, greywacke, sandstone, siltstone, mudstone and para-conglomerate
Myra Beds	Ddom	Carboniferous – Devonian	Slate, phyllite, chert, jasper, metabasalt extrusives and intrusives, minor lithic wacke

Notes: Source: *Tamworth 1:250,000 Geology Map (Offenberg A.C. 1971)*

3.4.1 Potential acid forming rock

SMEC (2020) completed a desktop assessment to review potential acid forming (PAF) rock. PAF rock has the potential to generate acid mine drainage (AMD) when exposed to oxygen.

The review indicated that PAF rock was possible within the project area with pyrite typically found in metamudstone/silicified mudstone. The desktop assessment was verified through investigative drilling and subsequent testing (SMEC 2020).

A total of eight bores were drilled to a depth of 30 m below ground level, targeting the metamudstone/silicified mudstone, and analysed for PAF. Six of the eight samples were classified as non-acid forming and one samples was classified as mild-PAF. One sample was classified as uncertain. The inherent acid neutralisation capacity of the tested materials exceeded the acid production potential.

3.5 Groundwater

As identified in Section 3.1, the project is situated in the New England region, utilising the extensive relief associated with the uplifted metamorphosed fractured rock and the valley-filled floors to impound catchment flows and transfer water for strategic use downstream. Within the project area, as suggested by the geological setting, two distinct groundwater systems exist. These groundwater systems are characterised as having very different hydrogeological properties bound by their depositional environment.

The groundwater units within the project area are defined as:

- a localised highly permeable shallow groundwater system associated with the Quaternary-aged alluvium. For the purposes of this assessment, this unit is divided into:

  - the Peel River Alluvium (PRA): located downstream of Dungowan Creek and Chaffey Dam, and comprised of coarse gravel sediments in relative thick deposits of up to 30 m; and

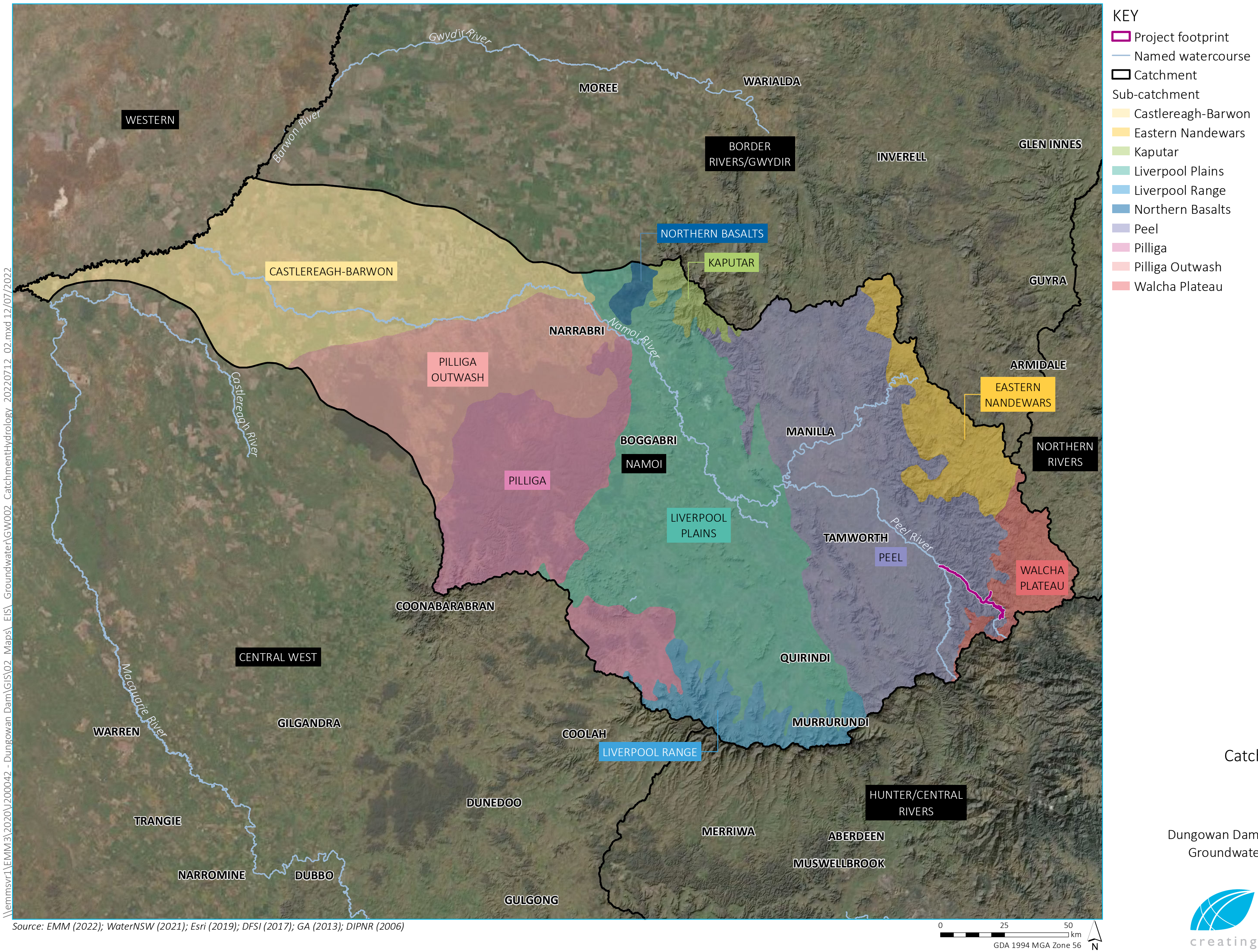
  - the Dungowan Creek Alluvium (DCA): located within the Dungowan Creek floodplain, comprising unconsolidated, sporadic pockets of alluvium ranging in thickness from 0-5 m and progressively increasing in thickness as Dungowan Creek reaches its confluence with the Peel River.

- a low permeability regional fractured rock groundwater system associated with the metasedimentary rock which occupies the uplifted, mountainous portion of the project area. This unit is formally termed the Peel Fractured Rock (PFR) (NOW 2010).

The PRA has been considered in this assessment because run-of-river water transfers from Chaffey Dam to Calala WTP via the Peel River would reduce during the operation of the new Dungowan Dam, due to its prioritisation for town water supply to Tamworth. The PRA and Peel River are highly connected and therefore any changes to the hydrological regime may have the potential to affect the groundwater regime.

The two alluvial systems (DCA and PRA) have high primary permeability, with the downstream and more developed PRA regarded as a productive groundwater system, utilised for extensive irrigation downstream of the project with reported yields up to 15 litres per second (L/s) (EMM 2019). The DCA, due to its depositional setting higher up in the catchment, is considerably less productive as a groundwater resource.

The PFR has very low primary permeability with groundwater flow occurring within secondary features such as sheared seams/zones, faulted zones, crushed seams, weathered seams and/or contact boundaries between different rock lithologies. The hydraulic conductivity and groundwater storage within these secondary features is typically low. Reported water supply bore yields range between 1 to 5 L/s, generally reducing in yield with depth as the rock mass becomes more consolidated.



Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013); DIPNR (2006)

Catchment hydrology

Dungowan Dam and pipeline project
Groundwater impact assessment
Figure 3.4

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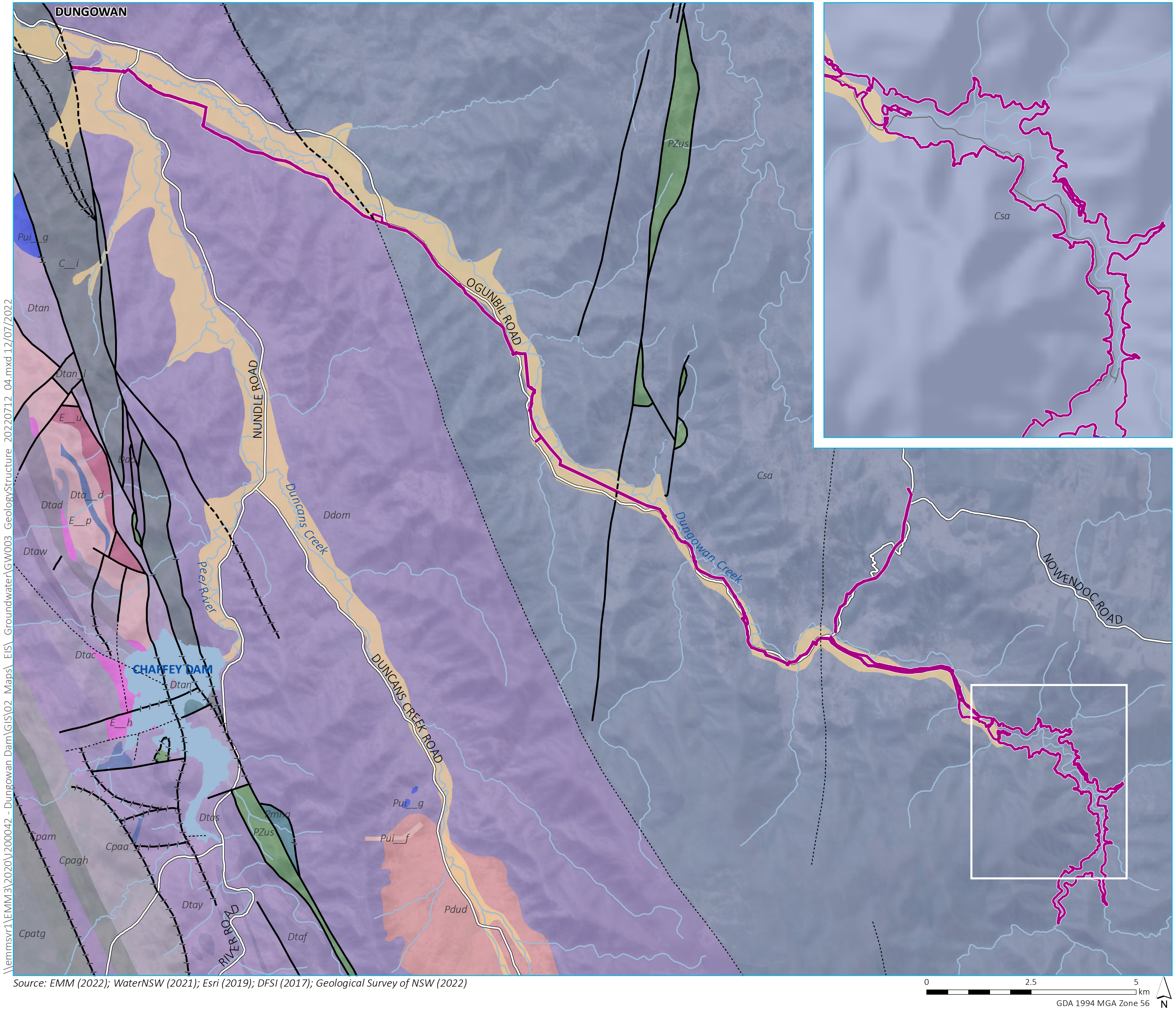

Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); Geological Survey of NSW (2022)

Geology and structure

Dungowan Dam and pipeline project
Groundwater impact assessment
Figure 3.5

EMM creating opportunities

4 Baseline monitoring program

Groundwater monitoring is an essential component in characterising the baseline conditions across the project area. Baseline water level and water quality field data collected from various monitoring bores, established in the two groundwater systems, has been used to determine the overall recharge and discharge characteristics, flow paths, water chemistry and groundwater-surface water connectivity. Field data has been an important input to validate the groundwater and surface water conceptual model.

In addition to monitoring bores installed during the Geotechnical Investigation (SMEC 2020), a hydrogeological drilling investigation was completed from 6 October 2020 to 10 October 2020 (EMM 2021). The objective of the investigation was to address the SEARs and inform the GIA by characterising:

- local groundwater levels and quality;
- the hydraulic properties within and between the Dungowan Creek Alluvium and Peel Fractured Rock; and
- any groundwater interaction between Dungowan Creek, the Dungowan Creek Alluvium and underlying Peel Fractured Rock.

A summary detailing relevant bore construction installation details is presented in Table 4.1 and the locations are shown on Figure 4.1. MB01A is the only bore installed in the DCA while remaining bores targeted the weathered and deeper competent rock of the PFR. Surface water sampling (SW1) from Dungowan Creek was also undertaken to inform consideration of the level of connectivity with the DCA and PFR.

Table 4.1 Monitoring bore installations

Site ID	Groundwater system	Elevation (mAHD)[1]	Total depth (mbgl)[2]	Screened interval (mbgl)	Standing water level (mbgl)	Date last measured
MB01A	Peel Fractured Rock	607.66	18.00	12.00 – 18.00	4.25	1 March 2022
MB01B	Dungowan Creek Alluvium	607.60	4.40	2.90 – 4.40	4.09	1 March 2022
MB02	Peel Fractured Rock	629.86	18.00	12.00 – 18.00	2.01	1 March 2022
MB03	Peel Fractured Rock	649.11	9.55	6.55 – 9.55	1.90	1 March 2022
BH02	Peel Fractured Rock	639.96	54.52	47.52 – 53.52	7.06	1 August 2020
BH04	Peel Fractured Rock	626.03	18.50	11.50 – 17.50	10.73	13 July 2020
BH06	Peel Fractured Rock	690.24	56.00	49.00 – 55.00	34.99	6 August 2020
BH08	Peel Fractured Rock	628.50	41.30	34.30 – 40.30	18.46	6 August 2020

Notes: 1. MAHD – metres Australian Height Datum; 2. Mbgl – metres below ground level.

KEY
Project footprint
Borehole
Site monitoring bore
Surface water sampling
Existing environment
Minor road
Named watercourse

Source: EMM (2022); WaterNSW (2021); Metromap (2019); DFSI (2017); GA (2013)

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Montioring bore network

Dungowan Dam and pipeline project
Groundwater impact assessment
Figure 4.1

EMM creating opportunities

4.1 Groundwater levels and flow

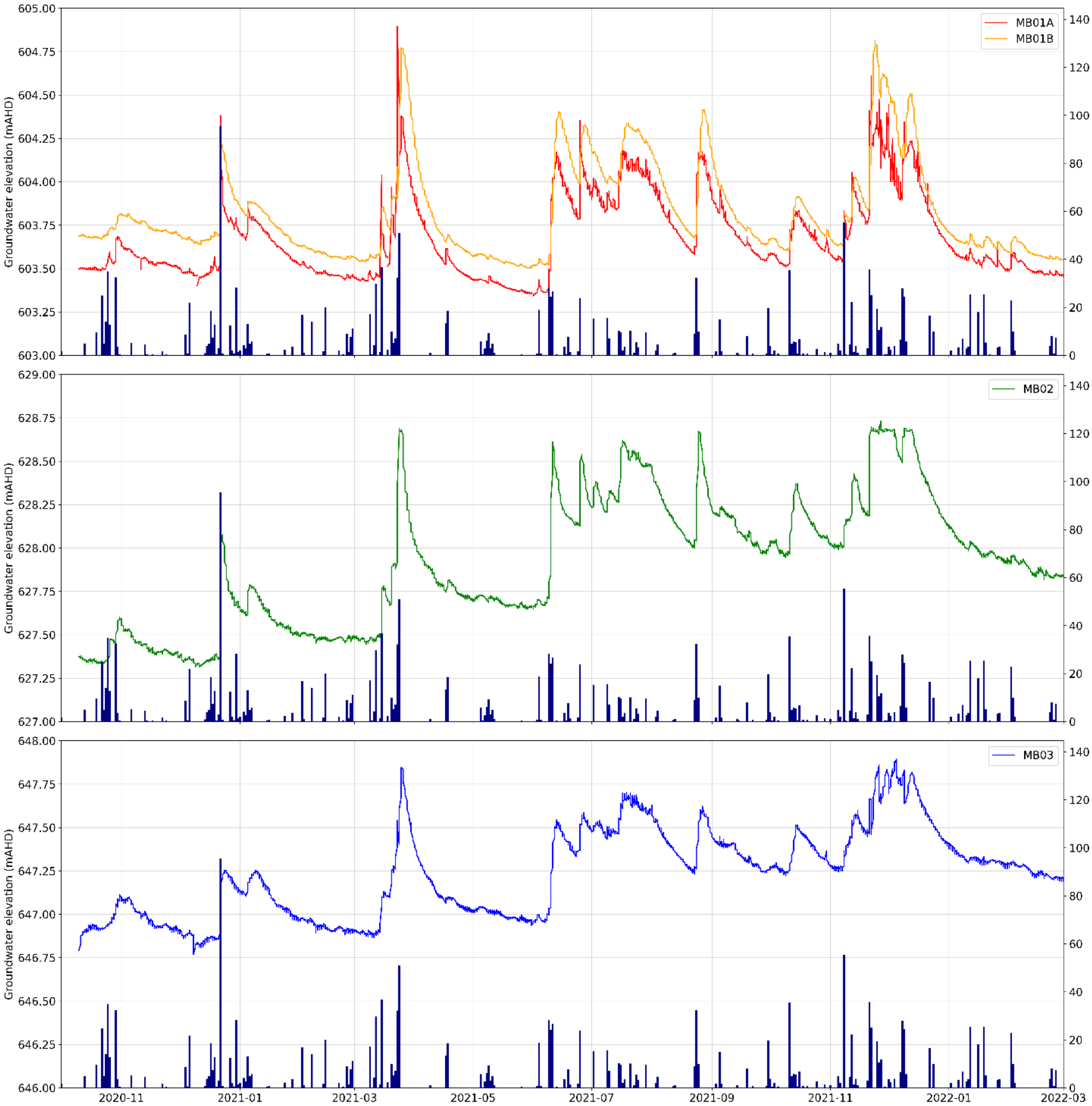
Groundwater level monitoring commenced in October 2020 with the most recent monitoring event completed in March 2022. A water level datalogger was installed at MB01A, MB01B, MB02, MB03, BH02, BH04, BH06 and BH08 and measured a hydrostatic pressure every six hours. A barometric logger was installed at MB02 and synced with the water level logger to correct for barometric pressure.

A piezometric surface has been interpreted from the available monitoring data to display the groundwater level elevation as hydrographs against SILO (Queensland Government 2022) rainfall data from a representative whether station (BoM Station: 55171). Hydrographs are presented in Figure 4.2.

All monitoring bores show a correlation with rainfall with a near instantaneous increase and decrease in groundwater levels in response to rainfall events. A degree of seasonality is evident at MB02 and MB03, showing gradually increasing trends following unseasonably above average and sustained rainfall, which has occurred since February 2020. A downward gradient is also evident from the DCA to the PFR (MB01B and MB01A).

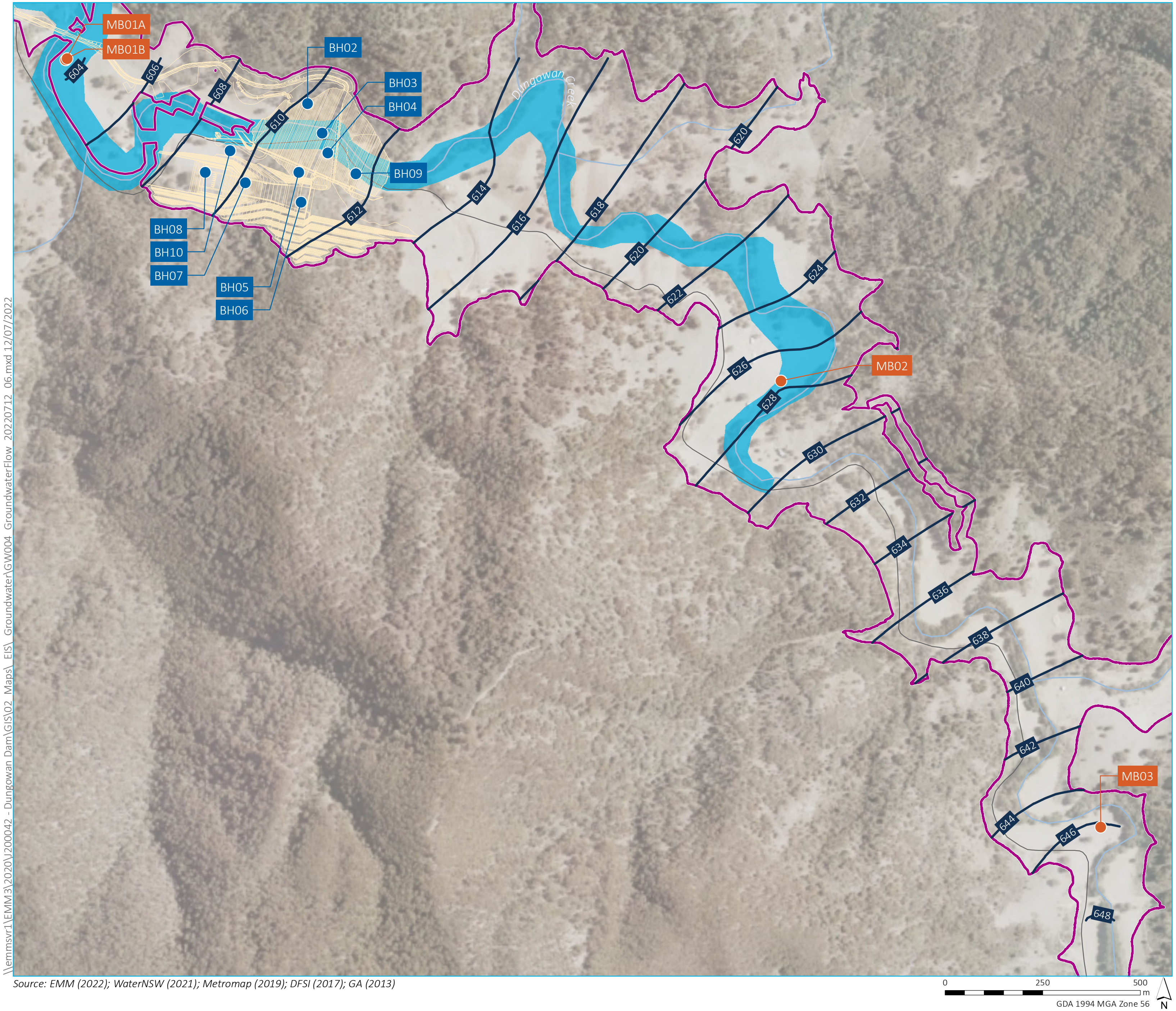
A groundwater flow contour map is shown on Figure 4.3 to provide a likely indication of flow within the PFR groundwater system. The contour map has been interpolated from groundwater level measurements from fractured rock monitoring bores MB01A, MB02 and MB03. No groundwater level data was available for the areas occupied by valley slopes and ridges, due to access constraints, and therefore flow contours are confined to the valley floor.

Using groundwater levels from monitoring bores installed for the project (see Table 4.1 and Figure 4.1), it is assumed that groundwater levels on the slopes and ridges are 10 to 15 metres below ground level (mbgl), generally displaying a muted reflection of topography with regional flow directed toward Dungowan Creek. Figure 4.3 shows the groundwater flow contours for the Dungowan Creek valley, from the southeast to the northwest, towards Tamworth.



Note: SILO rainfall data from BoM Station 55171

Figure 4.2 Site groundwater level hydrographs (MB01A and B, MB02, MB03)



KEY
- Project footprint
- Packer testing borehole
- Slug testing borehole
- Groundwater flow contour (RL mAHD)
- Concept design
- Dungowan Creek Alluvium Management Zone

Existing environment
- Minor road
- Named watercourse

Source: EMM (2022); WaterNSW (2021); Metromap (2019); DFSI (2017); GA (2013)

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Interpretive groundwater flow

Dungowan Dam and pipeline project
Groundwater impact assessment
Figure 4.3

EMM creating opportunities

4.2 Permeability

Hydraulic tests provide site-specific information on the hydraulic properties of the various groundwater systems. Hydraulic testing included rising/falling head (slug) tests and packer tests. The monitoring bore locations used for each test has been shown on Figure 4.3.

4.2.1 Slug testing

Slug testing was completed in MB01A, MB01B MB02 and MB03 and is used to estimate the bulk hydraulic conductivity in the immediate vicinity of the screened interval. Slug testing involves displacing water in the bore (using a slug, eg solid bailer) and measuring the change in groundwater level within the bore (using an automated pressure transducer data logger). When the groundwater level increases (falling head test) or decreases (rising head test) because of lowering or removing the slug in the bore, the change in water level is captured by the data logger and the aquifer response used to calculate horizontal hydraulic conductivity.

All tests were analysed using the Hvorslev or Bouwer-Rice straight line single well slug test solution for unconfined aquifers with a partially penetrating well. The results, presented in Table 4.2, span four orders of magnitude, with the highest result (44.71 metres per (m/day)) observed at MB01B (screened within the DCA) and the lowest result (0.02 m/day) observed in the underlying PFR at MB01A.

Table 4.2 Aquifer testing results

Site ID	Groundwater system	Aquifer type	K (m/day) [1]	Testing methodology	Solution
MB01A	Peel Fractured Rock	Unconfined, discrete fracture	0.02	Slug	Hvorslev
MB01B	Dungowan Creek Alluvium	Unconfined sediments	44.71	Slug	Bouwer-Rice
MB02	Peel Fractured Rock	Unconfined, discrete fracture	1.85	Slug	Hvorslev
MB03	Peel Fractured Rock	Unconfined, discrete fracture	0.42	Slug	Hvorslev

Notes: 1. K (m/day) – horizontal hydraulic conductivity (metres per day).

4.2.2 Packer testing

Packer testing (also known as Lugeon testing) is an in-situ method of testing the average hydraulic conductivity of a rock mass over a selected depth interval. The formation is tested by inflating pneumatic or hydraulic packers and injecting water at a constant pressure into the isolated section of the borehole. Packer testing is typically completed in five stages, gradually increasing then decreasing injection pressure and averaging the flow and pressure at each stage to estimate average hydraulic conductivity. Results are expressed in Lugeon units, which is the conductivity required to inject 1 litre of water per metre of the test interval under a constant pressure.

Packer testing was undertaken by SMEC (SMEC 2021) following the completion of geotechnical boreholes to estimate the in-situ permeability of multiple borehole intervals. For consistency with aquifer testing results, Lugeon values have been converted to indicative permeabilities (m/day). Results from packer testing are shown on Figure 4.4 and generally indicates that the rock mass permeability at each site decreases with depth.

Packer testing was undertaken at 6 m intervals from surface. Moderate to high Lugeons were observed between 6 to 36 mbgl and ranged in permeability from 0.05 to 0.67 m/day. These values are consistent with the slug test values of the shallow and weathered PFR. Below 36 m, permeability decreased, ranging from 3×10^{-3} to 3×10^{-2} m/day.

It is noted that on some boreholes, the rock mass was too fractured, or vertically fractured, to undertake packer testing. These boreholes typically had 100% loss in drilling fluids reported.

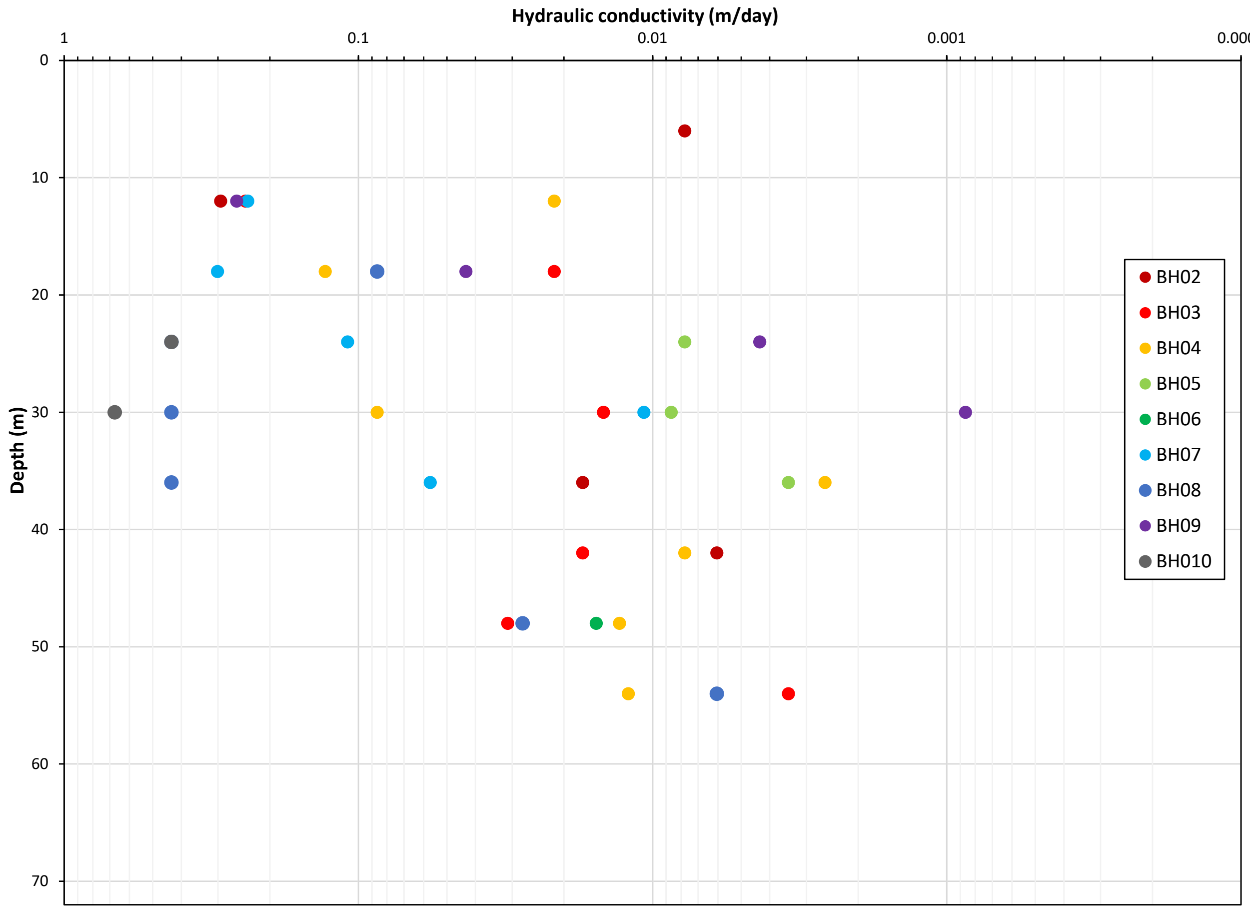


Figure 4.4 Packer testing results

4.3 Groundwater quality

A baseline groundwater quality monitoring program commenced in November 2020 following the installation of the groundwater monitoring network. Monthly sampling occurred between November 2020 and November 2021, with an additional single monitoring event completed in March 2022.

Groundwater sampling was undertaken in conjunction with surface water sampling in accordance with *AS/NZS 5667.11:1998 Australian Standard for Water Quality Sampling*. Samples were taken after purging three well volumes using a 12-volt pump. The sampling and analysis methods and monitoring analytes for the groundwater monitoring program are described in Table 4.3, with results presented in Annexure A.

Table 4.3 Groundwater analysis methods and parameters

Category	Monitoring analytes	Analysis method
Physico-chemical properties	pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen, temperature, redox potential	Measured in situ using a portable water quality meter
	alkalinity (bicarbonate, carbonate, hydroxide and total as $CaCO_3$)	Analysis undertaken by a NATA certified laboratory
Major ions	calcium, chloride, magnesium, sodium, potassium, sulphate.	
Nutrients	total nitrogen, ammonia, oxidised nitrogen and total kjeldahl nitrogen	
	total phosphorus	
Metals (field filtered)	Al, As, B, Ba, Be, Cd, Cr, Co, Cu, Fe, Hg, Mn, Ni, Pb, Se, V and Zn	

Field and laboratory quality assurance and quality control (QA/QC) procedures are used to establish accurate, reliable and precise results. QA/QC procedures included: analysis of unstable parameters in the field, calibration of equipment, submitting laboratory samples within holding times, collection of blind duplicate samples, keeping samples chilled and wearing gloves during sampling.

To assist with the characterisation of aquifer chemistry across the project area, graphical interpretations of the water quality data was undertaken including a Piper plot (Figure 4.5) and box and whisker plots (Annexure A) and of major ions and chemical composition. Surface water sampling (SW1) from Dungowan Creek has been included as a comparison to groundwater samples in order to determine the level of connectivity with the DCA and PFR. The location of surface water sampling is shown in Figure 4.1.

Surface and groundwater samples were compared to default water quality and river flow objectives for the Namoi River (NSW Government 2006). The beneficial uses of Dungowan Creek are commercial activities, drinking water supply, recreation and the preservation of aquatic and terrestrial ecosystems. Water quality sampling results have been compared to:

- physical and chemical stressors – default trigger values for upland rivers in South Eastern Australia that are reported in ANZECC/ARMCANZ (2000); and
- toxicant trigger values for the protection of 99% of freshwater aquatic species that are provided in ANZECC/ARMCANZ (2000).

In general, the following observations can be made from the data collected:

<u>Dungowan Creek (surface water)</u>

- surface water is characterised as neutral to slightly alkaline, with a pH range of 6.72 to 8.44;
- groundwater is fresh, with a salinity range of 81 to 192 microsiemens per centimetre (µS/cm);
- major ions are dominated by calcium and bicarbonate;
- the Piper plot shows a similar spread and grouping of ions to groundwater samples collected in the DCA (MB01B);
- dissolved metals are below the limit of reporting for most analytes; and
- nitrogen and phosphorus exceed default guidelines, similar to MB01B.

Dungowan Creek Alluvium (DCA)

- groundwater is characterised as neutral, with a pH range of 6.60 to 7.37;
- groundwater is fresh, with a salinity range of 334 to 414 µS/cm;
- major ions are dominated by calcium and bicarbonate;
- the Piper plot shows a similar spread and grouping of ions to samples collected from Dungowan Creek (SW1);
- dissolved metals are below the limit of reporting for most analytes; and
- nitrogen and phosphorus exceed default guidelines, similar to SW1.
- Peel Fractured Rock (PFR)
- groundwater is characterised as neutral, with a pH of 6.61 to 7.94;
- groundwater is fresh, with a slightly elevated comparative salinity of 649 to 1,020 µS/cm;
- major ions are dominated by calcium and bicarbonate;
- the Piper plot shows similar spread and grouping for ions and differs to samples collected in the DCA (MB01B) and Dungowan Creek (SW1);
- dissolved metals are below the limit of reporting for most analytes with higher concentrations of dissolved iron and manganese reported at MB02 and MB03;
- MB01A has elevated concentrations of barium; and
- phosphorus exceeds the default guidelines for MB01A, MB02 and MB03.

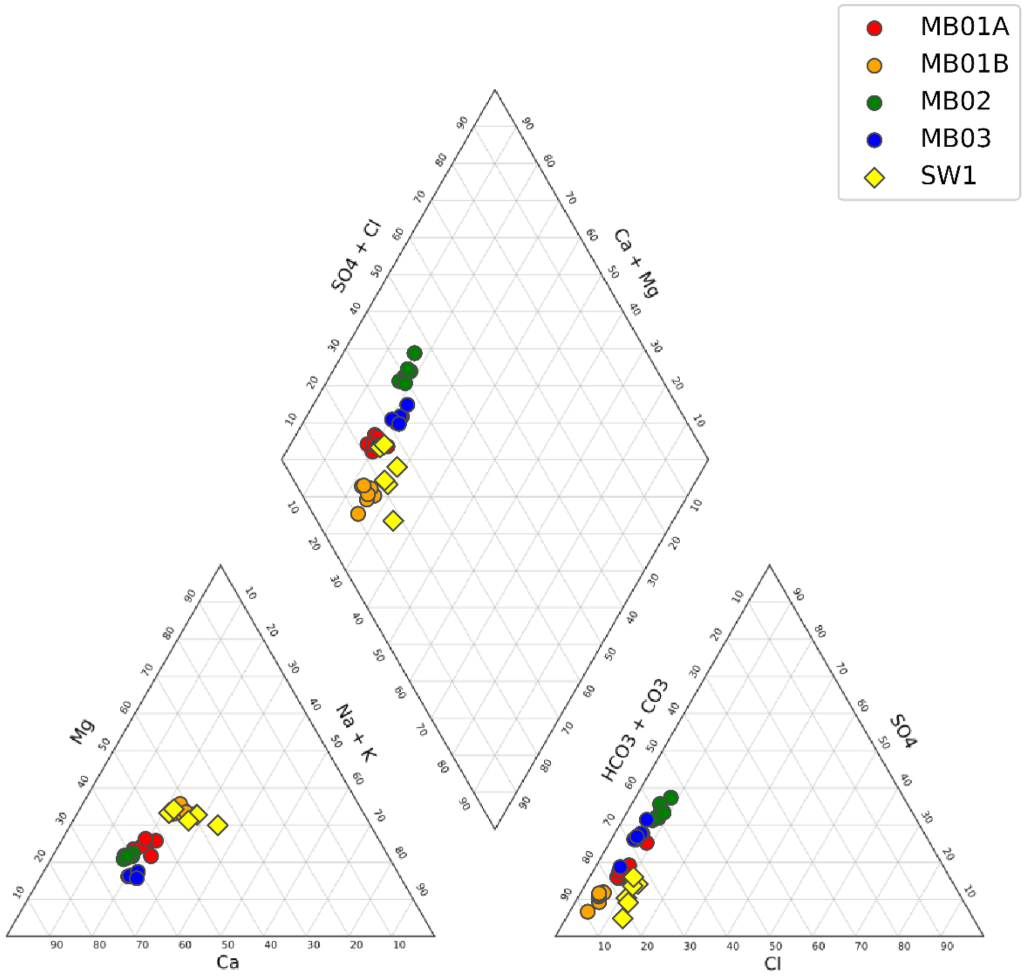


Figure 4.5 Piper plot

5 Sensitive receivers

5.1 Overview

This chapter identifies key environmental and third-party receptors of relevance to this assessment that are characterised as having a level of dependence on groundwater. These include:

- third-party groundwater users (ie water supply bores operated for stock and domestic, irrigation or other commercial purposes);
- listed high priority groundwater dependent ecosystems (GDEs) and culturally significant sites;
- potential GDEs, as characterised by publicly available mapping (BoM GDE Atlas) and field mapping and investigations, including:
  - terrestrial GDEs;
  - aquatic GDEs; and
  - subterranean GDEs.
- surface water/groundwater connectivity, including discussion around gaining and losing streams.

5.2 Private landholder bores

The NSW DPE-Water database has been searched to identify records of private landholder bores located within a 10 km radius from the centre of the new Dungowan Dam, as well as within a 1 km radius of the pipeline infrastructure and the Peel River downstream of Chaffey Dam to the Calala WTP. Water entitlement data from the Water Access Licence Register has also been considered. The location of registered bores, relative to the project area search radii, are shown in Figure 5.1to Figure 5.1c.

5.2.1 Private landholder bores in the vicinity of the new Dungowan Dam

There are nine registered groundwater bores used for domestic water supply, all of which target the PFR groundwater system (Table 5.1) within 10 km of the centre of the new Dungowan Dam. The two closest bores (GW900697 and GW966975) are located approximately 3.6 km to the north of the new Dungowan Dam, located on the New England Tablelands.

Total bore depths ranged from 4.0 to 72.9 mbgl and standing water levels ranged from 2.4 to 10.6 mbgl. Most bores are located to the east of the proposed development. Measured yields from the established bores were generally low, ranging from 0.1 to 1.2 L/s.

Table 5.1 Registered bores in a 10 km radius of the project site

Bore ID	Bore depth (m)[1]	Screen interval (mbgl)[2]	Lithology	Standing water level (mbgl)	Yield (L/s)[3]
GW022819	4.0	Unknown	Weathered basalt	3.0	-
GW057495	19.0	Unknown	Unknown	-	-
GW058245	18.3	11.0 – 17.2	Basalt	5.0	1.20
GW052166	72.9	60.8 – 72.9	Granite	-[4]	0.13
GW900697	23.2	Unknown	Unknown	-[4]	-[4]
GW966975	25.3	Unknown	Unknown	2.4	-[4]
GW969260	18.9	10.5 – 16.5	Basalt	10.6	0.13
GW969261	18.6	14.0 – 18.0	Limestone	10.0	1.00
GW967964	24.4	12.0 – 24.0	Basalt	4.6	0.50

Notes: 1. M – metres; 2. Mbgl – meters below ground level; 3. L/s – litres per second; 4. No data.

5.2.2 Private landholder bores in the vicinity of the new pipeline

The Peel Valley is supported by extensive irrigation, enabled by the highly productive PRA and more productive downstream DCA. Near the pipeline infrastructure and downstream of Chaffey Dam along the Peel River there are 236 registered groundwater bores used for domestic water supply, 119 for irrigation and 22 for stock and domestic supply. Most of the registered bores target the DCA and PRA groundwater systems. Total bore depths ranged from 1.2 to 137 mbgl, although most (approximately 90%) are drilled to depth of less than 30 metres.

5.3 Potential groundwater dependent ecosystems

A desktop assessment was undertaken to identify potential GDEs located within the vicinity of the project area. The desktop assessment involved:

- review of the GDE Atlas (BoM 2022);
- review of the Water Sharing Plan for the Namoi Alluvial Groundwater Sources 2020, Dungowan Creek Alluvium Management Zone;
- review of the Water Sharing Plan for the NSW Murray Darling Basin Fractured Rock Groundwater Sources 2020, Peel Fractured Rock water source;
- collation of depth to groundwater information from the NSW DPE-Water database; and
- review of aerial photographs, topographic and geologic maps.

There are four 'high priority' GDEs listed in the *Water Sharing Plan for the NSW Murray Darling Basin Fractured Rock Groundwater Sources 2020*. However only the Black Spring site is relevant to the project. The Black Spring site is:

- located on Black Spring Creek approximately 9 km north of Ogunbil
- a tributary to Dungowan Creek

- located downstream of the new Dungowan Dam.

A review of the BoM GDE Atlas (BOM 2022) identified the following plant community types (PCTs) may have groundwater dependence. The presence and extent of identified PCTs were verified through field investigations (EMM 2022b):

- PCT 78 – River Red Gum riparian tall woodland/open forest wetland in the Nandewar Bioregion and Brigalow Belt South Bioregion;
- PCT 84 - River Oak - Rough-barked Apple - red gum - box riparian tall woodland (wetland) of the Brigalow Belt South and Nandewar Bioregions; and
- PCT 582 - Sedgeland fens wetland of impeded drainage of the Nandewar Bioregion and New England Tableland Bioregion.

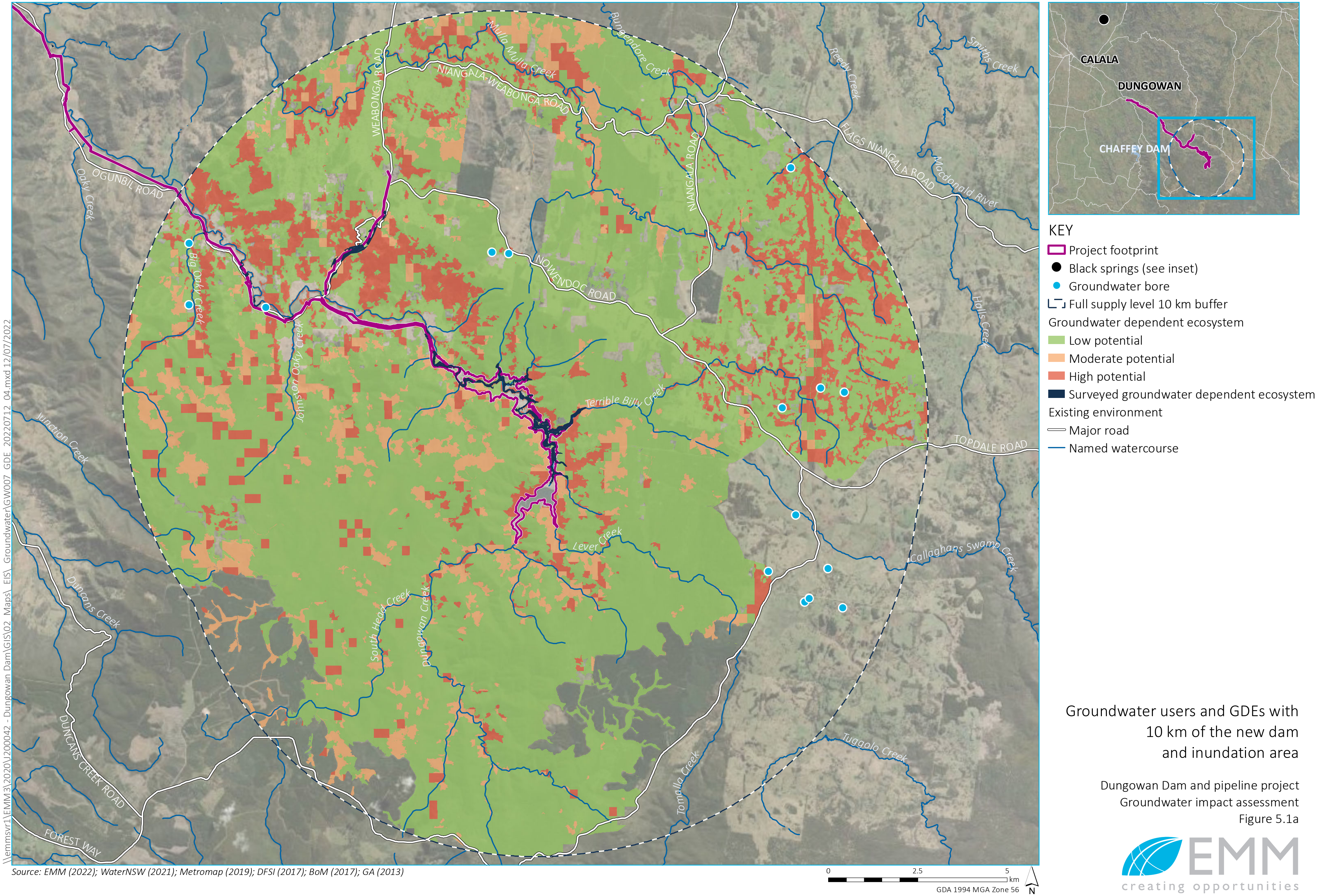
The location of potential GDEs within 10 km radius from the centre of the new Dungowan Dam, as well as within a 1 km radius of the pipeline infrastructure and along the Peel River from Chaffey Dam to the Calala WTP are shown in Figure 5.1a – Figure 5.1c.

Ecosystem dependence associated with these listed PCTs are characterised as having a facultative-opportunistic reliance on groundwater, accessing temporary groundwater within the shallow alluvial sediments of the DCA following flooding events or extended wetting periods (EMM 2022b).

5.4 Surface water groundwater interaction

The Peel River and Dungowan Creek each flow through alluvial valleys, which support native vegetation and farmland. Both watercourses lose water to the groundwater system along most of their length (NOW 2010). The Peel River Alluvium and Dungowan Creek Alluvial Management Zones of the Peel Alluvium Water Source are highly connected to surface water features, with more than 70% of the groundwater extracted drawn ultimately from the river (CSIRO 2007) (NOW 2010).

Estimates of groundwater recharge due to infiltration from the Peel River between Chaffey Dam and Calala are estimated to be between 13 to 17 GL/yr for periods with consistent flow in the Peel River (EMM 2022e).



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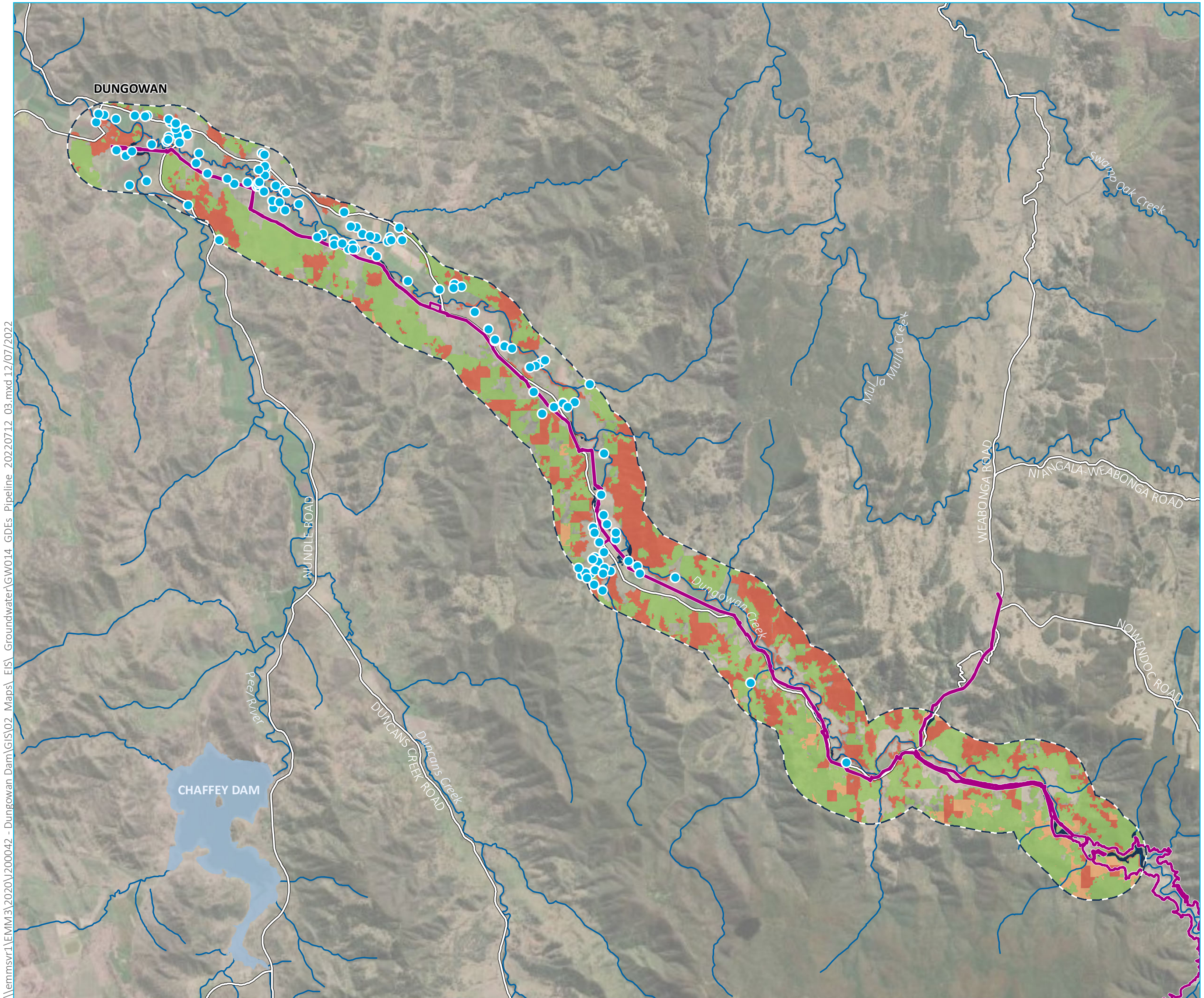
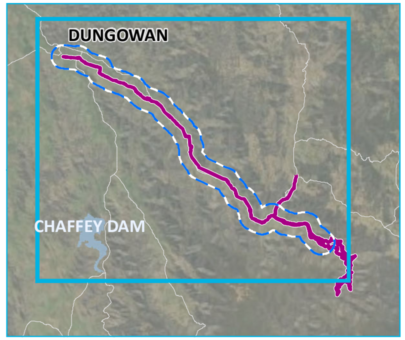
Source: EMM (2022); WaterNSW (2021); Metromap (2019); DFSI (2017); BoM (2017); GA (2013)

Groundwater users and GDEs with 10 km of the new dam and inundation area

Dungowan Dam and pipeline project
Groundwater impact assessment
Figure 5.1a

EMM creating opportunities





KEY
- Project footprint
- Groundwater bore
- Pipeline 1 km buffer
- Surveyed groundwater dependent ecosystem

Groundwater dependent ecosystem
- Low potential
- Moderate potential
- High potential

Existing environment
- Major road
- Named watercourse
- Named waterbody

Source: EMM (2022); WaterNSW (2021); Metromap (2019); DFSI (2017); BoM (2017); GA (2013)

0 2.5 5 km
GDA 1994 MGA Zone 56
N

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Groundwater users and GDEs within 1 km of the pipeline

Dungowan Dam and pipeline project
Groundwater impact assessment
Figure 5.1b

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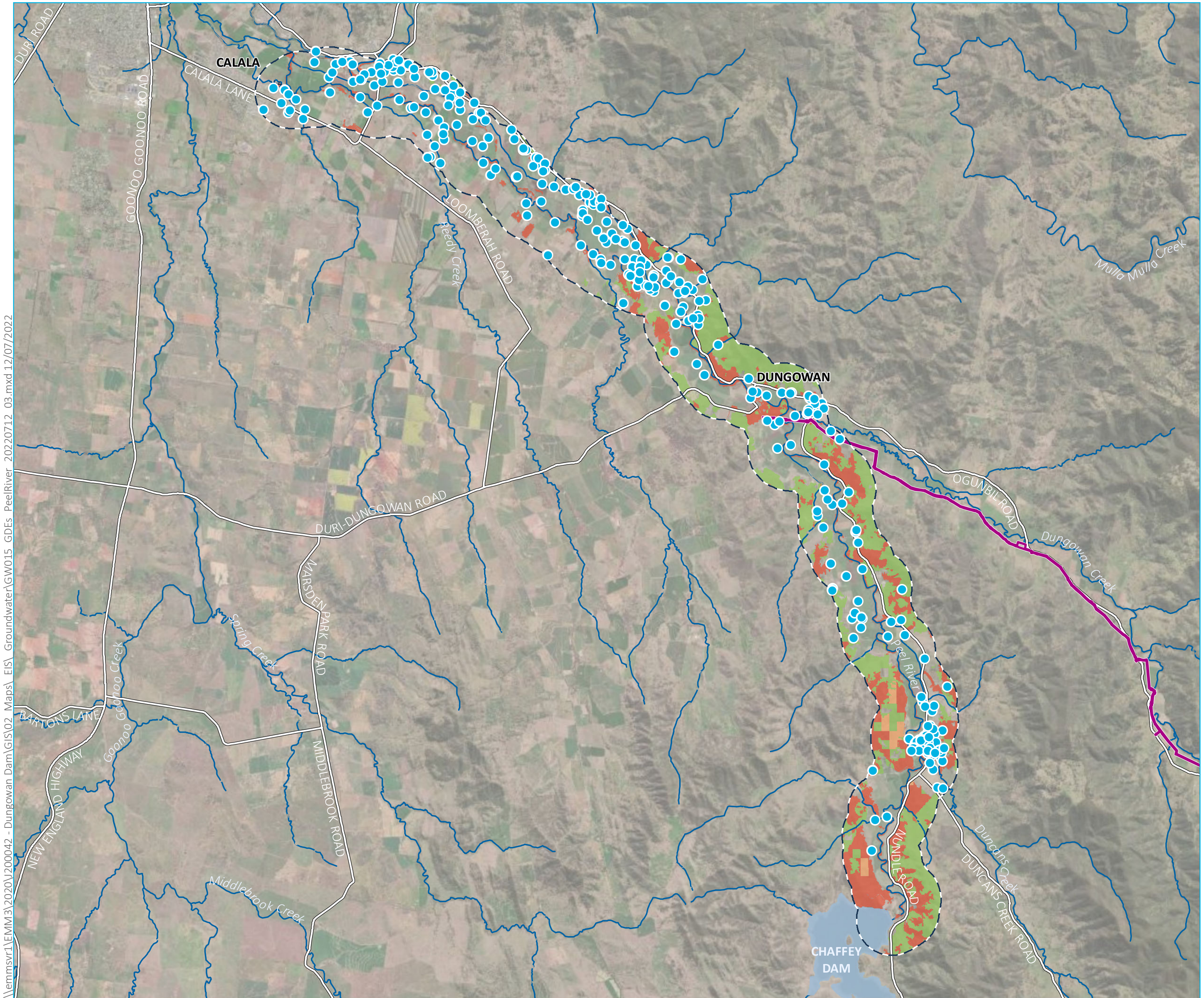

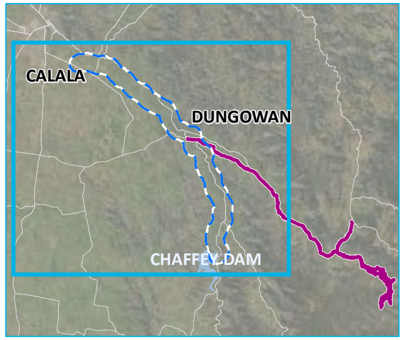

KEY

- Project footprint
- Groundwater bore
- Peel River 1 km buffer
- Surveyed groundwater dependent ecosystem

Groundwater dependent ecosystem

- Low potential
- Moderate potential
- High potential

Existing environment

- Major road
- Named watercourse
- Named waterbody

Groundwater users and GDEs with 1 km of the Peel River

Dungowan Dam and pipeline project
Groundwater impact assessment
Figure 5.1c

EMM
creating opportunities

Source: EMM (2022); WaterNSW (2021); Metromap (2019); DFSI (2017); BoM (2017); GA (2013)

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6 Site hydrogeological conceptual model

6.1 Overview

The hydrogeological units of the project area have been simplified as follows:

- Alluvium (DCA and PRA):
  - groundwater in shallow alluvium along creeks and rivers is recharged during moderate to high rainfall and flooding events. The alluvium provides bank storage during high flow events; and
  - groundwater in shallow alluvium is recharged during rainfall events and a shallow watertable is maintained due to high soil moisture and basal recharge from the underlying fractured rock groundwater system.
- Fractured rock (PFR):
  - the fractured rock is recharged by infiltration of rainfall migrating from shallow groundwater systems. Permeability is generally lowest at depth, coinciding with the level of consolidation of the rock matrix. There is downward flow of groundwater from shallow aquifers in recharge areas and upward flow to shallow aquifers in discharge areas.

There is inherent variability and uncertainty in groundwater flow, vertical connectivity and baseflow contributions to terrestrial GDEs and watercourses in fractured rock groundwater systems. A graphical depiction of the conceptual hydrogeological understanding for the project area is shown in Figure 6.1. Water tables oscillate between wet recharge periods and dry summer periods when there is negligible recharge.

6.2 Groundwater recharge, discharge and flow

6.2.1 Recharge

Groundwater recharge processes for the DCA and PRA are unconfined and recharged by rainfall infiltration, flooding events from Dungowan Creek and the Peel River, and side slope seepage through colluvium and weathered rock (that is from the PFR). Groundwater recharge processes for the PFR is unconfined and recharged by rainfall infiltration on the upper slopes, ridgelines, and hilltops where it sub-crops or outcrops, and by leakage from the DCA and PRA at select sites.

6.2.2 Discharge

Groundwater discharge processes for the DCA and PRA are:

- DCA and PRA drainage to Dungowan Creek, Peel River and their tributaries during/following flooding as a result of bank storage;
- leakage from the DCA and PRA to the PFR; and
- transpiration from overlying vegetation intercepting shallow groundwater systems.

Groundwater discharge processes for the PFR are:

- seepage/springs and evaporation along hill slopes;
- regional groundwater flow toward the existing Dungowan Dam and new Dungowan Dam;

- baseflow to Dungowan Creek; and
- pumping from landholder bores.

6.2.3 Flow

Groundwater flow processes for the DCA and PRA are:

- groundwater flow in the DCA and PRA is down gradient; and
- permeability in the alluvium is via primary porosity.

Groundwater flow processes for the PFR are:

- regional groundwater flow displays a muted reflection of topography, flowing from catchment highs to valley floors, or southeast to northwest, toward Tamworth;
- localised groundwater flow direction is largely controlled by stratigraphy, dip of the strata, faulting, fractures and topography; and
- the bulk of groundwater movement and permeability in the fractured rock groundwater systems is determined by secondary porosity.

6.3 Surface and groundwater interaction

On a regional scale, both Dungowan Creek and the Peel River are considered losing systems for most of their lengths, losing surface water to the underling shallow groundwater system.

On a local scale, Dungowan Creek in its upper reaches (from the new Dungowan Dam to the existing Dungowan Dam) is conceptually a gaining system receiving groundwater discharge as baseflow along its length, controlled by the steep hydraulic gradient created by local topography. As the valley widens downgradient of the new Dungowan Dam (lower reaches), Dungowan Creek transitions to a mostly losing stream. Minor groundwater discharge is also possible through leakage under and around the existing Dungowan Dam, which could also be contributing some base flow to Dungowan Creek.

Figure 6.2conceptualises the distinctions between gaining and losing streams in the context of both Dungowan Creek and the Peel River.

6.4 Groundwater dependent ecosystems

6.4.1 Terrestrial

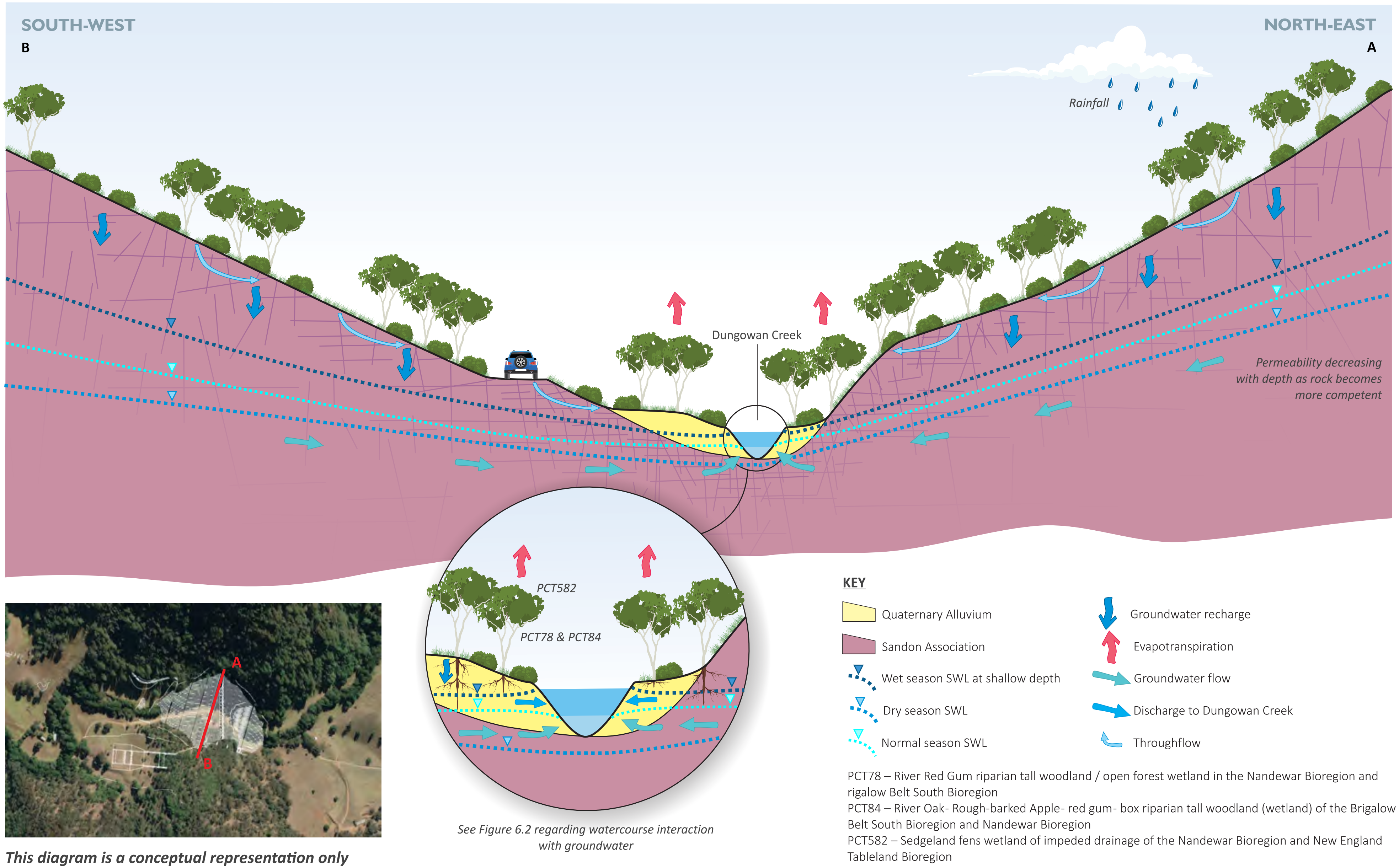
Groundwater dependent PCTs have been identified as being facultative-proportional or facultative-opportunistic type GDEs, and intercept shallow alluvial and/or deeper fractured rock groundwater systems. Other PCTs are non-dependent on groundwater (see EMM 2022b for further discussion). Where there is a reduction in depth to groundwater, or variability in climate, this may be reflected as a proportional change in ecosystem condition for facultative-proportional and facultative-opportunistic PCTs, but the ecosystem remains resilient in the absence of groundwater (Serov et al 2012).

6.4.2 Aquatic

Dungowan Creek in its upper reaches is predominately a gaining stream. The prevalence of aquatic GDEs in Dungowan Creek is likely reliant on groundwater baseflow contribution to Dungowan Creek during dry seasons. The Peel River is considered as a losing stream with flow largely reliant on rainfall, surface water runoff and environmental flows from Chaffey Dam. Subsequently, the prevalence of aquatic ecosystems is reliant on these processes and are considered inflow (eg surface water, soil water, irrigation) dependent.

6.4.3 Subterranean

Subterranean stygofauna have not been identified in the project area. However, if stygofauna are present, they are likely to be more common in hyporheic zones and shallower zones of the underlying fractured rock groundwater systems due to the greater availability of dissolved oxygen and nutrients.



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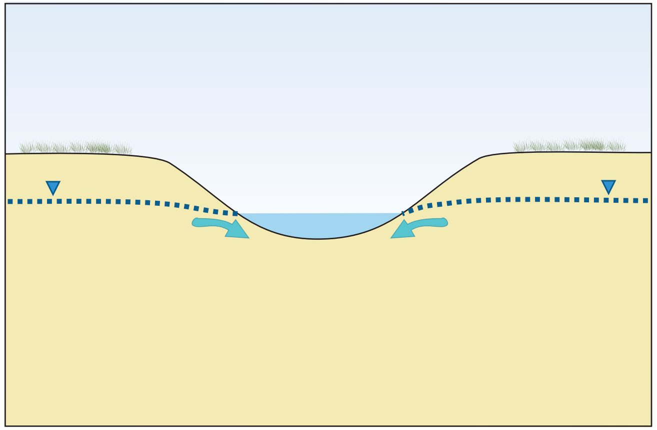
Conceptual hydrogeological model

WINSW

Dungowan Dam

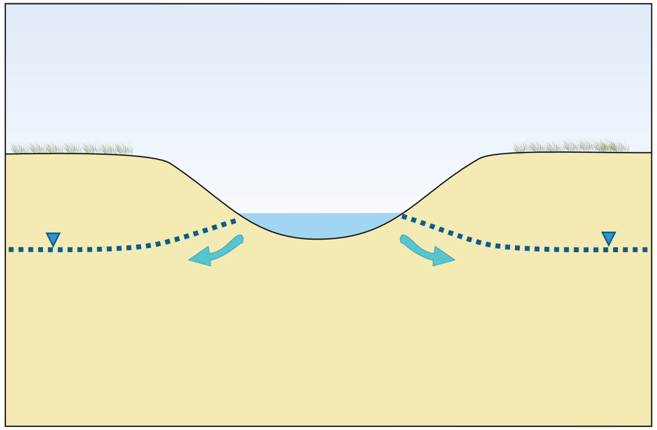
Figure 6.1

Gaining – connected



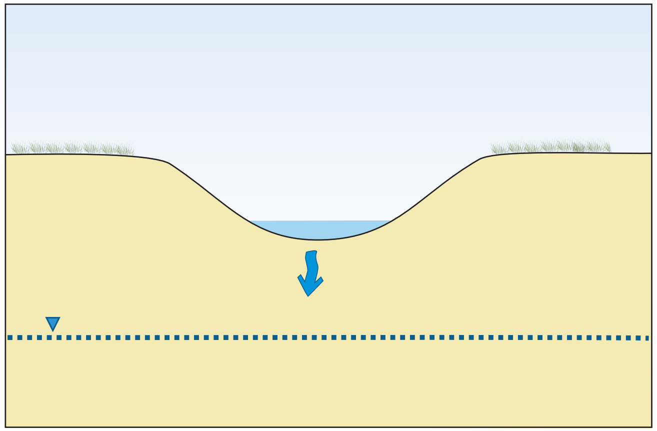
Baseflow occurs when/where groundwater level is higher than the surface water. Groundwater discharges to the watercourse.

Losing– connected

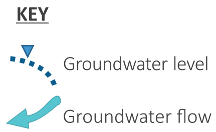


River leakage occurs when/where the groundwater level is high enough to be connected to surface water, but lower than the surface water level of the watercourse.

Disconnected



The surface water and groundwater are not connected when/where the groundwater level is lower than the base of the watercourse. River leakage may still occur if the watercourse flows after rainfall. However, any change in groundwater level will not affect the surface water level or flow.



EMM
creating opportunities

Watercourse interaction with groundwater

WINSW

Dungowan Dam project description

Figure 6.2

7 Regulatory and policy context

The primary water related statutes that apply to the project are the NSW Water Management Act 2000 (WMA), NSW Water Act 1912, NSW Protection of the Environment Operations Act 1997 (POEO Act), the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), and their attendant regulations (including Water Sharing Plans (WSPs) under the WMA).

Projects that intercept groundwater also need to consider the NSW Aquifer Interference Policy (AIP) (DPI Water 2012b), which requires projects to hold licences that account for the volume of water intercepted and consider changes in water quality and water levels at sensitive receptors in accordance with prescribed minimal impact criteria.

7.1 Water Act 1912

The *Water Act 1912* (Water Act) has been largely superseded by the WMA with WSPs developed for all water sources across NSW. However, some aspects of the Water Act are still operational such as licences for monitoring bores. Monitoring bores would continue to be licensed under the Water Act unless installed as part of a CSSI project.

7.2 Water Management Act 2000

The WMA is based on the principles of ecologically sustainable development and the need to share and manage water resources for future generations. The WMA recognises that water management decisions must consider economic, environmental, social, cultural and heritage factors. The WMA provides for water sharing between different water users including environmental, basic rights and all consumptive users including industry. In addition, the WMA provides security to holders of Water Access Licences (WALs). The licensing provisions of the WMA apply to those areas where a WSP has commenced; it has progressively been enacted across NSW since July 2004. The licensing provisions of the WMA become effective for any water source once a WSP for that water source commences.

One of the key components of the WMA is the separation of the water licence from the land; this facilitates opportunities for licence holders to trade water. The WMA outlines the requirements for taking and trading water through WALs, water supply works, and water use approvals.

The WMA is the primary legislation governing water management and licensing relevant to the project. The licensing requirements for industrial use are similar to other consumptive licensing requirements.

7.2.1 Water sharing plans

WSPs are statutory documents dictating the management and sharing of water sources. The WSPs set the water management vision and objectives, management rules for WALs, what water is available within the various water sources, and procedures for dealing in licences and water allocations, water supply works approvals and the extraction of water. WSPs are designed to establish sustainable use and management of water resources and are periodically reviewed (every 10 years).

Each WSP documents the water available and how it is shared between environmental, basic rights, and other consumptive uses. The WSPs outline the water availability for extractive uses within different categories, such as: local water utilities, domestic and stock, basic rights, and access licences.

The development footprint overlies two WSP areas that relate to the alluvial and regional fractured rock groundwater units. These areas are detailed in Figure 7.1 and are:

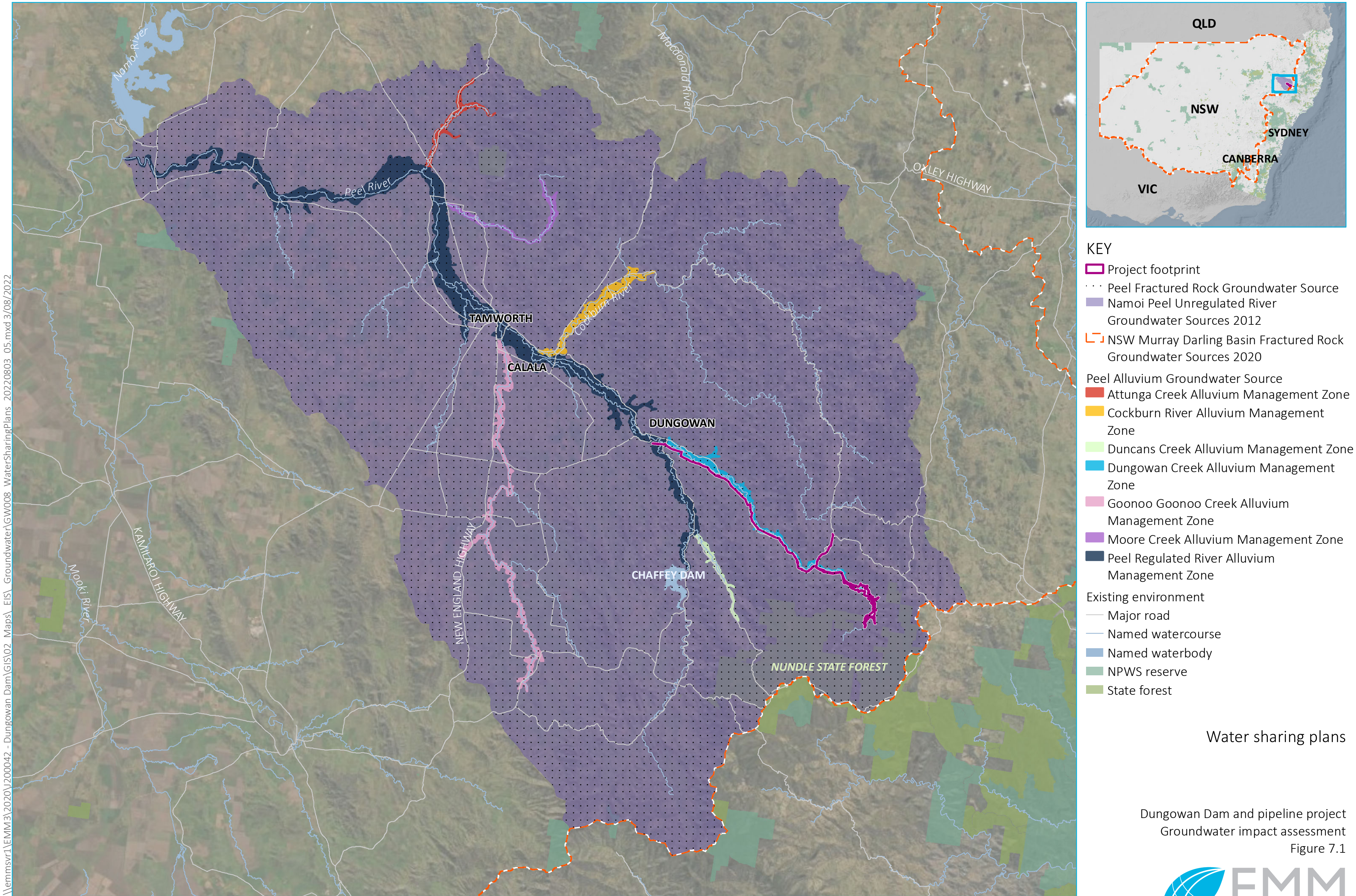
- *Water Sharing Plan for the Namoi Alluvial Groundwater Sources 2020;*
    - Dungowan Creek Alluvium Management Zone and Peel Regulated River Alluvium Management Zone within the Peel Alluvium Groundwater Source; and
- *Water Sharing Plan for the NSW Murray Darling Basin Fractured Rock Groundwater Sources Order 2020;*
    - Peel Fractured Rock Groundwater Source.

The WSPs, associated water sources, available water, basic rights and licence shares as outlined in the WSPs applicable to the project are outlined in Table 7.1. Data for Table 7.1 was sourced from the WaterNSW Water Register (WaterNSW 2022b), which is an online and real-time database that contains information on licence volumes within different licence categories, which may change over time.

Table 7.1 Available water, basic rights and licence shares

WSP	***Water Sharing Plan for the Namoi Alluvial Groundwater Sources 2020***	***Water Sharing Plan for the NSW Murray Darling Basin Fractured Rock Groundwater Sources 2020***
Water source	**Peel Alluvium Groundwater Source**	**Peel Fractured Rock Groundwater Source**
Water Requirements (ML/yr)		
Domestic and Stock rights	209	4,052
Native title	0	0
Access licences (as per the NSW Water Register on 5 May 2022)		
Aquifer	18,676	11,030
Aquifer (general security)	32,336.8	-
Domestic and stock	39	68
Domestic and stock (domestic)	170	276
Domestic and stock (Town water supply)	-	104
Local water utility	660	100
TOTAL requirements for water	51,882	11,578
Usage		
LTAAEL[4]	9,344	15,874
Unassigned water – available (LTAAEL minus total requirements for water)	Not applicable[5]	4,296

Notes: 1. Data based on search of the NSW Water Register (accessed 5 May 2022); 2. The conversion from a unit share to a megalitre is 1:1 unless otherwise stated; 3. Megalitres per unit share; 4. long term annual average extraction limit. ; 5. Unassigned water is negative and system is overallocated – carry over from legacy policy and LTAAEL is managed through AWDs; ML/yr = megalitres per year; WSP = water sharing plan; LTAAEL = long term; BLR = basic landholder rights; BR – basic rights



KEY

- Project footprint
- Peel Fractured Rock Groundwater Source
- Namoi Peel Unregulated River Groundwater Sources 2012
- NSW Murray Darling Basin Fractured Rock Groundwater Sources 2020

Peel Alluvium Groundwater Source

- Attunga Creek Alluvium Management Zone
- Cockburn River Alluvium Management Zone
- Duncans Creek Alluvium Management Zone
- Dungowan Creek Alluvium Management Zone
- Goonoo Goonoo Creek Alluvium Management Zone
- Moore Creek Alluvium Management Zone
- Peel Regulated River Alluvium Management Zone

Existing environment

- Major road
- Named watercourse
- Named waterbody
- NPWS reserve
- State forest

Water sharing plans

Dungowan Dam and pipeline project
Groundwater impact assessment
Figure 7.1

EMM
creating opportunities

Source: EMM (2022); WaterNSW (2021); DPIE (2021); Metromap (2019); DFSI (2017); BoM (2017); GA (2013)

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The Peel Fractured Rock Groundwater Source is approximately 73% allocated, with an additional 4,296 shares (one share component is equivalent to 1 ML) of water available for release. Despite there still being a significant portion of unallocated water in the PFR no water has been made available via controlled allocation order to date. The Peel Alluvium Groundwater Source is fully allocated, with total allocated water exceeding the Long Term Average Annual Extraction Limits (LTAAEL). Detail regarding how these groundwater sources are managed can be found in Chapter 10.

Under the AIP, the project would need to hold a licence to the equivalent volumes of the water extracted each year. When submitting an EIS for a project, there needs to be a demonstrated pathway for the peak water demand to be obtained from the source to which it originates. The analytical model (Section 9.2.4) demonstrates that groundwater seepage that reports to the project during construction would be sourced from the Peel Fractured Rock and Peel Alluvium (Dungowan Creek Management Zone) Groundwater Sources.

Surface water licences required for project construction and operation are discussed in the Surface Water Assessment (EMM 2022e).

i Trading rules

WSPs are accompanied by rules for sustainably sharing, trading and managing water resources within water source areas and outline the vision, objectives and strategies for achieving sustainable water sharing.

Trading of water is allowed between WAL holders within a water source and is usually restricted to management zones if they exist. For example, the project is within the Dungowan Creek Management Zone, which is part of the Peel Alluvium Groundwater Source. Under the WSP for the *Namoi Alluvial Groundwater Sources 2020*, water trading between management zones in the Peel Alluvium is prohibited (ie no trading of entitlement from another management zone within the Peel Alluvium Groundwater Source to Dungowan Creek Management Zone).

ii Available water determinations

Available Water Determinations (AWDs) are announced for the forthcoming water year and specify what percentage of allocation is available to the user. AWDs are dependent on available water in the regulated/unregulated river system and headwater storages.

The aim of the AWD is to balance domestic and commercial use of water as well as environmental flows during drought or low storage conditions. The lower limit of environmental flows is relatively fixed and to make sure environmental flows are maintained. AWDs are enforced to ensure enough water is reserved for environmental flows.

Due to the connectivity between surface water and alluvium, aquifer (general security) access licences are 51% (ie 0.51 ML per share) of the AWD for the Peel Alluvium Groundwater Sources plus 49% of the AWD for regulated river (general security) access licenses in the Peel Regulated River Water Source. AWDs can be increased or decreased throughout the water year depending on flow conditions and commitments to meet environmental objectives.

7.3 Water Availability

Historic groundwater usage for the Peel Fracture Rock Groundwater source is shown on Figure 7.2. Groundwater availability and licences for the Peel Fractured Rock Groundwater source indicates that the volume of licences held within this water source represents approximately 73% of the total available water. The groundwater source is generally not highly productive and groundwater abstraction from this system is generally required for stock and domestic purposes. The actual measured and recorded groundwater usage for the 2020/21 water year was 333.5 ML (or 2% of the LTAAEL). Therefore, there is a significant portion of both unallocated water and an underuse of allocated water available to be either acquired via controlled allocation order (if released) or potentially traded with existing licence holders.

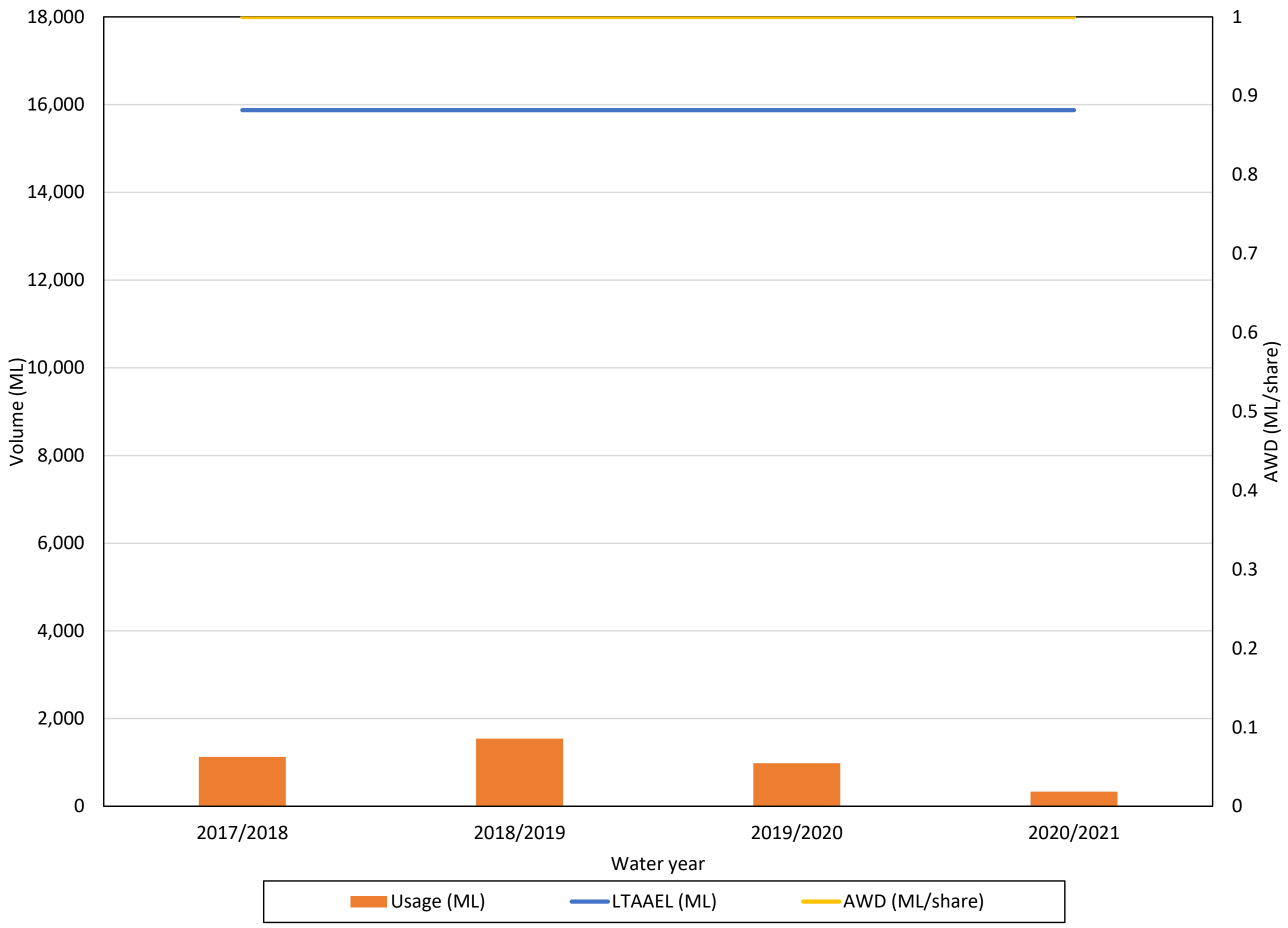

Figure 7.2 Groundwater availability – Peel Fractured Rock Groundwater Source

Historic groundwater usage for the Peel Alluvium Groundwater Source relative to the LTAAEL is shown on Figure 7.3, demonstrating that whilst entitlement within this source significantly exceeds the LTAAEL by a factor of 4:1, actual usage is much lower and critically, below the LTAAEL. Further, the trading market for temporary General Security aquifer access licences is considered reliable (refer Table 7.2). There is no detail on trading within management zones (ie Dungowan Creek Management Zone) within the Peel Alluvium Groundwater Source.

Under the AIP, the project would need to hold a licence to the equivalent volume of water extracted each year. When submitting an EIS for a project, there needs to be a demonstrated pathway for the peak water demand to be obtained from the source in which it originates.

The analytical groundwater model (refer Section 9.2.4) predicts groundwater inflow to the new Dungowan Dam excavations during construction would be sourced from the Peel Fractured Rock and Peel Alluvium (Dungowan Creek Management Zone) Groundwater Sources. The pathway to obtain the requisite entitlement in both sources is well understood. The trading market, as discussed in Section 7.3.3, represents a viable pathway to secure the required entitlement on a temporary basis.

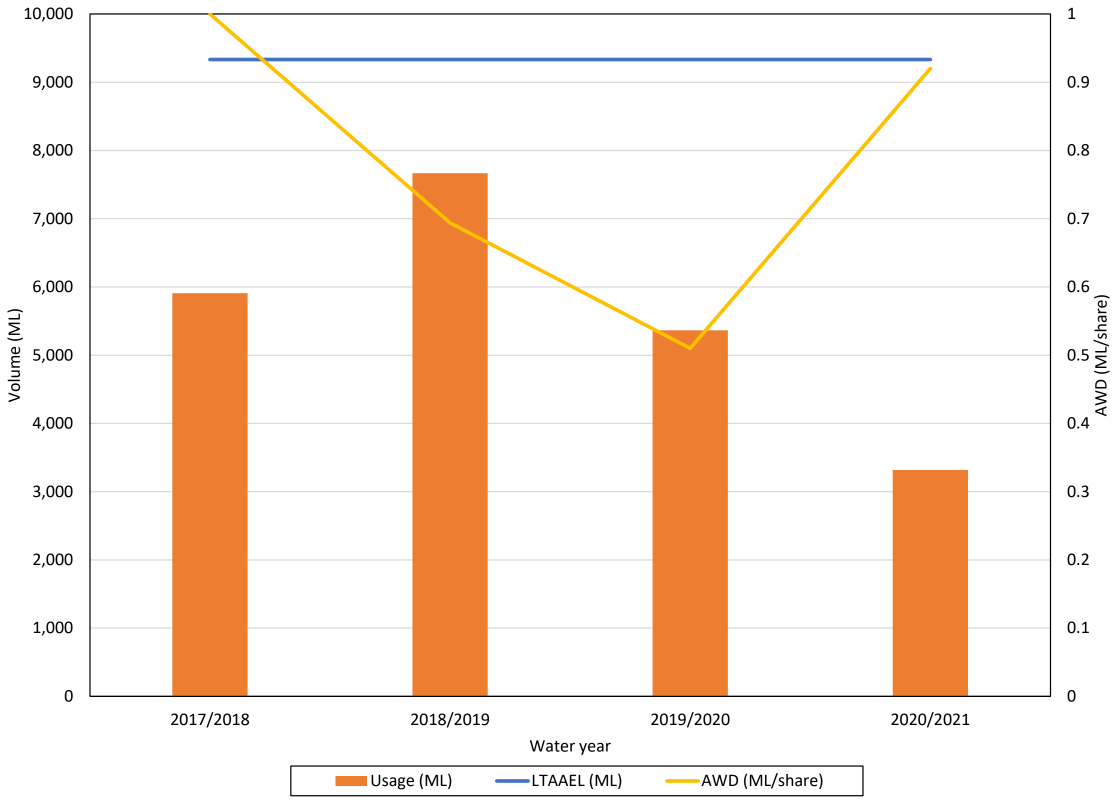

Figure 7.3 Groundwater availability – Peel Alluvium Groundwater Source

7.3.1 Water access licence

WALs entitle licence holders to specified shares (entitlement) in available water within a particular water management area or water source (i.e. separate WALs for the Peel Alluvium and Peel Fractured Rock Groundwater Sources). Entitlement within a water source cannot be traded or used outside of that water source (eg shares secured in the Peel Alluvium cannot be used for the Peel Fractured Rock). These applications, generally referred to as water dealings, are lodged with WaterNSW.

Water can be traded on a temporary or permanent basis:

- temporary trade - water within the same water source or management zone as a water supply works (ie bore or river pump) can be traded temporarily from one WAL's water account to another; and
- permanent trade – water within the same water source or management zone as the water supply works can be purchased in perpetuity from one WAL holder to another.

7.3.2 Water supply works and use approval

To take water from a water source, proponents are required to hold a WAL, with shares for a specified water source, which is linked to an approved water supply works (i.e. a bore, dam or river pump) and use (ie irrigation, production, water supply, dewatering) approval. A water supply works and use approval authorises its holder to construct and use a specified water supply work at a specified location.

An application for a water supply works and use approval (for each supply works) is lodged with the NSW Natural Resources Access Regulator (NRAR). Applications are reviewed, for compliance with the WSP rules and the sustainable abstraction limit within a water source, by DPE Water. Water supply works and use approvals can come with conditions (following DPE Water's review) to minimise adverse impacts (to other users, ecosystems etc). Water supply works and use approvals cannot be traded from one property to another.

For CSSI projects, a water supply works and use approval is not required if the water supply works are included and assessed as part of the EIS. If approved, the project would be conditioned to secure a miscellaneous works approval. A miscellaneous works approval, once linked to a WAL(s), allows the proponent to use water as permitted under the project approval.

7.3.3 Water trading market

Trading data for relevant water sources was sourced from the NSW Water Register (WaterNSW 2022b). An active water trading market exists for the Peel Alluvium and Peel Fractured Rock Groundwater Sources. No detail has been provided regarding trading in specific management zones within the Peel Alluvium Groundwater Source. Table 7.2 details water trading statistics during the last three water years.

Table 7.2 Water trading statistics

Groundwater source	Water year	Trades	Type	Unit shares traded[1]	Price range per unit share
Peel Alluvium	2020 to 2021	15	Temporary	17 - 240	$5 - 100
	2019 to 2020	24	Temporary	10 - 200	$18 - 100
	2018 to 2019	6	Temporary	50 - 200	$20 - 50
Peel Fractured Rock	2020 to 2021	3	Temporary	10 - 50	$80
	2019 to 2020	5	Temporary	12 - 116	$50 - 70
	2018 to 2019	2	Temporary	12 - 40	$40 - 50

Engagement with willing vendors to negotiate the terms of the trade is undertaken by a water broker.

7.4 NSW Aquifer Interference Policy

The AIP is the policy with respect to groundwater interference activities (DPI Water 2012b). The WMA (under Section 91) defines an 'aquifer interference activity' as an activity involving:

- penetration of an aquifer;
- interference with water in an aquifer;
- obstruction of the flow of water in an aquifer;
- taking of water from an aquifer in the course of carrying out mining, or any other activity prescribed by the regulations; or
- disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed in the regulations.

Both the construction and operation of the new Dungowan Dam and the pipeline infrastructure has the potential to interfere with water in an aquifer. Other activities forming part of the project, such as the construction and upgrades to the powerline, the construction of ancillary facilities and decommissioning of the existing dam, would have negligible effects on groundwater and are not considered relevant to this assessment as groundwater interference activities (see Section 2.2).

Section 91(3) of the WMA relates to aquifer interference approvals. The requirement to obtain an aquifer interference approval under Section 91(3) is triggered only when a proclamation has been made under Section 88A of the WMA that the particular type of approval is required. To date, no proclamation has been made specifying that an aquifer interference approval is required in any part of NSW. This is expected to remain the case for the project. In the meantime, the AIP sets the policy with respect to aquifer interference. The policy explains the role and requirements of the Minister in determining applications for aquifer interference activities. The aquifer interference assessment framework is included (and completed) in Table 7.3.

The AIP specifically refers to 'take' that is 'required to allow for the effective and safe operation of an activity, for example dewatering to allow mining' (p.3), regardless of whether the take would be used. The take, use, and incidental interception of groundwater requires a licence. The AIP states that, unless specifically exempt, a WAL is required under the WMA where any act by a person carrying out an aquifer interference activity causes:

- the removal of water from a water source;
- the movement of water from one part of an aquifer to another part of an aquifer; and
- the movement of water from one water source to another water source, such as:
    - from an aquifer to an adjacent aquifer; or
    - from an aquifer to a river/lake; or
    - from a river/lake to an aquifer.

7.4.1 Assessment criteria

The AIP defines water sources as being either 'highly productive' or 'less productive' based on levels of salinity and average yields from bores. The mapped distribution of the highly productive and less productive groundwater sources in NSW are included in the AIP (DPI Water 2012b). The AIP further defines water sources by their lithological character, being one of alluvium, coastal sand, porous rock, or fractured rock.

For each category of water source, the AIP identifies thresholds for minimal impact considerations. These thresholds relate to impacts on the watertable, water pressure and water quality, and are ranked as being either 'level 1 minimal impact' or 'level 2 exceeding minimal impact'. The definition of 'minimal impact' is outlined in a series of tables which demonstrate how the criteria are applied for different types of water sources and for different sensitive receptors (ie other users and ecosystems).

Based on mapped areas of groundwater productivity in NSW (DPI Water 2012b), the project is considered to be within a 'less productive' fractured rock water source for areas intercepting the Peel Fracture Rock Groundwater Source, and 'highly productive' alluvial water source for project areas intercepting the Dungowan Creek Management Zone within the Peel Alluvium Groundwater Source. The applicable minimal impact considerations are shown in Table 7.3 and Table 7.4, respectively.

The minimal impact considerations have been developed for impacts on groundwater sources, connected water sources, and their dependent ecosystems, culturally significant sites and water users. For each category, the AIP identifies thresholds for minimal impact considerations. These thresholds relate to impacts on the watertable, water pressure and water quality, and are ranked as being either 'level 1 minimal impact' or 'level 2 exceeding minimal impact'.

If the impact of an activity is assessed as being Level 1: minimal impact, then the project is considered to have impacts that are acceptable. Where the predicted impacts exceed the Level 1 thresholds by no more than the accuracy of the model, then this is considered as having impacts within the range of acceptability and extra monitoring or mitigation or remediation would be required during operations. Minimal impact considerations for fractured rock groundwater sources are presented in Figure 7.4.

Where the predicted impact of an activity is assessed as being 'Level 2' or 'greater than minimal impact', additional studies are required to fully understand the predicted impacts. If the assessment shows that the predicted impacts, although greater than 'minimal', do not prevent the long-term viability of the relevant water-dependent asset, then the impacts would be considered to be acceptable. Where impacts are predicted to be 'greater than minimal impact' and the long-term viability of the water-dependent asset is compromised, the impact is subject to make good provisions.

AIP Fact Sheet 4 (DPI Water 2013) outlines how a minimal impact is to be considered. It describes how the minimal impact criteria are applied to both a water supply work and a GDE defined in a WSP. This fact sheet also defines the term 'make good provisions' as the requirement to ensure that third parties with water supply works have access to an equivalent supply of water through enhanced infrastructure or other means, for example deepening an existing bore, compensation for extra pumping costs or constructing a new pipeline or bore.

Table 7.3 Minimal impact criteria for 'less productive' porous and fractured rock water sources

Watertable	Water pressure	Water quality
1. Less than or equal to 10% cumulative variation in the watertable, allowing for typical climatic 'post-water sharing plan' variations, 40 m from any: a) high priority groundwater dependent ecosystem; or b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan. c) A maximum of a 2 m decline cumulatively at any water supply work. 2. If more than 10% cumulative variation in the watertable, allowing for typical climatic 'post-water sharing plan' variations, 40 m from any: a) high priority groundwater dependent ecosystem; or b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan if appropriate studies demonstrate to the Minister's satisfaction that the variation would not prevent the long-term viability of the dependent ecosystem or significant site. If more than a 2 m decline cumulatively at any water supply work then make good provisions should apply.	1. A cumulative pressure head decline of not more than a 2 m decline, at any water supply work. 2. If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline would not prevent the long-term viability of the affected water supply works unless make good provisions apply.	1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity. 2. If condition 1 is not met then appropriate studies would need to demonstrate to the Minister's satisfaction that the change in groundwater quality would not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.

Note: Sourced from NSW Aquifer Interference Policy (DPI Water 2012b)

Table 7.4 Minimal impact criteria for 'highly productive' alluvial water sources

<table>
<tr><th>Watertable</th><th>Water pressure</th><th>Water quality</th></tr>
<tr><td>1. Less than or equal to 10% cumulative variation in the watertable, allowing for typical climatic 'post-water sharing plan' variations, 40 m from any:
a) high priority groundwater dependent ecosystem; or
b) high priority culturally significant site;
listed in the schedule of the relevant water sharing plan.
A maximum of a 2 m decline cumulatively at any water supply work unless make good provisions should apply.
2. If more than 10% cumulative variation in the watertable, allowing for typical climatic 'post-water sharing plan' variations, 40 m from any:
a) high priority groundwater dependent ecosystem; or
b) high priority culturally significant site;
listed in the schedule of the relevant water sharing plan then appropriate studies would need to demonstrate to the Minister's satisfaction that the variation would not prevent the long-term viability of the dependent ecosystem or significant site.
If more than a 2 m decline cumulatively at any water supply work then make good provisions should apply.</td><td>1. A cumulative pressure head decline of not more than 40% post water sharing plan pressure head above the base of the water source to a maximum of a 2 m decline, at any water supply work.
2. If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline would not prevent the long-term viability of the affected water supply works unless make good provisions apply.</td><td>1(a) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.
1(b) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. Redesign of a highly connected surface water source that is defined as a reliable water supply is not an appropriate mitigation measure to meet considerations 1(a) and 1(b) above.
2. If condition 1(a) is not met then appropriate studies would need to demonstrate to the Minister's satisfaction that the change in groundwater quality would not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.
If condition 1(b) is not met then appropriate studies are required to demonstrate to the Minister's satisfaction that the River Condition Index category of the highly connected surface water source would not be reduced at the nearest point to the activity.</td></tr>
</table>

Note: Sourced from NSW Aquifer Interference Policy (DPI Water 2012b), with reference to mining related works removed

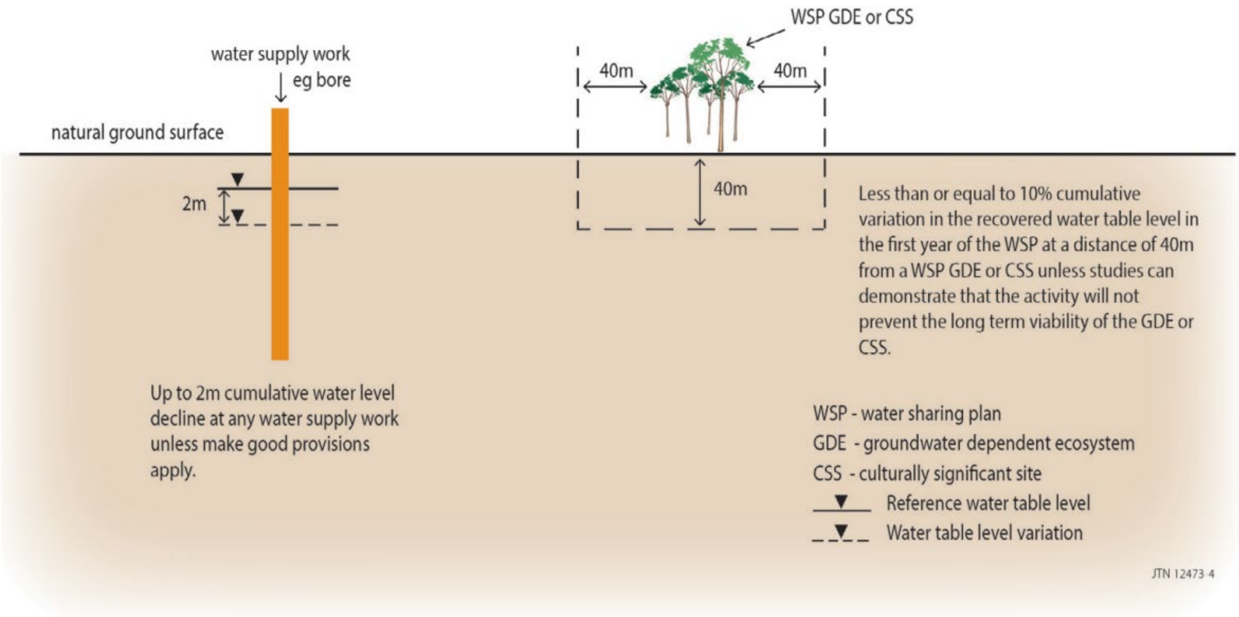

Figure 7.4 Fractured rock groundwater source minimal impact considerations

The AIP requires that two years of baseline groundwater data be collected and incorporated into an impact assessment before lodging a development application for an activity. The project has an extensive groundwater monitoring network, that includes eight groundwater monitoring bores at seven locations. The baseline monitoring program commenced in October 2020 and is ongoing. The project would therefore have over two years of baseline monitoring prior to any project approval.

7.5 NSW Protection of the Environment Operations Act

The POEO Act is the key piece of environment protection legislation administered by the NSW Environment Protection Authority (EPA). The POEO Act enables the government to set protection of the environment policies that provide environmental standards, goals, protocols, and guidelines. The POEO Act also establishes a licensing regime for pollution generating activities in NSW. Under Section 48, an environment protection licence (EPL) is required for 'scheduled activities'. Accordingly, an EPL for the project would be applied for. This is discussed further in Waste Management Assessment (EMM2022f).

7.6 Commonwealth Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities, and heritage places, which are defined as matters of national environmental significance (MNES).

In early 2020, a referral was submitted to the Commonwealth Department of the Climate Change, Energy, the Environment and Water (DCCEEW) (formerly the Department of Agriculture, Water and the Environment) for a proposed action under the EPBC Act for the Project (EPBC Ref: 2020/8655). This referral considered impacts to matters of MNES and the environment generally and detailed that the project would potentially have a significant impact on MNES, including national heritage places, listed threatened species and ecological communities and listed migratory species. The referral also identified that the project would potentially have a significant impact on the environment, as defined under the EPBC Act.

Due to the potential impacts of the project on MNES and the environment, an accredited assessment process was sought under section 87(4) of the EPBC Act, where the Commonwealth accredits the assessment process under Division 5.2 of the EP&A Act. On 30 June 2020, the Commonwealth Minister for the Environment and Water provided notification of their referral decision and designated proponent, determining that the Project's action was a controlled action and is to be assessed by accredited assessment process under Part 5, Division 5.2 of the EP&A Act.

As part of the accredited assessment process, the Commonwealth Minister for the Environment and Water's assessment requirements have been included in the SEARs.

7.7 Relevant NSW plans, policies, strategies and guidelines

Several other guidelines and policies relevant to the water assessment are discussed in the following sections.

7.7.1 State Groundwater Policy Framework Document

The NSW State Groundwater Policy Framework Document (DLWC 1997) aims to manage the groundwater resources of the state so they can sustain environmental, social, and economic outcomes for the people of NSW. The policy would be considered in resource management decisions made in NSW.

The document is a framework for the following three policies:

- NSW State Groundwater Quantity Management Policy (2001 (unpublished))
- NSW State Groundwater Quality Protection Policy (DLWC 1998)
- NSW State Groundwater Dependent Ecosystem Policy (DLWC 2002)

This policy establishes the overarching principles for the management of groundwater in NSW, which still remains valid more than twenty years after its inception. The principles of sustainability across the three environmental, social, and economic aspects are still referenced in modern water policies released by the NSW Government.

The design of the project would closely follow the NSW State Groundwater Policy Framework Document objectives of achieving beneficial environmental, social, and economic outcomes for the state of NSW.

7.7.2 Risk assessment guidelines for groundwater dependent ecosystems

The risk assessment guidelines for GDEs (Serov et al 2012) (GDE Risk Assessment Guidelines) are the NSW requirements for assessment and management of GDEs under the WMA. The GDE Risk Assessment Guidelines provide that GDEs:

> explicitly include any ecosystem that uses groundwater at any time or for any duration in order to maintain its composition and condition.

An ecosystem's dependence on groundwater can be variable, ranging from partial and infrequent dependence, ie seasonal or episodic (facultative), to total continual dependence (entire/obligate) (see Figure 7.5). A GDE assessment was made for the project, which considered variations in available water and ecosystem types with assessment methods based on the GDE Risk Assessment guidelines. The relevant sections of this GIA and the Biodiversity Development Assessment Report (EMM 2020b) provide further information on the GDE assessment approach and results.

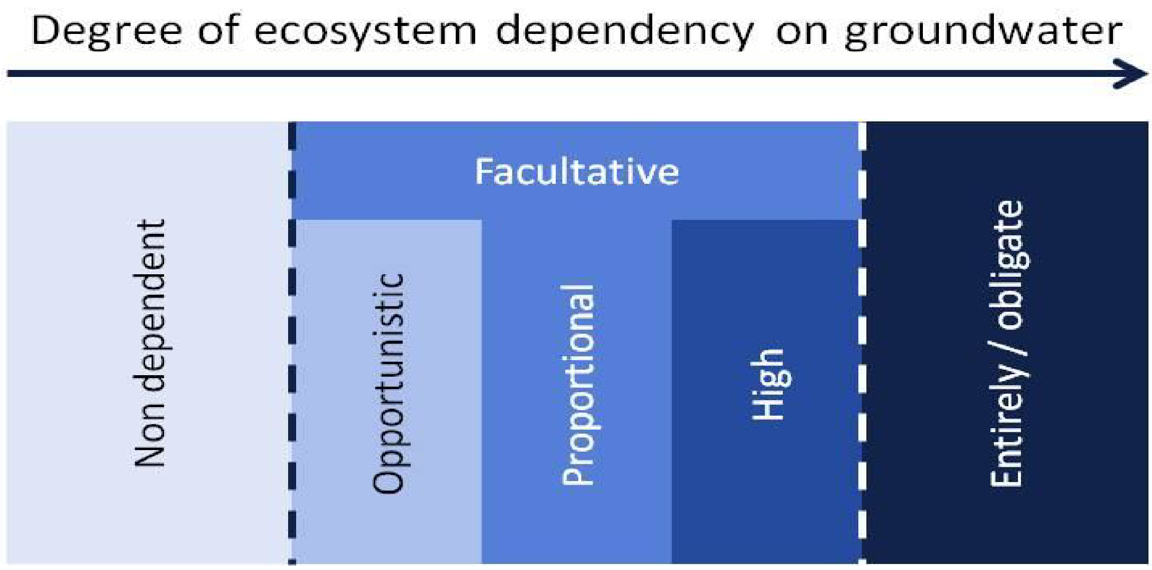

Figure 7.5 Ecosystem level of dependence on groundwater

7.7.3 Draft NSW Groundwater Strategy

The draft NSW Groundwater Strategy (the Strategy) (DPE 2022) is a long term state wide high-level strategy for the future protection and sustainable use groundwater resources. The Strategy emphasises the importance of groundwater for communities, industries, economies and environment, and the need to better understand and protect groundwater, in order to better adapt to a changing climate and future droughts.

The draft Strategy does not currently influence the approach to assessing potential groundwater impacts due to new projects, including this project.

7.8 Relevant Commonwealth policy and guidelines

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

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Agriculture and Resource Management Council of Australia and New Zealand and the Australian and New Zealand Environment and Conservation Council (ANZECC & ARMCANZ) 2000 describe the water quality objectives for marine and freshwater environments, aquatic ecosystems, primary industries, and recreational water. The guidelines should be considered when setting water quality objectives for natural and semi-natural water resources in Australia and New Zealand sustaining current or likely future environmental values (uses). They also set out a framework for the application of water quality trigger levels. The guidelines are a generic reference and should be used accordingly, ie only as a default reference. It is recommended to collect and use site-specific baseline data to establish baseline conditions and develop trigger levels. Project impacts should be assessed using site-specific baseline data and not the generic guidelines, where sufficient (typically > 24 months) baseline data allows.

Further revisions to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality were made in 2018 with the release of a web-based guideline (ANZG 2018). The revised default guideline values for chemical contaminants/toxicants that are relevant to the project area are consistent with ANZECC/ARMCANZ (2000). Physical and chemical stressors have not yet been released for the ecoregion that contains the project area. Hence, the ANZECC/ARMCANZ (2000) guidelines have been applied to establish water quality objectives and environmental values for the project.

7.8.2 National Water Quality Management Strategy Guidelines for Groundwater Quality Protection in Australia

The National Water Quality Management Strategy Guidelines for Groundwater Quality Protection in Australia (DAWR 2013) provides a risk-based management framework to protect and enhance groundwater quality for the maintenance of specified environmental values. The framework involves the identification of specific beneficial uses and values for the major groundwater systems, and several protection strategies that can emerge to protect each aquifer, including monitoring for all aquifers.

8 Assessment methodology

8.1 Overview

8.2 AIP assessment criteria

The elements of the project that could potentially impact groundwater resources (and associated receptors) have been assessed against the minimal impact thresholds defined in the AIP. Impacts to groundwater are assessed via the consideration of high priority GDEs, high priority culturally significant sites, and third-party bores and other environmental receptors, which are characterised as having a level of dependence on groundwater.

The minimal impact criteria are defined to establish principles for assessing impact to water table levels, water pressure levels and water quality across a range of different groundwater system types. The applicable minimal impact considerations for both the PFR and the PRA are presented in Table 7.3 and Table 7.4. The groundwater in the vicinity of the project is classified as 'less productive' for the PFR based on low yields and ‘highly productive’ for the PRA based on higher yields (typically greater than 5 L/s). The categories of less productive groundwater include porous rock and fractured rock. The category for highly productive groundwater includes alluvium.

8.3 Risk assessment approach

A National Water Commission (NWC) risk framework (Moran 2010) has been adopted for the groundwater risk assessment. The framework uses a source-pathway-analysis that describes how water-affecting activities might impact on sensitive groundwater receptors. For an effect to occur to a sensitive water receptor, a pathway must exist between a water-affecting activity and a receptor. Risks are characterised by making an informed decision as to the potential for adverse effects to impact sensitive groundwater receptors because of project-related activities, while also considering the AIP.

The impact assessment quantifies the risk from water-affecting activities and involves assessing the potential consequences arising from the water-affecting activities in terms of direct effects (ie altered water resource condition, Section 8.3.1) and of possible indirect effect at identified receptors (Section 8.3.2). The risk assessment also provides a basis for communicating risks and consequences and identifying the management approach that may be necessary to eliminate or reduce risk. Results of both existing and new monitoring data would be used to review the effectiveness of management measures over the construction and operation of the project.

8.3.1 Direct effects on groundwater

Direct effects encompass the changes to physical and/or quality aspects of groundwater due to water affecting activities, or the changes to the physical characteristics of aquifers affected by these activities. Potential direct effects arising through the construction and operation of the project are summarised in Table 8.1.

Table 8.1 Potential direct effects of water affecting activities

Water affecting activity	Potential risk/effect	Project Phase
Groundwater quantity		
Excavation for coffer dams, tunnel diversion, main dam, spillway, quarry and borrow areas	Localised depressurisation of the PFR at excavations, causing drawdown of the watertable and changes to groundwater flow paths	Construction
Dungowan pipeline trenching	Minor trenching excavation works required to lay pipe downstream of the dam wall has the potential to cause temporary localised depressurisation of the DCA, causing drawdown of the watertable.	Construction
Peel River Horizontal Directional Drilling (HDD) for Dungowan pipeline	Drilling works have the potential to cause temporary localised groundwater mounding in the PRA, causing potential migration of drilling fluids and changes in water quality for third-party groundwater users.	Construction
New Dungowan Dam	The establishment of an impermeable concrete and earth structure within the valley have the potential to cause a groundwater pressure increase and watertable mounding in the PFR, altering local groundwater flow path. Once operational, the dam has the potential to increase recharge to the PFR.	Operation
Groundwater quality		
Excavated material stockpiling	Seepage of PAF from stockpiled fractured rock material upstream of the new Dungowan Dam. Potential to oxidise forming AMD which may generate acid and metal enriched leachate to the DCA and underlying PFR.	Construction
Chemical and fuel spills during construction of dam and pipeline Hazardous goods storage	Short-term release of contaminants with the potential to interact with the PFR, DCA and Dungowan Creek.	Construction
Blasting	Introduction of blasting substances that intersect fracture networks resulting in the release of substances beyond the influence of the blasting area. Residual substances occurring on the face of blasted material leaching from stockpiled material when meeting rain.	Construction
Surface water-groundwater interaction		
Operation of Dungowan Dam and Chaffey Dam	Altered baseflow to downstream watercourses due to a change in flow conditions. Reduced run of river transfers available to recharge the PRA, potentially resulting in a declining water table in the PRA.	Operation
Aquifer disruption		
New Dungowan Dam	Impoundment of groundwater flow disrupting hydraulic gradients and flow paths.	Operation
Cumulative Impacts (Surface water-groundwater interaction)		
Chaffey Dam pipeline project – ie Chaffey Dam to Calala Water Treatment Plant water transfer	A separate approval is being sought by WaterNSW to operate the Chaffey Dam pipeline. The project would result in releases, including run-of-river water transfers, from Chaffey Dam to Calala WTP reducing when Chaffey Dam falls below 20% capacity. Below 20% capacity, the Chaffey Dam pipeline would be used in conjunction with the new Dungowan Dam to reduce transmission loses to the PRA and evaporation. It is possible that the PRA groundwater regime may change due to the reduction in run-of-river water transfers and environmental flows.	Operation

8.3.2 Indirect effects on groundwater

Indirect effects typically occur as a response to direct effects, commonly impacting a sensitive receptor (ie GDE, third party bore). The assessment of potential receptor exposure to adverse changes in the groundwater regime (quantity, quality, groundwater and surface water interactions, and physical disruption of aquifers) requires:

- knowledge of the location of sensitive receptors within the landscape, particularly in relation to the location and area of influence of water affecting activities;
- an understanding of the receptor's reliance on groundwater (eg depth to watertable, groundwater flux to baseflow-fed streams, groundwater quality to meet beneficial purposes); and
- an understanding of the spatial and temporal scale of direct groundwater effects at the location of sensitive receptors.

Potential indirect effects arising through the construction and operation of the project are summarised in Table 8.2.

Table 8.2 Indirect effects of water affecting activities and potential effects

Impacted environmental value	Potential risk/effect (source-pathway-receptor)	Project phase
Groundwater quantity		
Aquatic ecosystems	Aquatic ecosystems are largely associated with both the Dungowan Creek and Peel River. Possible effects are: 1. Temporary reduced baseflow due to construction dewatering during pipeline trenching works. 2. Reduced run of river transfers from Chaffey Dam, potentially reducing flow in Peel River, particularly during dry periods.	1. Construction 2. Operation
Terrestrial ecosystems with potential groundwater dependency	Terrestrial ecosystems are largely associated with both the Dungowan Creek and Peel River. Possible effects are: 1. Temporary reduction in groundwater levels due to construction dewatering during pipeline trenching works. 2. Reduced run of river transfers from Chaffey Dam. Potential to reduce groundwater recharge to the PRA, potentially resulting in a declining water table limiting groundwater availability to GDEs.	1. Construction 2. Operation
Third party bores	Third party bores may be affected by: 1. Temporary reduction in groundwater levels due to dewatering during pipeline trenching works. 2. Decrease in groundwater levels due to the reduction of run-of-river transfers from Chaffey Dam. Potential to reduce groundwater recharge to the PRA, potentially resulting in a declining water table limiting groundwater availability to third party bores.	1. Construction 2. Operation
Groundwater quality		
Aquatic ecosystems Terrestrial ecosystems with potential groundwater dependency Third party bores	There is the potential for the project construction works to cause contamination through spills of hazardous materials/chemicals and/or the generation of solid or liquid waste and AMD. Examples of this include spills of hydrocarbons while refuelling or lubricants used by machinery, and generation of solid construction waste or liquid and AMD waste during excavation and stockpiling of materials.	Construction

Table 8.2 Indirect effects of water affecting activities and potential effects

Impacted environmental value	Potential risk/effect (source-pathway-receptor)	Project phase
Surface and groundwater interaction		
Aquatic ecosystems	Aquatic ecosystems are largely associated with both the Dungowan Creek and Peel River. Possible effects could include reduced run of river transfers from Chaffey Dam, potentially reducing flow in Peel River, particularly during dry periods.	Operation
Aquifer disruption		
Aquatic ecosystems	Any aquifer disruption would be temporary and limited to construction works. Aquifer disruption such as changes in groundwater levels may be caused by temporary dewatering during pipeline trenching and excavation works. Any disruption may temporarily reduce baseflows or groundwater access to GDEs.	Construction
Terrestrial ecosystems with potential groundwater dependency		
Cumulative impacts (Surface water-groundwater interaction)		
Aquatic ecosystems	A separate approval is being sought by WaterNSW to operate the Chaffey Dam pipeline. The project would result in releases, including run-of-river water transfers, from Chaffey Dam to Calala WTP reducing when Chaffey Dam falls below 20% capacity. Below 20% capacity, the Chaffey Dam pipeline would be used in conjunction with the new Dungowan Dam to reduce transmission loses to the PRA and evaporation. It is possible that the PRA groundwater regime may change due to the reduction in run-of-river water transfers and environmental flows which may impact GDEs and third party bores.	Operation
Terrestrial ecosystems with potential groundwater dependency		
Third party bores		

9 Groundwater assessment

9.1 Overview

This chapter discusses the various water affecting activities of the project and presents a residual risk summary for both direct and indirect impacts in Section 9.5. Water affecting activities are discussed with context to the relevant project phase, ie Construction and Operation. It is anticipated that the other components of the project including the construction and upgrades to the powerline, existing dam decommissioning works and the construction of ancillary facilities would have negligible effects on groundwater and have not been assessed further.

Relevant monitoring, management and mitigation measures are outlined in Chapter 10.

9.2 Construction impacts

9.2.1 Diversion tunnel

i Groundwater seepage

A circular horseshoe tunnel, to divert Dungowan Creek during construction, would be completed using a road header or drill and blast techniques. The tunnel is anticipated to be approximately 8.5 m in diameter and 250 m in length. Tunnelling occurs at an average depth of 20 mbgl for most of the length, except for a short section at the upstream end and the last 100 m of the downstream end (SMEC 2020).

Groundwater seepage is possible during construction as the tunnel may intersect the watertable. The construction of the diversion tunnel has the potential to cause drawdown, which could impact any potential GDEs that may be overlying, or within the vicinity, of the works. However, if groundwater is intercepted during construction, seepage is expected to be minimal as any seepage would be immediately treated with shotcrete and thereafter with a permanent concrete segmental lining, limiting flow to negligible volumes, and critically less than 3 ML/year. Any residual flow, entering the tunnel through untreated sections are expected to dissipate over time due to limited storage in the fractured rock. Any excessive seepage from rock defects could also be grouted, which would reduce seepage rates.

Sumps would be established along the length of the tunnel to collect seepage. Pumps operating in the tunnel would be equipped with flow meters, ensuring the total cumulative volume of water does not exceed 3 ML annually.

Given adequate mitigation, management and engineering controls are implemented during construction, seepage to the diversion tunnel, and potential impacts to GDEs, during construction is likely to be minimal. No third-party groundwater users are within the vicinity of the works. The operation of the diversion tunnel is unlikely to impede groundwater flow or impact the PFR groundwater system.

ii Drilling and blasting

Drill and blast have been proposed as a potential method of excavating the diversion tunnel. Blasting has the potential to leach soluble substances into groundwater (NHDES 2010) through:

- incomplete combustion within the blast borehole;
- introduction of blasting substances that intersect fracture networks resulting in the release of substances beyond the influence of the blasting area;
- poor storage, transfer and handling of substances associated with blasting; and

- residual substances occurring the face of blasted material leaching from stockpiled material when meeting rain.

The implementation of appropriate environmental controls during construction and operation of the project to capture any blasting residue that may leach into the groundwater system or nearby watercourses is required and identified in Table 9.2 and Chapter 10.

9.2.2 Quarrying and borrow areas

The construction of a proposed quarry and borrow areas are required to meet construction material demands for the dam embankment and to serve as rock wave protection. The location of the quarry and borrow areas are shown on Figure 2.1.

i Quarry

Rock for construction purposes may be sourced from a quarry upstream of the new Dungowan Dam. Drill and blast have been proposed as the method to excavate quarry material.

The excavated rock would be used as rip rap material. Once excavated, the quarry is estimated to yield up to 250,000 m^3. No detail on excavation depth has been provided but it is assumed that the material would be stripped from surface to a maximum depth of 3.5 m to achieve the estimated yield.

While any groundwater seepage at shallow depth would be minimal, quarrying could cause drawdown, which could impact any potential GDEs within the vicinity of the works. Whilst a dedicated network of monitoring bores has not been established nearby to the quarry, the wider network indicates a depth of groundwater of between 7 and 30 mbgl, below the base of the quarry (3.5 m in depth). It is therefore unlikely that groundwater would be intercepted through the construction of the quarry and therefore have any impact on potential GDEs.

Potential groundwater quality impacts, due to drill and blast techniques, detailed in Section 9.2.1ii are also applicable to this activity.

ii Borrow areas

Earthfill material, to construct the low permeability core of the embankment, would be sourced from upstream and downstream alluvial deposits (borrow material). Groundwater is unlikely to be intercepted when excavating borrow material. The targeted material (silty sandy clays) is situated at depths of between 0.15 to 3 m depth (SMEC 2021) and is generally above groundwater, based on observations made during test excavation field works.

9.2.3 Dungowan pipeline

The pipeline infrastructure would extend 32 km from the new Dungowan Dam to a connection point with the existing pipeline between Dungowan Showground and Calala WTP. Trenching (main alignment and across Dungowan Creek) and directional drilling (under the Peel River) works would be completed during the construction phase of the project to facilitate this activity. The location of the pipeline infrastructure relative to nearby groundwater monitoring bores is shown on Figure 9.1.

i Trenching

The pipeline infrastructure would be progressively installed in open trenches through the DCA, a unit comprising alluvial and colluvial sediments, and the shallow residual soils of the PFR. The trench would be constructed to 1.35 m wide by 2.2 m in depth over a length of 32 km, potentially reducing in depth at eight locations to cross Dungowan Creek and 13 other ephemeral tributary crossings (Figure 9.2).

Based on a review of the available standing groundwater levels (WaterNSW 2022a) derived from stock and domestic and monitoring bores in the vicinity of the pipeline infrastructure, the majority of the trenching works would be undertaken in areas where the standing groundwater levels exceed 2.2 mbgl, the quoted maximum depth of the trench (MPCK 2021) (Figure 9.1). Where the pipeline crosses low-lying alluvium, creeks or tributaries, there is the potential for the interception of shallow groundwater should trenches be open during and immediately after periods of high rainfall. However, based on the available groundwater level data, groundwater seepage is likely to be negligible to small (even during higher rainfall periods) and temporary given the temporary nature of higher groundwater levels observed in the DCA following rainfall. If groundwater is intercepted during trenching, dewatering would cause localised drawdown within the vicinity of the works and has the potential to impact potential GDEs and nearby third-party bores.

Given adequate mitigation, management and engineering controls are implemented during construction, the need for dewatering, and potential impacts to GDEs and third-party bores during trenching is likely to be minimal. Careful laying of the pipeline and associated backfilling of the trench with appropriate bedding and excavated material is unlikely to impede groundwater flow or impact the shallow alluvial groundwater system. Appropriate sediment controls would be implemented to prevent sediments entering Dungowan Creek.

It is noted that trenching works within Dungowan Creek are exempt from requiring a Controlled Activity approval as the project is being assessed as CSSI (DPIE 2021).

ii Directional drilling

The Peel River would be crossed at one location using Horizontal Directional Drilling (HDD) (Figure 9.2). Temporary groundwater level mounding may occur where drilling is close to the shallow groundwater table due to the injection of biodegradable drilling fluids. If flow conduits are intercepted when drilling is close to the watertable, mounding could cause drilling fluids to surface into the Peel River and/or migrate to third party bores, altering groundwater quality and possibly levels. No groundwater quality impacts are expected given drilling fluids are biodegradable.

Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013)

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Dungowan pipeline and nearby bore groundwater levels

Dungowan Dam and pipeline project
Groundwater impact assessment
Figure 9.1

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Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013)

Waterway crossing locations

Dungowan Dam and pipeline project
Groundwater impact assessment
Figure 9.2

EMM
creating opportunities

9.2.4 Dungowan Dam

Localised groundwater drawdown near the excavations is expected and could impact nearby GDEs and possibly baseflow to Dungowan Creek. There are no third-party bores within the vicinity of the works.

Groundwater level measurements obtained from groundwater monitoring bores, geotechnical boreholes and test pits were assessed against the concept design to determine the project's potential for groundwater interception. The assessment identified two aspects of the concept design that are likely to intercept groundwater:

1. The construction of upstream and downstream coffer dams and the main dam (dam excavation area). These activities are expected to intercept groundwater from the DCA and PFR as the abutments would be excavated to 5 m below the natural surface.

2. The construction of the spillway (spillway excavation area). This activity is expected to intercept groundwater in the PFR with planned excavation to extend to a maximum depth of 21 m below the natural surface.

To assess seepage to the dam excavations, the Mansur & Kaufman (1962) steady state analytical solution was used to provide preliminary estimates of groundwater seepage from the DCA and PFR Groundwater Sources. The solution assumes:

- the aquifer is a continuous porous medium;
- the aquifer is homogenous, isotropic and infinite in extent; and
- flow is steady and laminar.

Given groundwater seepage would be from two different groundwater sources the assessment has estimated seepage from the DCA and PFR. Results from the assessment are summarised in Table 9.1.

Table 9.1 Groundwater seepage estimate

Component	Groundwater source	Seepage (kL/day[1])	Seepage (ML/yr[2])
Dam excavation area	Dungowan Creek Alluvium	68.4	24.9
	Peel Fractured Rock	2.7	1.0
Spillway Excavation area	Peel Fractured Rock	7.8	2.9
Total		**78.9**	**28.8**

Notes: 1. kilolitres per day 2. megalitres per year

Seepage from the DCA and PFR are likely to be less than predicted because:

- When coffer dams are established and excavation for the main dam commences, groundwater seepage from the DCA would be low to negligible due to limited groundwater storage. Seepage from the PFR is still expected when excavated at the lower levels of Dungowan Creek.
- The analytical model assumes seepage to the whole excavation. Excavations would likely be progressively backfilled with earth fill material, which would limit exposed excavations and ongoing dewatering.

- When excavating the spillway, any structural rock defects causing excessive seepage would be grouted. The same would be completed for excessive seepage during excavation of foundations for the coffer dams and the main new Dungowan Dam. The spillway would be concrete lined when completed and coffer dams and main dam constructed with low permeability material.

- Groundwater levels on the left and right dam abutments are likely to be greater than 5 mbgl. Any seepage would be limited to through-flow following excessive rainfall.

- Seepage from the PFR to the dam excavation area are conservative. The area used to estimate seepage is likely to be larger than the actual area saturated by groundwater. This is likely to be the same for the seepage estimates for the DCA.

During construction, seepage from the DCA and PFR should be metered and compared to predicted seepage to assist in validation of seepage predictions. Groundwater take would be detailed in compliance reporting in accordance with licensing and agency requirements and management plans detailed in Section 10.1.

Given adequate mitigation, management and engineering controls are implemented during construction, the potential impact to GDEs, and possibly baseflow to Dungowan Creek, near the dam and spillway excavation areas is negligible to low. Drawdown is expected to be localised and temporary due to the sequential nature of the works, which would reduce the need for ongoing dewatering during construction.

i Inflow from Dungowan Creek Alluvium

The following assumptions were used to estimate seepage from the DCA to the dam excavation area:

- the aquifer is unconfined;

- the extent of saturated DCA is the same as the extent of the Peel Alluvium Water Source as shown in the *WSP for Namoi Alluvial Groundwater Sources 2020* (Figure 9.3);

- the alluvial footprint would be excavated to a depth of 5 mbgl, as indicated in the concept design;

- the standing water level is 4 mbgl across the alluvial footprint (ie 1 m of saturated thickness);

- the hydraulic conductivity is 44 m/day, estimated from a single slug test completed at MB01B; and

- seepage to the DCA comes from the upstream and downstream intersections of the alluvium, with minimal seepage from the northern and southern extents.

ii Inflow from the Peel Fractured Rock

The assessment identified two areas in which groundwater in the PFR is likely to be intercepted and therefore dewatered due to dam construction. These two areas are referred to as the dam excavation area and the spillway excavation area. The following assumptions were used to estimate inflow from the PFR to the dam excavation area:

- the aquifer is confined;

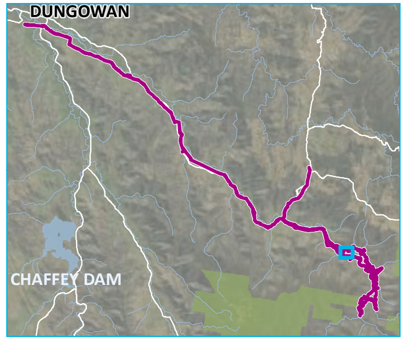
- the dam excavation area would intercept saturated PFR in the grey hatched area in Figure 9.4. In this area, the existing surface would be excavated to a depth of 5 mbgl, as indicated in the concept design;

- the standing water level is 4 mbgl across the extent of the grey hatched area in Figure 9.4 (ie 1 m of saturated thickness);

- the hydraulic conductivity of the PFR is 0.5 m/day, which represents a conservative estimate from slug tests and packer tests completed at several monitoring bores and geotechnical boreholes;
- seepage from the PFR into the excavation are from the northern and southern intersections of the fractured rock aquifer (see Figure 9.4); and
- seepage from the eastern and western extents would occur dominantly from the alluvial aquifer.

The following assumptions were used to estimate inflow from the PFR into the spillway excavation area:

- the spillway would intercept saturated PFR along its southern face (groundwater flow downgradient, toward Dungowan Creek), which is represented by the red line on Figure 9.4;
- it is assumed the length of the red line would be excavated to 21 mbgl. The water table at the spillway is assumed to be 10 mbgl (ie saturated thickness of 11 m); and
- the hydraulic conductivity of the PFR is 0.5 m/day.



KEY

- Project footprint
- Concept design
- Intercept of fractured rock with spillway
- Dungowan Creek alluvium modelled extent

Existing environment

- Minor road
- Named watercourse

Source: EMM (2022); WaterNSW (2021); Metromap (2019); DFSI (2017); GA (2013)

0 50 100 m

GDA 1994 MGA Zone 56

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Dungowan Creek alluvium modelled extent

Dungowan Dam and pipeline project
Groundwater impact assessment
Figure 9.3

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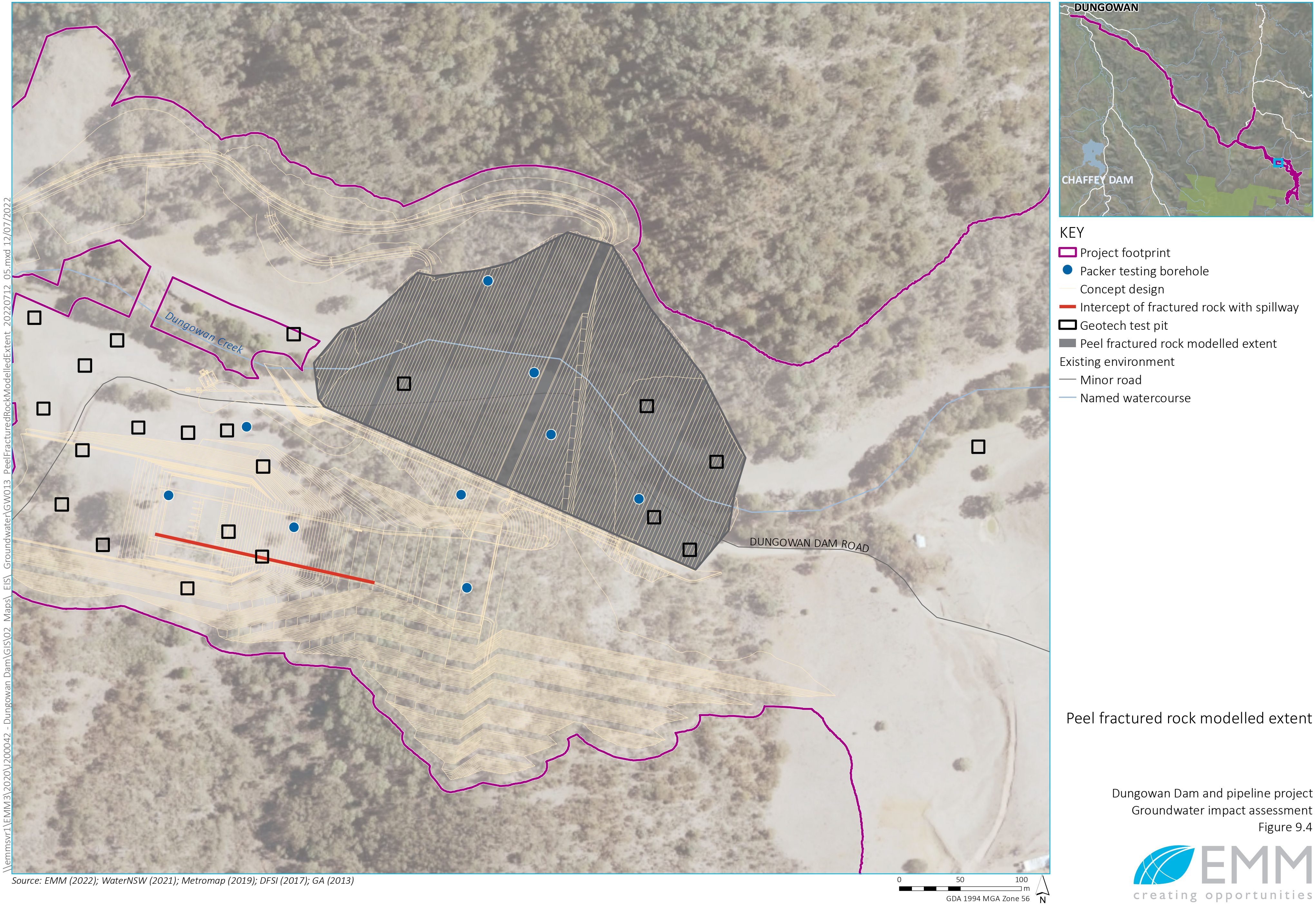

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Source: EMM (2022); WaterNSW (2021); Metromap (2019); DFSI (2017); GA (2013)

Peel fractured rock modelled extent

Dungowan Dam and pipeline project
Groundwater impact assessment
Figure 9.4

EMM
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9.2.5 Material stockpiling

Surface excavation works for the diversion tunnel, quarry, borrow areas, dam abutments and spillway may potentially intersect PAF material. However, the occurrence of PAF materials is likely to be highly variable due to the tendency of pyrite to occur in veins and seams (SMEC 2021).

The potential AMD impacts via the generation of acidic leachate from the improper temporary or permanent storage of excavated PAF rock poses a risk to local groundwater environment. SMEC (2021) concluded that further testing would be required in key construction areas to enhance the understanding of PAF rock characteristics where PAF material may be present. Testing should target materials from the proposed disturbance footprint (eg the upstream spillway excavation and quarry), and exclude samples from below the dam design excavation levels.

Further detail on AMD can be found in the Contamination Preliminary Site Investigation (EMM 2022c).

9.2.6 Material transport

The transportation of PAF material (from quarries), expected to be deposited as rip rap on the upstream section of the dam, has the potential to generate AMD unless adequately treated, stored and managed. The impacts associated with incorrect transportation, disposal, and stockpile management of PAF material are consistent with those mentioned in Section 9.2.5 and the Contamination Preliminary Site Investigation (EMM 2022c).

9.2.7 Storage and transportation of chemicals and fuels

Spills of hazardous materials/chemicals and/or the generation of solid or liquid waste has the potential to contaminate groundwater. Examples of this include spills of hydrocarbons while refuelling or lubricants used by machinery, and generation of solid construction waste or liquid waste during tunnelling. All scenarios have the potential to impact human and environmental health depending on the type of contaminant if not managed accordingly.

Further detail on handling chemicals and fuels on site can be found in the Contamination Preliminary Site Investigation (EMM 2022c).

9.3 Operational impacts

9.3.1 Hydraulic loading

The applied load from the dam on the DCA and PFR has the potential to cause the water pressure (groundwater level) to rise, altering the local groundwater flow regime near the inundation area and dam embankment.

During the initial fill of the reservoir, water would infiltrate into fracture networks and conduits that were not saturated. Hydraulic loading could also reactivate (unclog) existing conduits that were infilled with sediment and clay and dilate fractures and bedding planes to create new conduits. The water table may find new discharge areas around or downstream of the dam embankment, increasing baseflow to Dungowan Creek. Furthermore, discharge areas around the sides of the dam embankment could create swampy or moist environments that could result in landslides or effect the integrity of the dam embankment.

Should conduits form following inundation, or baseflow increase to Dungowan Creek, groundwater pressures are expected to be temporary and dissipate over time as the groundwater system and rock mass gradually equilibrates to loading pressures. Any seepage under or around the dam embankment would be impeded by the grout curtain, which would be installed along the embankment centreline to 30 m below the dam foundations. Any seepage through the new Dungowan Dam would be impeded by a central low permeability clay core extending the full height of the embankment.

9.3.2 Hydrological changes to streamflow and depth regimes

The DCA and PRA are highly connected to Dungowan Creek and the Peel River, respectively. Any changes to streamflow and depth have the potential to effect groundwater recharge and discharge, as well as groundwater access by GDEs and third-party bores.

Due to the new Dungowan Dam being prioritised for town water supply to Tamworth over Chaffey Dam, there would be corresponding reduction in the run-of-river transfers of water from Chaffey Dam to Calala WTP. Environmental flows from Chaffey Dam down the Peel River would remain the same. Environmental flows in Dungowan Creek would increase from 10 ML/day (existing Dungowan Dam) to 13 ML/day from the new Dungowan Dam (EMM 2022e).

The operation of the new Dungowan Dam would result in changes to the streamflow regime in Dungowan Creek downstream of the proposed new Dungowan Dam and within the Peel River downstream of Chaffey Dam. Whilst the current streamflow regime is already affected by the operations of the existing Dungowan Dam and Chaffey Dam, streamflow has the potential to be incrementally different to the current streamflow regime. The potential effects of the project on streamflow under different climate conditions have been modelled and are described in Annexure A of the Surface Water Assessment (EMM 2022e).

The modelled changes to streamflow were also analysed to consider changes to the depth regime. Predicted changes in daily depth effects are presented at locations immediately downstream of the new Dungowan Dam, at Dungowan and immediately downstream of Chaffey Dam in Figure 9.5, Figure 9.6 and Figure 9.7 respectively. A change in depth could reduce groundwater recharge and subsequently groundwater levels, limiting groundwater access or quantity to GDEs and third-party bores.

Looking at the changes in depth immediately downstream of Dungowan Dam, Figure 9.5 shows there is predicted to be a general one-centimetre increase in creek depth, due to the proposed increase in transparent flow threshold from 10 ML/d to 13 ML/day. Figure 9.5 also indicates that 5% of the time, the new Dungowan Dam would cause depth to be more than 5 cm less than current, but also 5% of the time would cause depth to be more than 5 cm greater than current.

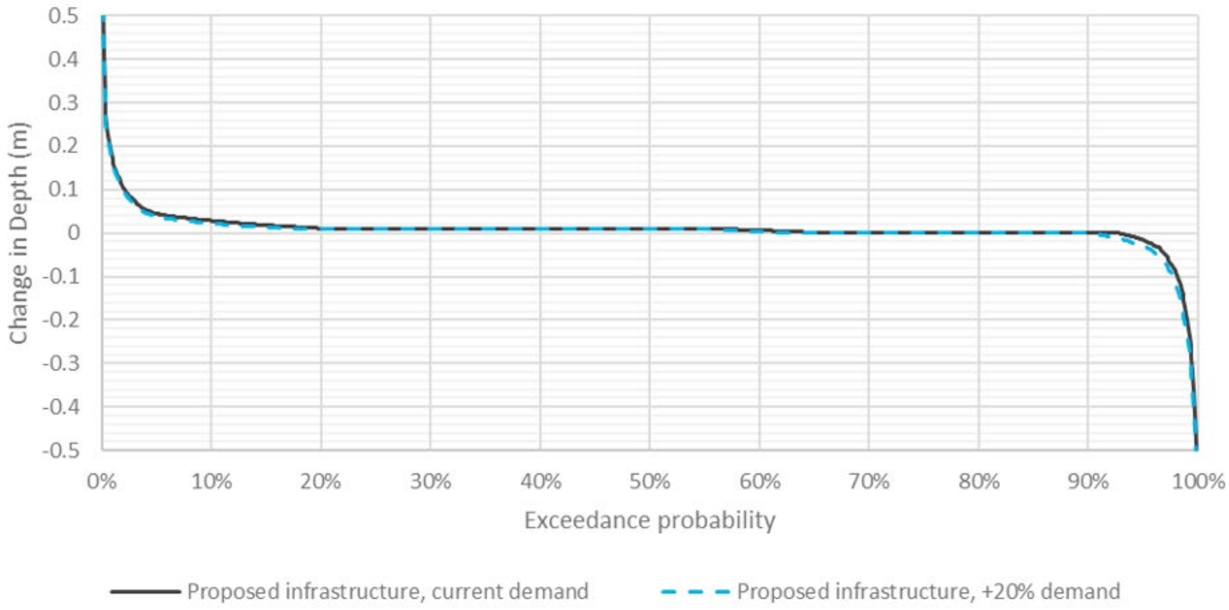

Figure 9.5 Daily depth effects immediately downstream of Dungowan Dam, current climate

At Dungowan (gauge 419103), Figure 9.6 shows no change to daily water depths through most of the plot and that for around 5% of the time the project may cause the depth to reduce by more than 5 cm. This is likely to be when the new Dungowan Dam is capturing inflows that would otherwise have gone down Dungowan Creek.

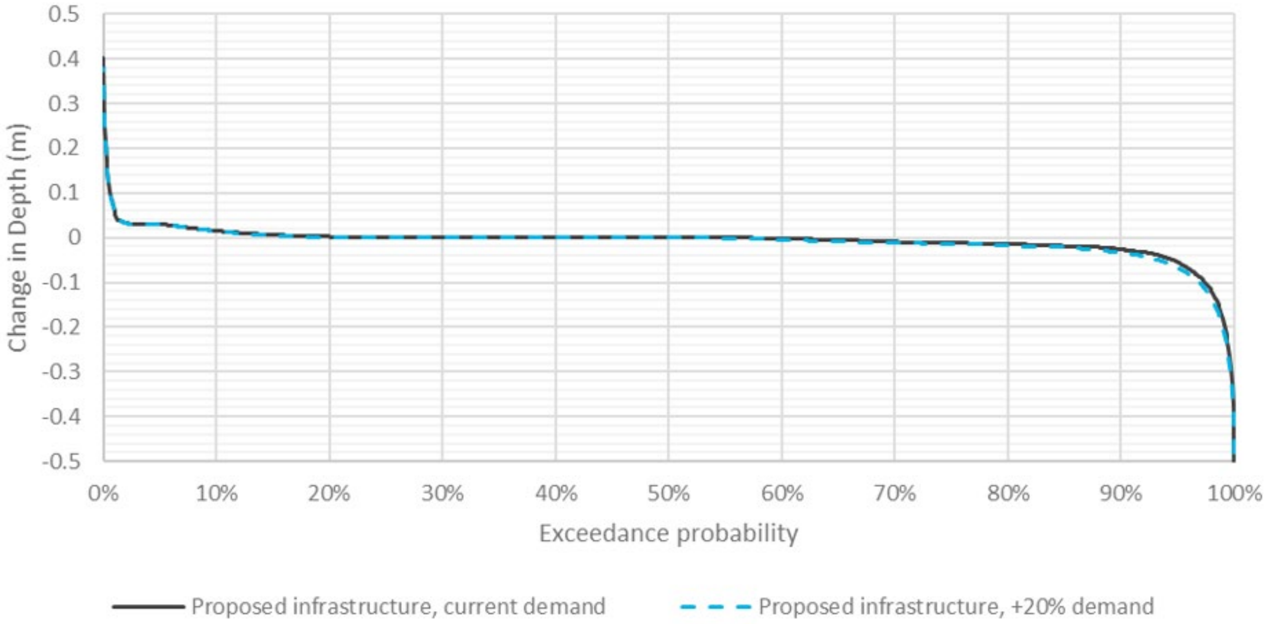

Figure 9.6 Daily depth effects at Dungowan (419103), current climate

At the Chaffey Dam outlet, Figure 9.7 shows that there is no predicted change in depth for about half of the time, a predicted reduction in depth of 0 to 4 cm for about 30% of the time, a predicted reduction in depth of 4 to 6 cm for about 10% of the time, and a predicted reduction in depth of over 6 cm for about 10% of the time. This is the effect of reduced releases for run of river water supply transfers from Chaffey Dam because water supply from the new Dungowan Dam would be prioritised over Chaffey Dam. For about 15 percent of the time the depth is predicted to be greater than existing, and about two percent of the time this would be greater than 4 cm. This is likely due to increased chance of the dam spilling because it would supply less water to Tamworth and so would be allowed to fill more often.

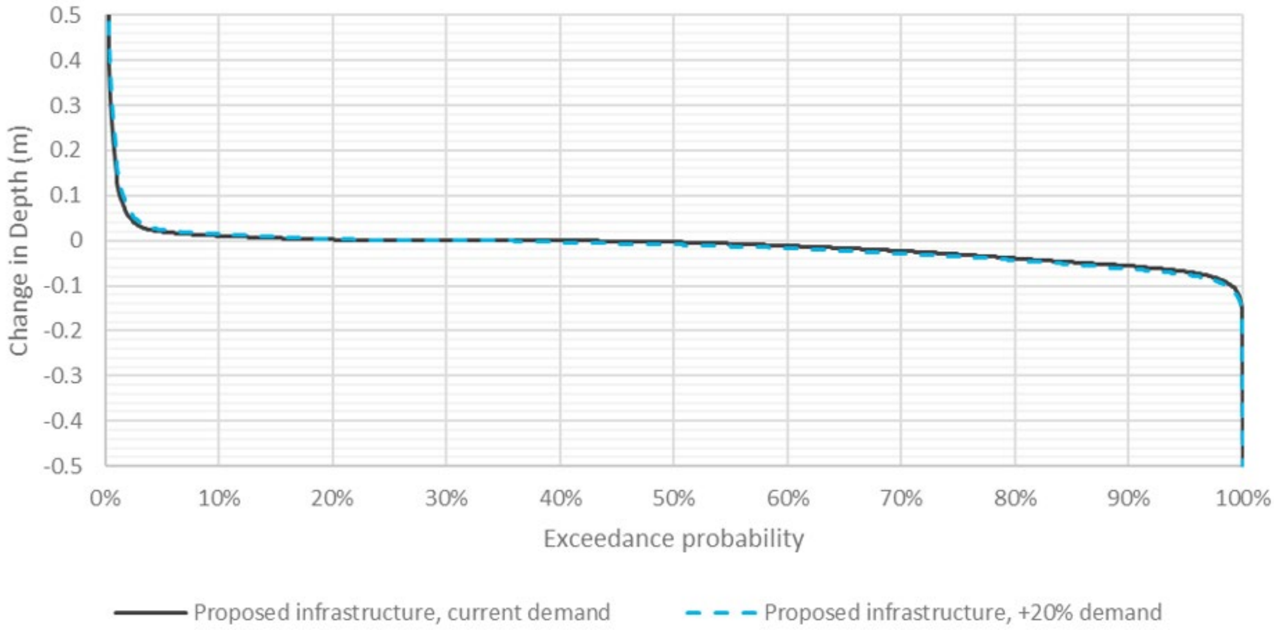

Figure 9.7 Daily depth effects at Chaffey Dam outlet (419045), current climate

Analysis of the overall depth regime at all locations considered indicates that the minor changes to stream flow due to the project would result in negligible changes to stream depth in Dungowan Creek and the Peel River. By inference, the project is not expected to affect recharge rates to the DCA (below the new Dungowan Dam) and PRA (below Chaffey Dam), or effect groundwater access to GDEs or other users (Annexure A, EMM 2022e).

Higher groundwater levels in the DCA could be expected due to increased environmental flows. The increase in flow in Dungowan Creek is not expected to impact riverbank stability (EMM 2022e). A change in groundwater height is not expected to have any negative impacts on GDEs, third party bores or groundwater quality.

9.3.3 Groundwater balance

Section 6.2 details the conceptual understanding of groundwater inputs (ie rainfall, river leakage and flooding) and outputs (ie springs. GDEs, baseflow, evapotranspiration and pumping) for the project. There is a large variance in these inputs and outputs which are highly dependent on climate.

The river component of the conceptualised groundwater system would change in response to water levels in Dungowan Creek and the Peel River but the Streamflow Analysis (Section 9.3.2) shows that water levels will have minimal change due to the project. Given the inputs and outputs have not changed due to the project, the groundwater balance also remains unchanged.

9.4 Cumulative impacts

The effect of operating the Chaffey Dam pipeline during drought (when water storages are below 20% capacity) was modelled as a separate set of scenarios to assess the cumulative effects of the Chaffey Dam pipeline project.

The cumulative effects of the Dungowan Dam project and the Chaffey Pipeline project were assessed using the DPE Peel Valley Source model. The Chaffey Dam pipeline project proposes that the Chaffey Pipeline authorisation becomes a long term approval, with the pipeline used to deliver water to Tamworth during drought conditions to reduce transmission losses in the Peel River between Chaffey Dam and Calala.

The Streamflow Analysis (Annexure A, EMM 2022e) shows no meaningful cumulative changes to river hydrology due to the operation of the Chaffey Dam pipeline and the new Dungowan Dam and pipeline. As the Chaffey pipeline would be operated only infrequently, when dam levels are low during drought, the largest cumulative effects of pipeline operation would likely be the frequency of low flow events during drought years, particularly evident immediately below Chaffey Dam. By inference, groundwater recharge to the PRA is also expected to show no meaningful changes under these conditions.

Impacts associated with the operation of the Chaffey Dam pipeline would be considered as part of the EIS for the Chaffey Dam pipeline project, currently under preparation by WaterNSW.

9.5 Residual risk summary

The following summary tables, detailed in Table 9.2 (direct impacts) and Table 9.3 (indirect impacts), considers management and mitigation measures for each of the direct and indirect water affecting activities characterised in Table 8.1 and Table 8.2. A qualitative residual risk to groundwater following the implementation of relevant management and mitigation measures is discussed in both tables with consideration of AIP criteria. Annexure B reproduces the DPE Water AIP assessment framework with commentary to assist the DPE Water with the assessment.

General management and mitigation measures for the construction and operation of the Dungowan Dam and pipeline project are provided in Chapter 10.

Table 9.2 Direct groundwater effects residual risk assessment

Water affecting activity	Potential risk/effect	Project phase	Assessment with mitigation actions/controls	Residual risk
Groundwater quantity				
Excavation for coffer dams, tunnel diversion, main dam, spillway, quarry and borrow areas	Localised depressurisation of the PFR at excavations, causing drawdown of the water table and changes to groundwater flow paths	Construction	• Seepage from the DCA to main dam excavation is expected to be negligible as groundwater flow from DCA from upstream and downstream would be impeded by coffer dams. • Excavation sequencing and progressive backfilling of dam excavations would limit exposed excavations and ongoing dewatering. • Excessive seepage from defects can be grouted to reduce permeability. • Quarry and borrow areas would not intercept groundwater.	The residual risk is considered minimal and less than the Level 1 impact defined by the AIP.
New Dungowan Dam	The establishment of an impermeable earth and concrete structure within the valley has the potential to cause a groundwater pressure increase and watertable mounding in the PFR, altering local groundwater flow path. Once operational, the dam has the potential to increase recharge to the PFR.	Operation	• Seepage under or around the dam embankment would be impeded by engineering controls. • Any groundwater pressures created by the dam are expected to dissipate over time as the groundwater system and rock mass equilibrates to loading pressures. • Environmental flows are expected to increase from 10 to 13 ML/day therefore negligible changes to the DCA downstream of the new Dungowan Dam is expected.	The residual risk is considered minimal and less than the Level 1 impact defined by the AIP.

Table 9.2 Direct groundwater effects residual risk assessment

Water affecting activity	Potential risk/effect	Project phase	Assessment with mitigation actions/controls	Residual risk
Dungowan pipeline trenching	Minor trenching excavation works required to lay pipe downstream of the dam wall has the potential to intercept groundwater and cause temporary localised depressurisation of the DCA, causing drawdown of the water table.	Construction	• Along the pipeline route, the watertable is typically deeper than 2.2 m which is greater than the depth of trenching. • Trenching through alluvial plains during dry periods, would limit the potential to intercept high water tables following extended rainfall events. • Trenching across ephemeral waterways during dry periods and low flow conditions and leaving trenches open for the minimal length of time would limit groundwater interception. • Implementing appropriate construction methodologies to facilitate construction in flooded trenches (if necessary) would reduce the requirement for dewatering.	The residual risk is considered minimal and less than the Level 1 impact defined by the AIP.
Peel River Horizontal Directional Drilling (HDD) for Dungowan pipeline	Drilling works have the potential to cause temporary localised groundwater mounding in the PRA/DCA, causing potential migration of drilling fluids and changes in water quality for third-party groundwater users.	Construction	• Viscosity of drilling fluids can be increased to prevent drilling fluids from surfacing or migrating from the work area to nearby bores. • Close observation of the Peel River during under boring would ensure no drilling fluids are leaking to the Peel River. • Observation of any nearby third party bores would ensure groundwater levels and quality are not impacted by the potential migration of drilling fluids or reduction in groundwater levels.	The residual risk is considered minimal and less than the Level 1 impact defined by the AIP.
Groundwater quality				
Excavated material stockpiling	Seepage of PAF from stockpiled fractured rock material upstream of the new Dungowan Dam. Potential to oxidise, forming AMD which may generate acid and metal enriched leachate to the DCA, PFR and water courses.	Construction	• Implementing appropriate environmental controls during construction and operation would capture any AMD. • Environmental management systems (ie Groundwater management plans) would adequately manage this risk.	Given adequate implementation of mitigation measures, risk to groundwater from AMD is low.

Table 9.2 Direct groundwater effects residual risk assessment

Water affecting activity	Potential risk/effect	Project phase	Assessment with mitigation actions/controls	Residual risk
Chemical and fuel spills during construction of dam and pipeline Hazardous goods storage	Short-term release of contaminants with the potential to migrate to the PFR, DCA and watercourses.	Construction	Risks is readily managed through implementation of environmental management systems (ie Groundwater management plans), including storage of fuels, oils and chemicals in accordance with relevant legislation and Australian standards.	Given adequate implementation of mitigation measures, risk to groundwater from contamination is low.
Blasting	Introduction of blasting substances that intersect fracture networks resulting in the release of substances beyond the influence of the blasting area. Residual substances occurring the face of blasted material leaching from stockpiled material when meeting rain.	Construction	Risks is readily managed through implementation of environmental management systems (ie Groundwater management plans), including storage chemicals and explosives in accordance with relevant legislation and Australian standards.	Given adequate implementation of mitigation measures, risk to groundwater blasting chemicals and residue is low.
Surface and groundwater interaction				
Operation of new Dungowan Dam and Chaffey Dam	Altered baseflow to downstream watercourses due to a change in flow conditions. Reduced run of river transfers available to recharge the PRA, potentially resulting in a declining water table in the PRA.	Operation	Analysis of the overall depth regime at all locations considered indicates that that the minor changes to stream flow due to the project would result in negligible changes to stream depth in Dungowan Creek and the Peel River. By inference, the project is not expected to affect recharge rates to the DCA and PRA (below Chaffey Dam).	Negligible change to stream flow and groundwater recharge/discharge.
Aquifer disruption				
New Dungowan Dam	Impoundment of groundwater flow disrupting hydraulic gradients and flow paths.	Operation	• Engineering controls (ie grout curtain and low permeability clay core) would be implemented during construction to prevent excessive seepage under or around the new Dungowan Dam. • Any groundwater pressures created by the dam are expected to dissipate over time as the groundwater system and rock mass equilibrates to loading pressures.	Risk is low given engineering controls are adequately implemented.

Table 9.2 Direct groundwater effects residual risk assessment

Water affecting activity	Potential risk/effect	Project phase	Assessment with mitigation actions/controls	Residual risk
Cumulative Impacts (Surface water-groundwater interaction)				
Chaffey Dam pipeline project – ie Chaffey Dam to Calala WTP water transfer	A separate approval is being sought by WaterNSW to operate the Chaffey Dam pipeline. The project would result in releases, including run-of-river water transfers, from Chaffey Dam to Calala WTP reducing when Chaffey Dam falls below 20% capacity. Below 20% capacity, the Chaffey Dam pipeline would be used in conjunction with the new Dungowan Dam to reduce transmission loses to the PRA and evaporation. It is possible that the PRA groundwater regime may change due to the reduction in run-of-river water transfers and environmental flows and recharge to the PRA may be affected.	Operation	When the pipeline is operational, run-of-river transfers of water from Chaffey Dam to Calala WTP would reduce. The volume of water taken to Calala via the pipeline would be smaller than the volume that would have been released to the river as transmission losses would be avoided. Due to increased water storage in Chaffey Dam, the pipeline would increase the availability of water which could be used to prevent cease-to-flow conditions through the optimisation of dam operations conditions.	The residual risk is considered minimal and less than the Level 1 impact defined by the AIP.

Table 9.3 Indirect groundwater effects residual risk assessment

Impacted environmental value	Potential risk/effect (source-pathway-receptor)	Project phase	Assessment with mitigation actions/controls	Residual risk
Groundwater quantity				
Aquatic ecosystems	Aquatic ecosystems are largely associated with both the Dungowan Creek and Peel River. Possible effects are: 1. Temporary reduced baseflow due to construction dewatering during pipeline trenching works. 2. Reduced run of river transfers from Chaffey Dam, potentially reducing flow in Peel River, particularly during dry periods.	1. Construction 2. Operation	1. Where possible, dewatering during trenching would be limited by installing pipes in flooded trenches to reduce the requirement for dewatering. 2. Streamflow analysis study predicts negligible changes to the PRA, DCA and water courses due to the operation of the new Dungowan Dam.	Negligible impact to aquatic ecosystems

Table 9.3 Indirect groundwater effects residual risk assessment

Impacted environmental value	Potential risk/effect (source-pathway-receptor)	Project phase	Assessment with mitigation actions/controls	Residual risk
Terrestrial ecosystems with potential groundwater dependency	Terrestrial ecosystems are largely associated with both the Dungowan Creek and Peel River. Possible effects are: 1. Temporary reduction in groundwater levels due to construction dewatering during pipeline trenching works. 2. Reduced run of river transfers from Chaffey Dam. Potential to reduce groundwater recharge to the PRA, potentially resulting in a declining water table limiting groundwater availability to GDEs.	1. Construction 2. Operation	1. Where possible, dewatering during trenching would be limited by installing pipes in flooded trenches to reduce the requirement for dewatering. 2. Streamflow analysis study predicts negligible changes to the PRA, DCA and water courses due to the operation of the new Dungowan Dam.	Negligible impact to terrestrial ecosystems
Third party bores	Third party bores may be affected by: 1. Temporary reduction in groundwater levels due to dewatering during pipeline trenching works. 2. Decrease in groundwater levels due to the reduction of run-of-river transfers from Chaffey Dam. Potential to reduce groundwater recharge to the PTA, potentially resulting in a declining water table limiting groundwater availability to third party bores.	1. Construction 2. Operation	1. Where possible, dewatering during trenching would be limited by installing pipes in flooded trenches to reduce the requirement for dewatering. 2. Streamflow analysis study predicts negligible changes to the PRA, DCA and water courses due to the operation of the new Dungowan Dam.	Negligible impact to third party bores.
Groundwater quality				
Aquatic ecosystems Terrestrial ecosystems with potential groundwater dependency Third party bores	There is the potential for the project construction works to cause contamination to through spills of hazardous materials/chemicals and/or the generation of solid or liquid waste and AMD. Examples of this include spills of hydrocarbons while refuelling or lubricants used by machinery, and generation of solid construction waste or liquid and AMD waste during excavation and stockpiling of materials.	Construction	• Risks are readily managed through implementation of environmental management systems (ie Groundwater management plans), including storage of fuels, oils and chemicals in accordance with relevant legislation and Australian standards. • Implementing appropriate environmental controls during construction and operation would capture any AMD.	Given adequate implementation of mitigation measures, risk to groundwater from contamination is low.

Table 9.3 Indirect groundwater effects residual risk assessment

Impacted environmental value	Potential risk/effect (source-pathway-receptor)	Project phase	Assessment with mitigation actions/controls	Residual risk
Surface water-groundwater interaction				
Aquatic ecosystems	Aquatic ecosystems are largely associated with both the Dungowan Creek and Peel River. Possible effects could include reduced run of river transfers from Chaffey Dam, potentially reducing flow in Peel River, particularly during dry periods.	Operation	Streamflow analysis study predicts negligible changes to the PRA, DCA and water courses due to the operation of the new Dungowan Dam.	Negligible impact to aquatic ecosystems
Aquifer disruption				
Aquatic ecosystems Terrestrial ecosystems with potential groundwater dependency	Any aquifer disruption would be temporary and limited to construction works. Aquifer disruption such as changes in groundwater levels may be caused by temporary dewatering during pipeline trenching and excavation works. Any disruption may temporarily reduce baseflows or groundwater access to GDEs.	Construction	• Where possible, dewatering during trenching would be limited by installing pipes in flooded trenches to reduce the requirement for dewatering. • Temporary infrastructure would be implemented for releases of environmental flows (if required) downstream of coffer dams during construction.	Negligible impact to aquatic and terrestrial ecosystems
Cumulative Impacts (Surface water-groundwater interaction)				
Aquatic ecosystems Terrestrial ecosystems with potential groundwater dependency Third party bores	A separate approval is being sought by WaterNSW to operate the Chaffey Dam pipeline. The project would result in releases, including run-of-river water transfers, from Chaffey Dam to Calala WTP reducing when Chaffey Dam falls below 20% capacity. Below 20% capacity, the Chaffey Dam pipeline would be used in conjunction with the new Dungowan Dam to reduce transmission loses to the PRA and evaporation. It is possible that the PRA groundwater regime may change due to the reduction in run-of-river water transfers and environmental flows and GDEs and groundwater users (ie bores) may be affected.	Operation	When the pipeline is operational, run-of-river transfers of water from Chaffey Dam to Calala WTP would reduce. The volume of water taken to Calala via the pipeline would be smaller than the volume that would have been released to the river as transmission losses would be avoided. Due to increased water storage in Chaffey Dam, the pipeline would increase the availability of water, which could be used to prevent cease-to-flow conditions through the optimisation of dam operations conditions.	Negligible impact to aquatic and terrestrial ecosystems and third party bores

10 Monitoring, mitigation and management

10.1 Management plans

A groundwater management plan (GWMP) would be developed for the project to support construction activities, as a sub-plan of the Construction Environmental Management Plan (CEMP). The GWMP would document the proposed mitigation and management measures for the approved project, and would include the groundwater monitoring program, reporting requirements, spill management and response, water quality trigger levels, corrective actions, contingencies, and responsibilities for all management measures.

The GWMP would be prepared in consultation with DPE Water, EPA, Water Infrastructure NSW and key local stakeholders. The GWMP would include details of the groundwater monitoring program, which would incorporate and update the existing monitoring network (if required), monitoring frequencies and water quality constituents, and physical water take and usage. Reporting frameworks for the above would be prepared in accordance with licensing and agency requirements. Trigger levels for water quality parameters would be developed as part of the GWMP to assist in early identification of water quality trends. The monitoring program would be prepared in accordance with the approved project's EPL, once enacted.

10.2 Monitoring and thresholds

Baseline data would continue to be collected during the construction of the new Dungowan Dam. Expansion of the network may be considered once the project starts construction and then operation. The suite of water quality analytes (ie constituents) to be sampled and the frequency of sampling would be reviewed and updated in the GWMP developed for the project. Data loggers that currently monitor water levels would continue to operate.

10.3 Seepage inflow validation

Seepage estimations should be further validated during detailed design when the program schedule and construction methods are finalised. During construction, seepage from the DCA and PFR should be metered and compared to predictions. Groundwater take would be detailed in compliance reporting in accordance with licensing and agency requirements.

10.4 Summary of mitigation measures

Taking into consideration the groundwater assessment completed in Chapter 9, Table 10.1 details groundwater mitigation measures that should be implemented during the construction and operation of the project.

Table 10.1 Mitigation measures–- groundwater

Impact	Ref#	Mitigation Measure	Timing
Groundwater	GW_01	A Groundwater Management Plan (GWMP) would be prepared and implemented as part of the CEMP. The plan would include, but not be limited to consideration of the following: • groundwater monitoring program, • reporting requirements, • spill management and response, • water quality trigger levels, • corrective actions, contingencies, and responsibilities for all management measures.	Pre-construction Construction

Table 10.1 Mitigation measures–- groundwater

Impact	Ref#	Mitigation Measure	Timing
Groundwater quantity	GW_02	• Excavations to be sequenced and progressively backfilled with earth fill material to limit cumulative seepage to excavations and dewatering. • Excessive seepage from defects to be grouted to reduce permeability. • Seepage estimations to be further validated during detailed design when the program schedule and construction methods are finalised following detailed design. • Seepage from the DCA and PFR should be metred and compared to predictions. Groundwater take should be detailed in compliance reporting in accordance with licensing and agency requirements.	Construction
Groundwater quantity	GW_03	• Consideration of construction during extended dry periods to limiting the potential to intercept elevated water tables. • Trenching across ephemeral waterways during dry periods and low flow conditions. • Implementing appropriate construction methodologies to facilitate construction in flooded trenches (if necessary). • Leaving trenches open for the minimal length of time. • Any groundwater take would be measured, recorded and reported.	Construction
Groundwater quantity	GW_04	• Viscosity of drilling fluids can be increased to prevent drilling fluids from surfacing or migrating from the work area to nearby bores. • Close observation of the Peel River during under boring to ensure no drilling fluids are leaking to the Peel River. • Implementation of a monitoring program, utilising existing nearby landholder bores, during HDD to ensure groundwater levels and quality are not impacted by the potential migration of drilling fluids.	Construction
Groundwater quality	GW_05	• Minimising disturbance of pyritic materials where possible. • Ensuring the material has fully reacted and is treated prior to placement if the material is used in structural areas of the dam. • Implementing appropriate environmental controls during construction and operation to capture any AMD. • Implementation of environmental management systems (ie GWMP, contamination management plans). • Further studies into the occurrence of PAF material at the Dungowan Dam construction site.	Construction
Groundwater quality	GW_06	• Refuelling and washing down of plant and equipment away from water courses or in any location which drains directly to waters with appropriate temporary bunding. • Storage of fuels, oils and chemicals in suitably bunded areas in accordance with relevant legislation and Australian standards. • Implementation of environmental management systems (ie GWMP, contamination management plans).	Construction
Groundwater quality	GW_07	• Storage of explosives and chemicals in suitably bunded areas in accordance with relevant legislation and Australian standards. • Implementing appropriate environmental controls during construction and operation to capture any residual blasting residue. • Implementation of environmental management systems (ie GWMP, contamination management plans).	Construction
Aquifer disruption	GW_08	• Implementing appropriate engineering solutions to control seepage under or around the dam embankment (ie grout curtains, shotcreting, low permeability clay core).	Construction

Table 10.1 Mitigation measures–- groundwater

Impact	Ref#	Mitigation Measure	Timing
Cumulative impact (surface water and groundwater interaction)	GW_09	Optimisation of dam operations (ie environmental releases) to reduce the likelihood of cease to flow conditions.	Operation

11 Water licencing

Water Infrastructure NSW is required to hold WALs in each affected water source to account for all water extracted and intercepted in accordance with the WMA and the AIP. This includes water taken for use as well as water intercepted and managed as a result of project activities. .

In accordance with the AIP, the project is required to licence both the direct and indirect take from adjacent and overlying water sources. The volume of water to be licensed for the project is defined as:

- groundwater inflow to the project that is physically handled by the water management system; and
- groundwater inflow to the project that is evaporated and thereby lost from the system.

The results of the groundwater analytical modelling have been used to estimate the required groundwater licence entitlements for the project, based on the predicted total groundwater seepage rates to the project.

The WALs and associated entitlement are required to be held for the water year in which the impact occurs. The total required entitlement does not need to be held prior to the project approval, as some effects do not occur for years after construction and operation commences. However, a valid pathway to acquiring the total required entitlement needs to be demonstrated to prove entitlement can be obtained.

As per Section 9.2.4, the volumetric prediction for groundwater take during the construction of the new Dungowan Dam is:

- 24.9 ML/yr from the Dungowan Creek Management Zone within the Peel Alluvium Groundwater Source; and
- 3.9 ML/yr from the Peel Fractured Rock Groundwater Source.

As identified in Chapter 7, the licencing pathway for groundwater entitlement during construction is via the water market. No groundwater take is anticipated during operation of the project.

11.1 Water trading

The following section details the application process for securing groundwater entitlement for the project.

11.1.1 Zero share WAL

Under Schedule 4 of the *Water Management (General) Regulation 2018*, Water Infrastructure NSW, or the construction contractor, (licensee) are not exempt from requiring a WAL.

The licensee would need to apply for a zero share WAL, which is processed by NRAR. The determination is then lodged with Lands and Register Services (LRS) who release the zero share WAL and Certificate of Title (CoT). The licensee then enters the water market using a water broker. Entitlement can be secured temporarily or permanently (see Section 7.3.1). Engagement with willing vendors to negotiate the terms of the trade is undertaken by a water broker.

When shares are secured temporarily (up 1 to 3 water years depending on the agreement), the entitlement is linked to the zero share WAL by lodging an application with Water NSW who approve, issue notification and credit the water account. When entitlement is secured permanently, a similar process with Water NSW applies but they also issue a notification, which is lodged with LRS who release a new WAL and CoT.

11.1.2 Miscellaneous work

If the abstraction of water and associated impacts for a CSSI project are assessed, as they are in Chapter 9 and 10, and approved under the EP&A Act, the WAL is then linked to a miscellaneous work, which allows Water Infrastructure NSW or the construction contractor to take water as per the conditions of approval. A miscellaneous work can only be applied for when the project, and its aquifer interfering activities, is a CSSI project.

11.1.3 Trading rules

Under Part 10, Section 49(1) of the *WSP for the Namoi Alluvial Groundwater Sources 2020*, trading between groundwater management zones is prohibited. Water trading for the project would need to be undertaken within the Dungowan Creek Management Zone. No detail, with regards to the volume of water traded in pervious water years, has been provided on the NSW Water Register but a water broker would be able to source this information.

No explicit trading rules for the Peel Fractured Rock Groundwater source are detailed in the *WSP for NSW Murray Darling Basin Fractured Rock Groundwater Sources Order 2020.*

11.1.4 Available water determinations

AWDs need to be taken into consideration when securing share in the Dungowan Creek Management Zone. At the start of a water year, aquifer (general security) access licences are 51% (ie 0.51 ML per share) of the AWD for the Peel Alluvium Groundwater Sources (including the Dungowan Creek Management Zone).

The AWD can be increased or decreased throughout the water year depending on flow conditions in the Peel River and Dungowan Creek, and commitments to meet environmental objectives. To license predicted seepage from the DCA, regulated by the Dungowan Creek Management Zone, during construction of the new Dungowan Dam, approximately 49 unit shares (at an AWD of 0.51 ML per share) in the Dungowan Creek Management Zone would need to be secured in order to meet the predicted seepage of 24.9 ML/yr from the DCA. In previous water years, no AWDs are applicable to the Peel Fractured Rock Groundwater Source and one unit share is equivalent to 1 ML/yr.

12 Conclusion

This GIA forms part of the EIS for the Dungowan Dam and pipeline project. The assessment has been informed by the concept design for the project. The following aspects have been addressed by the GIA:

- Assessment of environmental and human users dependent on groundwater, including:
  - GDEs; and
  - landholder water supplies.
- Management of groundwater during construction of the project, including:
  - consideration for excavation sequencing, pre-grouting and segmental lining influence on groundwater inflow and environmental impacts; and
  - changes to water quality due to construction.
- Impacts to groundwater during the operation of the project including potential changes to recharge and discharge in the PRA due to reduction of run-of-river transfers from Chaffey Dam to Calala WTP.
- Assessment of the project against the assessment requirements of the AIP, including:
  - consideration for the minimal impact criteria, as it relates to groundwater pressures, levels and quality;
  - consideration for impacts to High Priority (as defined by relevant WSPs) listed GDEs;
  - consideration for Level 1 and 2 impacts; and
  - water licensing requirements.

Analytical modelling was used to predict groundwater seepage from the DCA and PFR to the dam and spillway excavation areas. The analytical model is likely to be overpredicting seepage due to the conservative assumptions used to estimate groundwater take. When the project is further refined through detailed design, the analytical model can be updated to provide a more accurate assessment of groundwater seepage from the DCA and PFR. Furthermore, suitable mitigation, management, and engineering measures (such as grouting structural defects with excessive seepage) can be implemented to further reduce potential groundwater seepage.

Drawdown near the excavations is expected to be localised and temporary due to the sequential nature of the works, which would reduce the need for ongoing dewatering during construction. There are no groundwater users within the vicinity of the new Dungowan Dam and spillway excavation areas, and the terrestrial and aquatic ecosystems present do not have a dependent relationship with groundwater. The potential impact to GDEs and groundwater users due to these construction works is negligible to low.

During the construction of the pipeline infrastructure, groundwater seepage to trenched excavation works is not expected to intercept groundwater. If groundwater is intercepted during trenching the implementation of management and engineering measures would minimise the need to dewater, reducing the likelihood of impact to GDEs and other groundwater users. Trenches would be left open for the minimal amount of time possible limiting dewatering if groundwater is intercepted.

A suitable licencing pathway via the water market has been outlined to account for groundwater take during construction of the new Dungowan Dam and spillway excavation areas. Trading groundwater shares in the Dungowan Creek Management Zone within the Peel Alluvium Groundwater Source and Peel Fractured Rock Groundwater Sources is well established and groundwater usage is currently below the extraction limit (LTAAEL). Water would be secured on a temporary or permanent basis. Groundwater seepage from the DCA and PFR would be metred and reported against predictions. Groundwater take would be detailed in compliance reporting in accordance with licensing and agency requirements.

During the operation of the project there would be a reduction in the run-of-river water transfers in the Peel River from Chaffey Dam to Calala WTP. Despite the reduced release of water from Chaffey Dam, environmental flows would remain the same. Despite these reduction in surface water flows, there would be a negligible impact on the PRA's groundwater regime and subsequently negligible impact for GDEs and groundwater users to access groundwater.

The cumulative effects of the Dungowan Dam and pipeline project and the Chaffey Pipeline project were assessed using the DPE Peel Valley Source model. Groundwater recharge to the PRA is expected to show no meaningful changes as a result of cumulative impacts.

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Annexure A

Water quality sampling results

EMM
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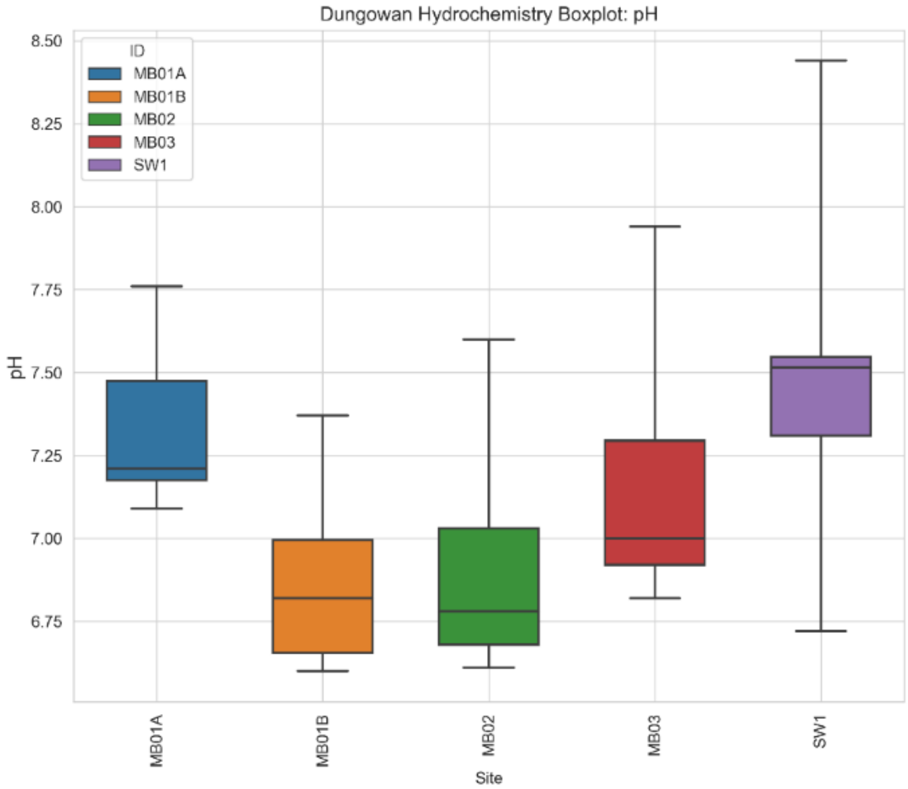
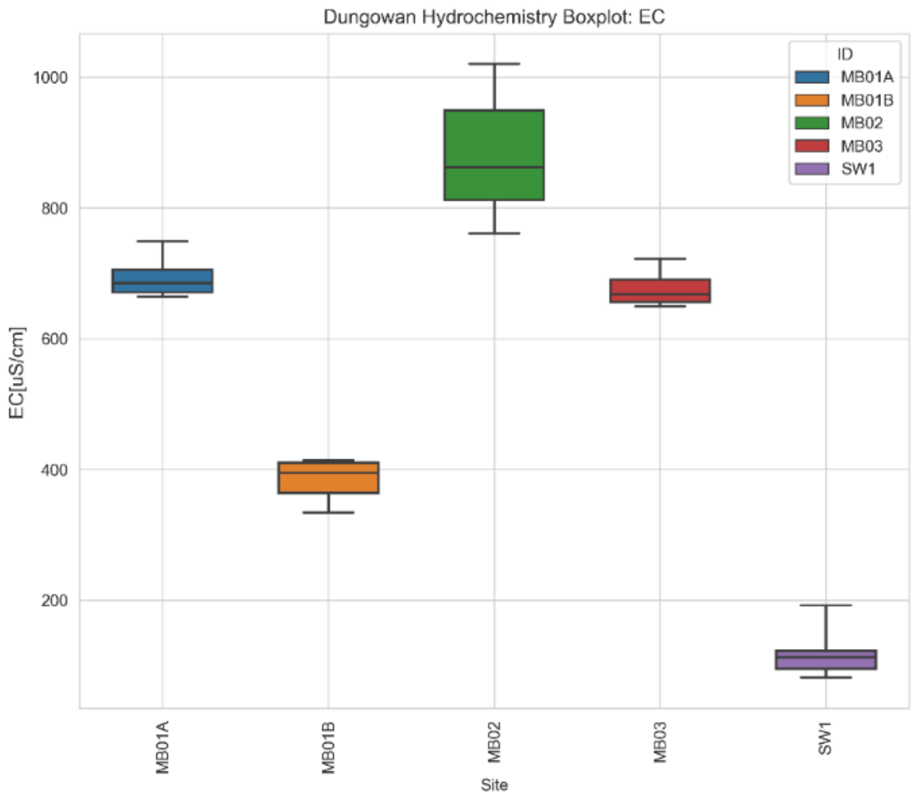
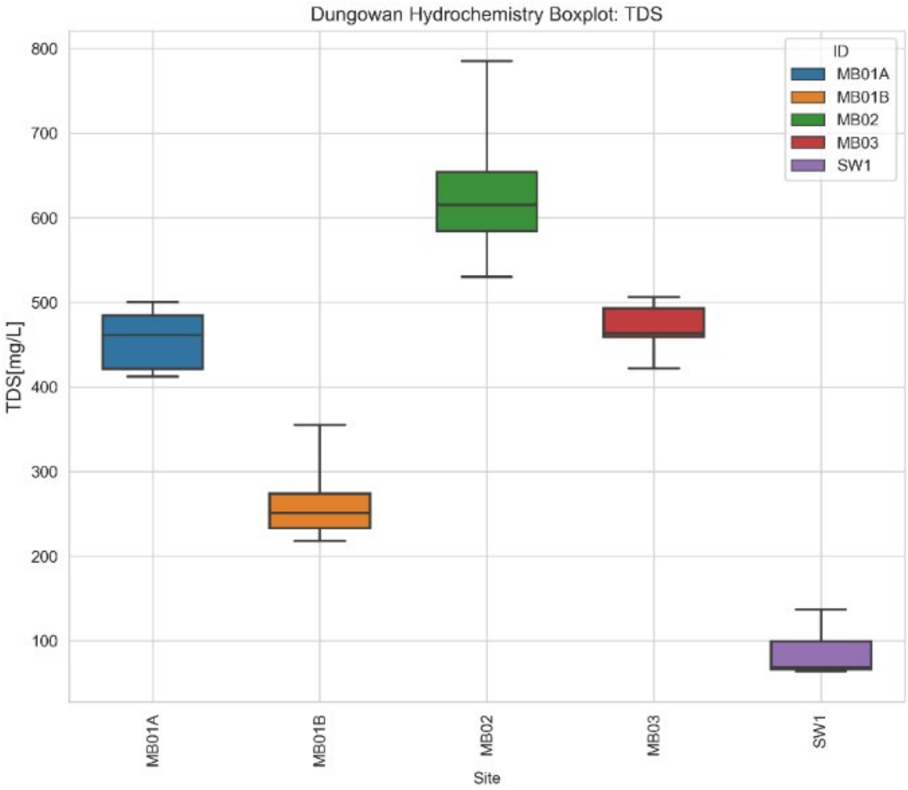
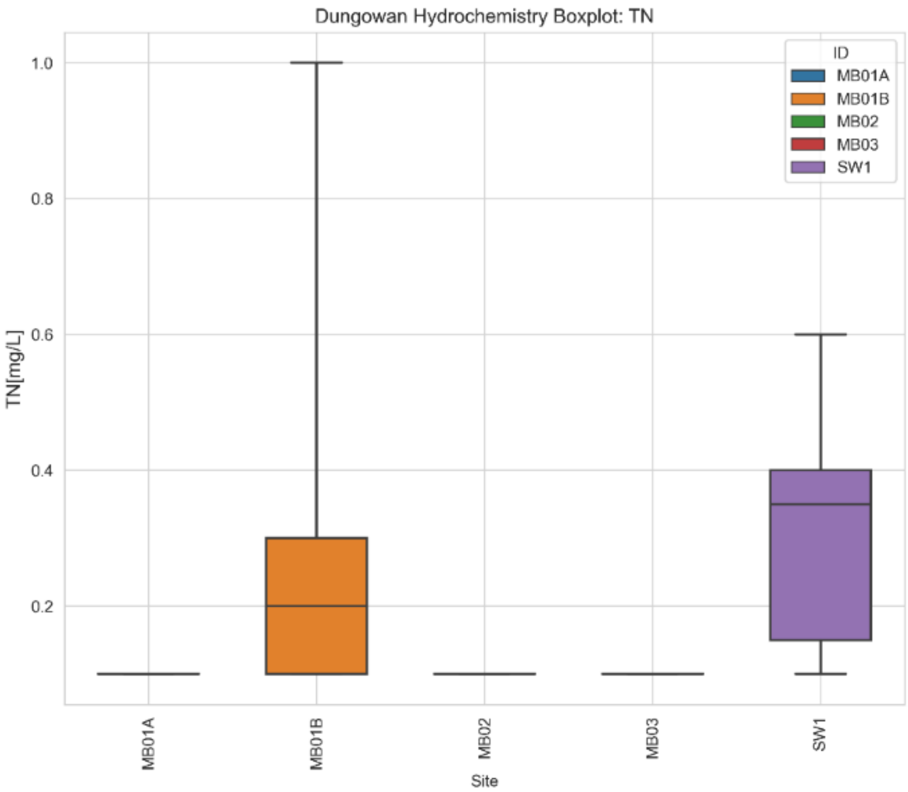
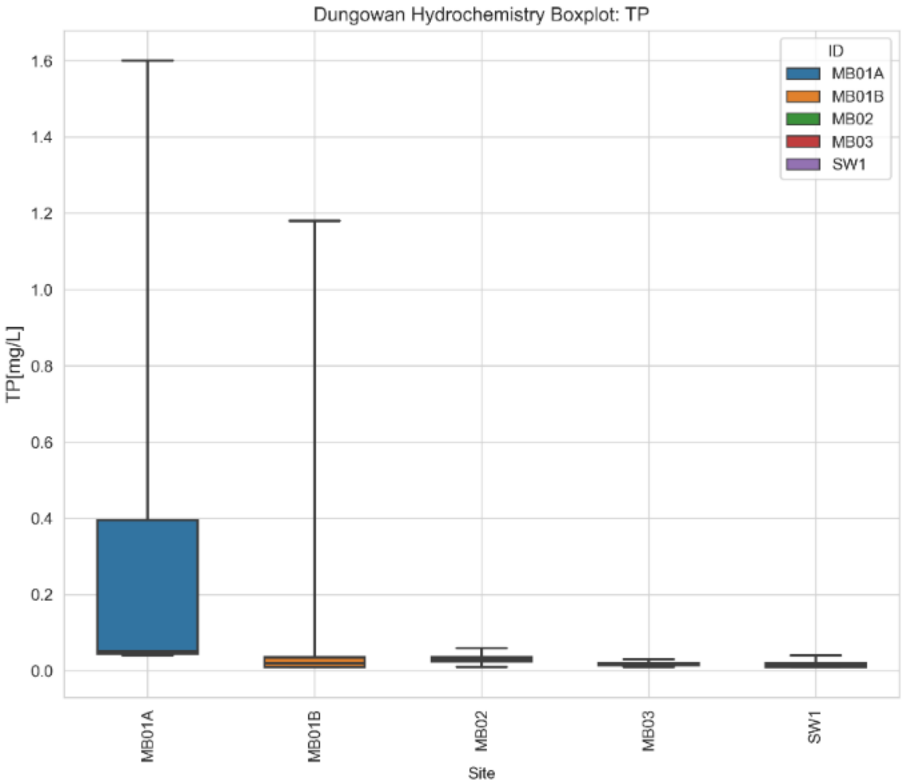
A.1 Box and whisker plots

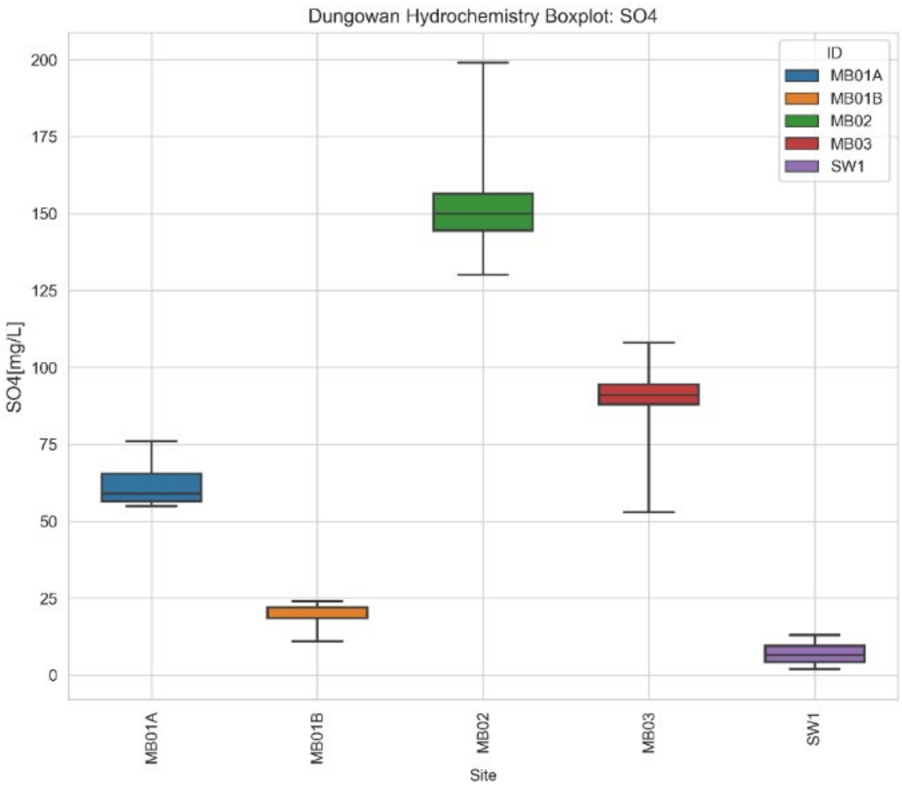


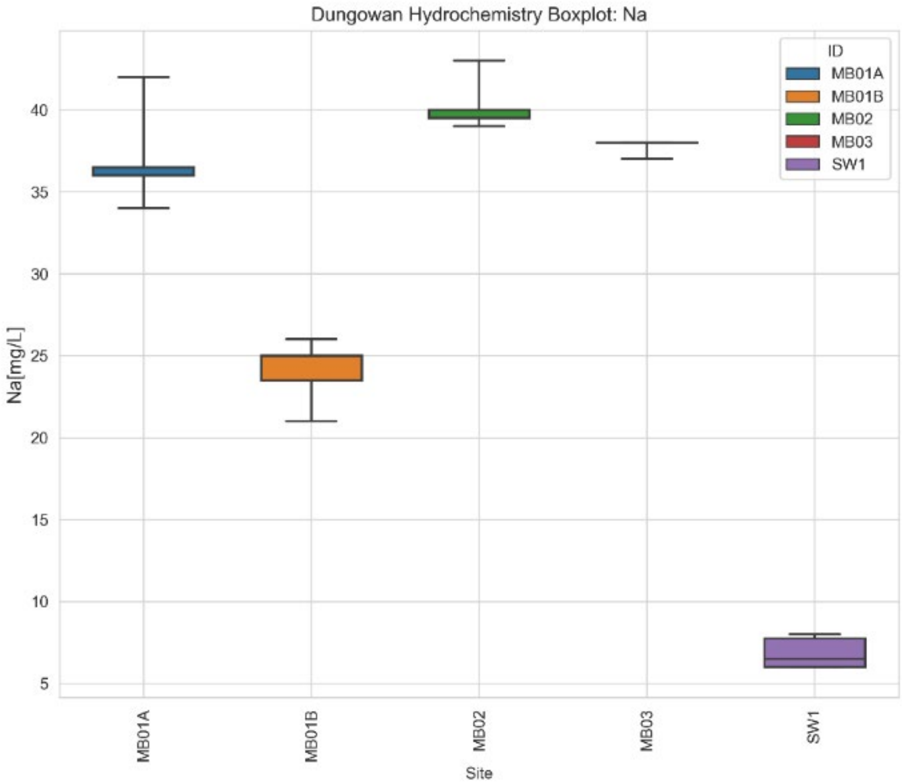



Dungowan Hydrochemistry Boxplot: TDS
TDS[mg/L]
800
700
600
500
400
300
200
100
ID
MB01A
MB01B
MB02
MB03
SW1
MB01A
MB01B
MB02
MB03
SW1
Site

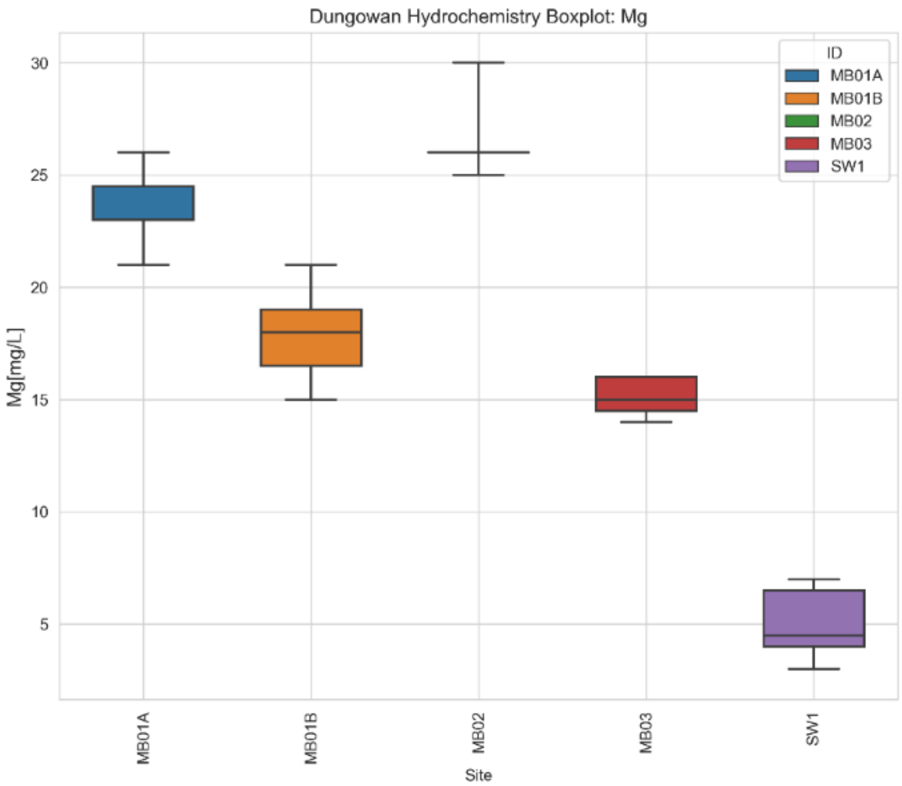

Dungowan Hydrochemistry Boxplot: TN
TN[mg/L]
1.0
0.8
0.6
0.4
0.2
ID
MB01A
MB01B
MB02
MB03
SW1
MB01A
MB01B
MB02
MB03
SW1
Site


Dungowan Hydrochemistry Boxplot: TP
TP[mg/L]
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
ID
MB01A
MB01B
MB02
MB03
SW1
Site

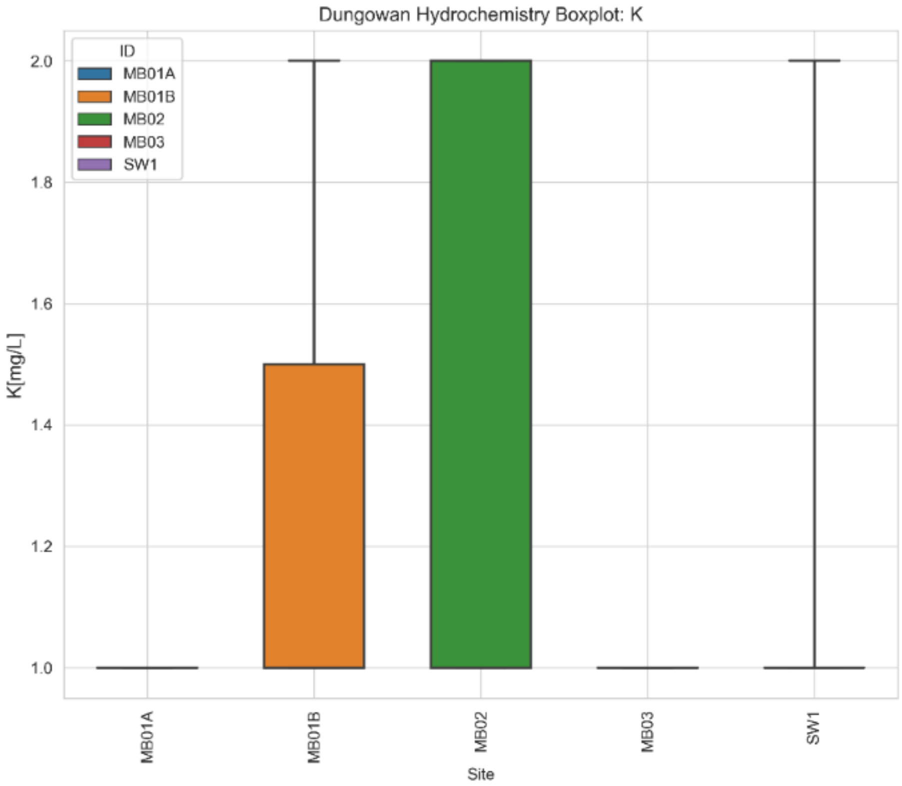

Dungowan Hydrochemistry Boxplot: SO4
SO4[mg/L]
200
175
150
125
100
75
50
25
0
ID
MB01A
MB01B
MB02
MB03
SW1
Site

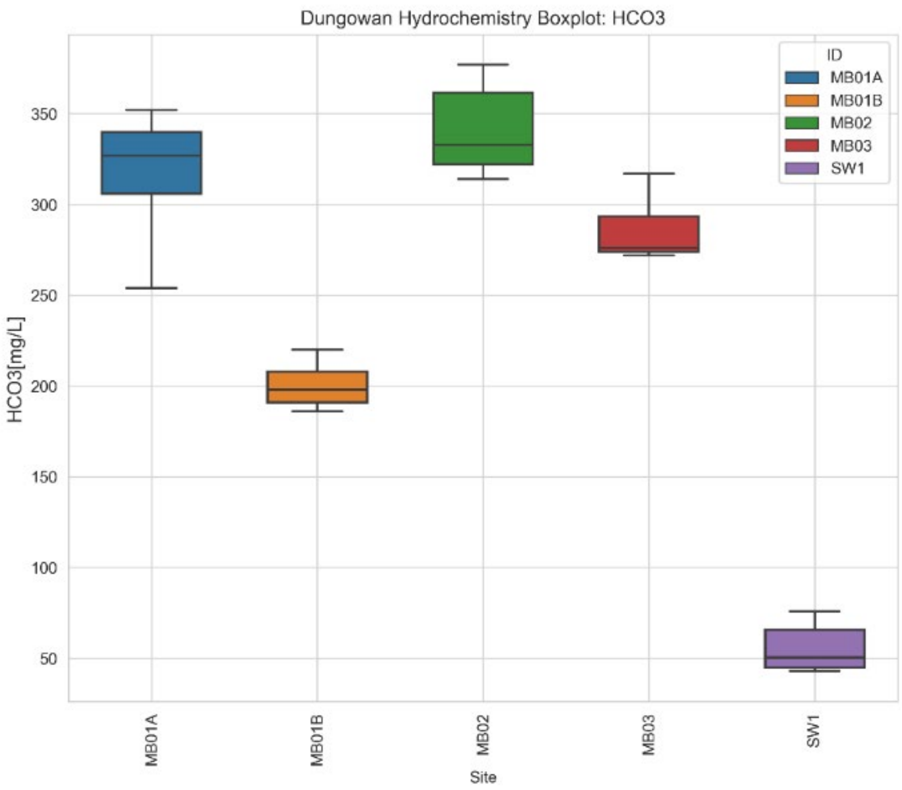


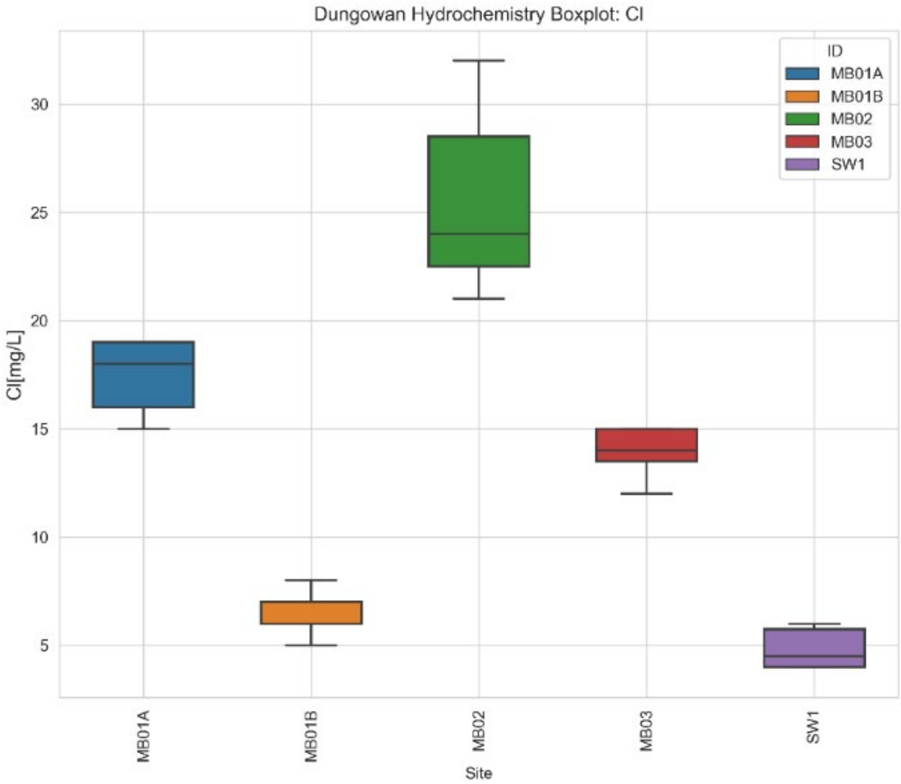
Dungowan Hydrochemistry Boxplot: Na
Na[mg/L]
40
35
30
25
20
15
10
5
ID
MB01A
MB01B
MB02
MB03
SW1
MB01A
MB01B
MB02
MB03
SW1
Site

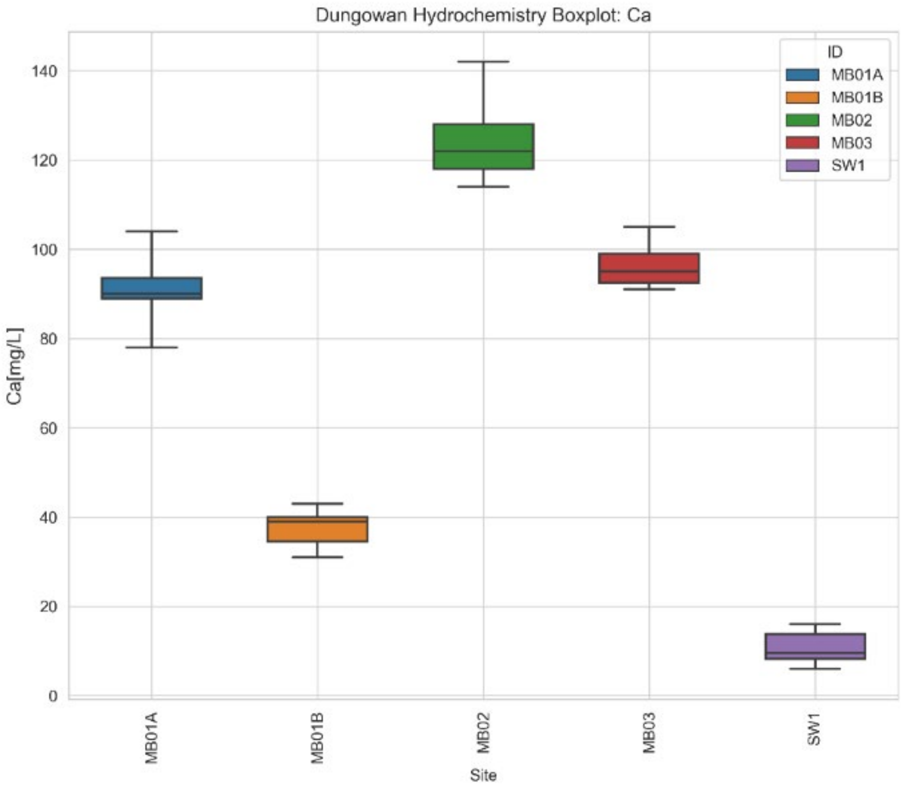


Dungowan Hydrochemistry Boxplot: Mg
Mg[mg/L]
30
25
20
15
10
5
ID
MB01A
MB01B
MB02
MB03
SW1
MB01A
MB01B
MB02
MB03
SW1
Site


Dungowan Hydrochemistry Boxplot: K
ID
MB01A
MB01B
MB02
MB03
SW1
2.0
1.8
1.6
1.4
1.2
1.0
K[mg/L]
MB01A
MB01B
MB02
MB03
SW1
Site


Dungowan Hydrochemistry Boxplot: HCO3
ID
MB01A
MB01B
MB02
MB03
SW1
350
300
250
200
150
100
50
HCO3[mg/L]
MB01A
MB01B
MB02
MB03
SW1
Site


Dungowan Hydrochemistry Boxplot: Cl
ID
MB01A
MB01B
MB02
MB03
SW1
Cl[mg/L]
30
25
20
15
10
5
MB01A
MB01B
MB02
MB03
SW1
Site


Dungowan Hydrochemistry Boxplot: Ca
ID
MB01A
MB01B
MB02
MB03
SW1
Ca[mg/L]
140
120
100
80
60
40
20
0
MB01A
MB01B
MB02
MB03
SW1
Site

Annexure B

AIP Assessment Framework

creating opportunities

B.1 AIP assessment framework

This annexure reproduces the DPE Water AIP assessment framework with commentary to assist the DPE Water with the assessment.

Table B.1 Does the activity require detailed assessment under the AIP?

	Consideration	Response
1	Is the activity defined as an aquifer interference activity?	Yes
2	Is the activity a defined minimal impact aquifer interference activity according to Section 3.3 of the AIP?	Yes

B.1.1 Accounting for, or preventing the take of water

Table B.2 Accounting for, or preventing the take of water, has the proponent:

	AIP requirement	Proponent response
1	Described the water source(s) the activity would take water from?	Yes, this information is provided in Chapter 3, 4 and 6.
2	Predicted the total amount of water that would be taken from each connected groundwater or surface water source on an annual basis as a result of the activity?	Yes, this information is provided in Chapter 9.
3	Predicted the total amount of water that would be taken from each connected groundwater or surface water source after the closure of the activity?	No, this does not apply to the project.
4	Made these predictions in accordance with Section 3.2.3 of the AIP?	Yes, this information is provided in Chapter 4, 7, 9 and 11.
5	Described how and in what proportions this take would be assigned to the affected aquifers and connected surface water sources?	Yes, this information is provided in Chapter 9 and 11.
6	Described how any licence exemptions might apply?	Yes, this has been described in Chapter 7 and 11
7	Described the characteristics of the water requirements?	Yes, this has been described in Chapter 7 and 11.
8	Determined if there are sufficient water entitlements and water allocations that are able to be obtained for the activity?	Yes, this has been described in Chapter 7 and 11.
9	Considered the rules of the relevant water sharing plan and if it can meet these rules?	Yes, this has been described in Chapter 7 and 11.
10	Determined how it would obtain the required water?	Yes, this has been described in Chapter 7 and 11.
11	Considered the effect that activation of existing entitlement may have on future available water determinations?	Yes, this has been described in Chapter 7, 9 and 11.

Table B.2 Accounting for, or preventing the take of water, has the proponent:

AIP requirement		Proponent response
12	Considered actions required both during and post-closure to minimize the risk of inflows to a mine void as a result of flooding?	Not applicable.
13	Developed a strategy to account for any water taken beyond the life of the operation of the project?	Not applicable.
Would uncertainty in the predicted inflows have a significant impact on the environment or other authorised water users? If **YES**, items 14-16 must be addressed.		No.
14	Considered any potential for causing or enhancing hydraulic connections, and quantified the risk?	Not applicable.
15	Quantified any other uncertainties in the groundwater or surface water impact modelling conducted for the activity?	Not applicable.
16	Considered strategies for monitoring actual and reassessing any predicted take of water throughout the life of the project, and how these requirements would be accounted for?	Not applicable.

Table B.3 Determining water predictions in accordance with Section 3.2.3

(complete one row only – consider both during and following completion of activity)		
AIP requirement		**Proponent response**
1	For the Gateway process, is the estimate based on a simple modelling platform, using suitable baseline data, that is, fit-for-purpose?	Yes. Details of the modelling platform is provided in Section 9.2.4. An analytical model was used to predict inflows due to the temporary take of groundwater and negligible to low risk to GDEs and third parties during construction. A description of available baseline data used for analytical model input has been described in Chapter 4.
2	For State Significant Development or mining or coal seam gas production, is the estimate based on a complex modelling platform that is: •Calibrated against suitable baseline data, and in the case of a reliable water source, over at least two years? •Consistent with the Australian Modelling Guidelines? •Independently reviewed, robust and reliable, and deemed fit-for-purpose?	Not applicable.

Table B.3 Determining water predictions in accordance with Section 3.2.3

(complete one row only – consider both during and following completion of activity)		
	AIP requirement	**Proponent response**
3	In all other processes, estimate based on a desk-top analysis that is: •Developed using the available baseline data that has been collected at an appropriate frequency and scale; and •Fit-for-purpose?	Yes, this has been described in Chapter 4 and sections 9.2.4 and 9.6. The analytical model is fit for purpose due to temporary take of groundwater and negligible to low risk to GDEs and third parties during construction and operation of the project.

Table B.4 Other requirements to be reported on under Section 3.2.3 of the AIP

Has the proponent provided details on:		
	AIP requirement	**Proponent response**
1	Establishment of baseline groundwater conditions?	Yes – see Chapter 3 and 4.
2	A strategy for complying with any water access rules?	Yes – see Section 7.2.2 and Chapter 11.
3	Potential water level, quality or pressure drawdown impacts on nearby basic landholder rights water users?	Yes – see Chapter 8 and 9.
4	Potential water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources?	Yes – see Chapter 8 and 9.
5	Potential water level, quality or pressure drawdown impacts on groundwater dependent ecosystems?	Yes – see Chapter 8 and 9.
6	Potential for increased saline or contaminated water inflows to aquifers and highly connected river systems?	Yes – see Chapter 8 and 9.
7	Potential to cause or enhance hydraulic connection between aquifers?	Yes – see Chapter 8 and 9.
8	Potential for river bank instability, or high wall instability or failure to occur?	Yes – see Section 9.3.2.
9	Details of the method for disposing of extracted activities (for coal seam gas activities)?	Not applicable.

B.1.2 Addressing the minimal impact considerations

Two sources are impacted:

- the Dungowan Creek Alluvium Management Zone within the Peel Alluvium Groundwater Source; and
- Peel Fractured Rock Groundwater Source.

Table B.5 Minimal impact considerations

Aquifer Category	Fractured rock - Less productive
Level 1 Minimal Impact Consideration	**Assessment**
<u>Water table</u> Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 metres from any: •high priority groundwater dependent ecosystem or •high priority culturally significant site listed in the schedule of the relevant water sharing plan. OR A maximum of a 2-metre water table decline cumulatively at any water supply work.	Predicted impacts have been presented in Chapter 8 and 9. No GDEs are predicted to be impacted during the construction and operation of the project. No culturally significant sites have been identified in relevant WSPs.
<u>Water pressure</u> A cumulative pressure head decline of not more than a 2-metre decline, at any water supply work.	No water supply works are predicted to be impacted by the project due to the temporary nature of the works.
<u>Water quality</u> Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.	No water quality impacts are anticipated due to project construction or operational activities.

B.1.3 Proposed remedial actions where impacts are greater than predicted

Table B.6 Proposed remedial actions where impacts are greater than predicted, has the proponent:

AIP requirement		Proponent response
1	Considered types, scale, and likelihood of unforeseen impacts *during operation*?	Impacts to water resources during project operations have been detailed in Chapter 8 and 9.
2	Considered types, scale, and likelihood of unforeseen impacts *post closure*?	Not applicable.
3	Proposed mitigation, prevention or avoidance strategies for each of these potential impacts?	Management, mitigation strategies have been recommended to address predicted impacts to water resources. These have been described in Chapter 10.
4	Proposed remedial actions should the risk minimization strategies fail?	Yes – see Chapter 10.
5	Considered what further mitigation, prevention, avoidance or remedial actions might be required?	Yes – see Chapter 10.
6	Considered what conditions might be appropriate?	Yes – see Chapter 10.

B.1.4 Other considerations

Table B.7 Other considerations, has the proponent:

AIP requirement		Proponent response
1	Addressed how it would measure and monitor volumetric take?	Yes – see Chapter 10.
2	Outlined a reporting framework for volumetric take?	Yes – see Chapter 10.

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