CHAPTER 14

Groundwater

CALVERT TO KAGARU ENVIRONMENTAL IMPACT STATEMENT

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.

Contents

Figures

Tables

14. Groundwater

14.1 Scope of chapter

This groundwater chapter includes:

- A description of the existing hydrogeological regime relevant to the Project
- A summary of potential groundwater impacts from the Project
- An assessment of the impacts of the Project on groundwater resources
- A description of proposed measures to mitigate these impacts.

Potential short- and long-term impacts have been assessed for the construction and operation phases of the Project. Cumulative groundwater impacts related to existing or planned activities in surrounding areas have also been assessed.

This chapter has been prepared in accordance with the groundwater-related Terms of Reference (ToR) for the Project and summarises groundwater investigations undertaken to inform this assessment. Full details of the groundwater impact assessment and the corresponding ToR requirements are provided in Appendix O: Groundwater Technical Report.

14.2 Terms of Reference

This chapter addresses the relevant groundwater ToR for the Project, as summarised in Table 14.1. Compliance of the EIS against the full ToR is documented in Appendix B: Terms of Reference Compliance Table.

TABLE 14.1: TERMS OF REFERENCE COMPLIANCE TABLE—GROUNDWATER

Terms of Reference requirements		Where addressed
Groundwater		
11.36	Identify the water-related environmental values and describe the existing surface water and groundwater regime within the study area and the adjoining waterways in terms of water levels, discharges and freshwater flows.	Sections 14.5, 14.5.3 and 14.5.9 Appendix O: Groundwater Technical Report, Sections 6.2, 6.6 and 7
11.38	At an appropriate scale, detail the chemical, physical and biological characteristics of groundwater within the area that may be affected by the project. Include a description of the natural water quality variability within the study area associated with climatic and seasonal factors, and flows.	Sections 14.5.1 and 14.5.4 Appendix O: Groundwater Technical Report, Sections 4.3, 4.4 and 6
11.39	Describe any existing and/or constructed waterbodies adjacent to the preferred alignment.	Sections 14.5 and 14.5.2 Appendix O: Groundwater Technical Report, Section 4.3
11.40	Undertake a landholder bore survey to identify the location and source aquifer of licensed groundwater extraction in areas potentially impacted by the Project (e.g. near tunnels and cuttings).	Section 14.5.6 presents registered groundwater bores and Table 14.11 includes the reported source aquifer per registered bore (as available) Appendix O: Groundwater Technical Report, Section 6.4.1 presents registered groundwater bores and Table 6.8 includes the reported source aquifer per registered bore (as available)
11.41	The assessment of impacts on water will be in accordance with the DEHP Information guideline for an environmental impact statement—ToR Guideline—Water, where relevant.	Section 14.6 Appendix O: Groundwater Technical Report, Section 2.3.4

Terms of Reference requirements		Where addressed
11.44	Where significant cuttings or tunnelling is proposed, identify the presence of any sulphide minerals in rocks with potential to create acidic, metalliferous and saline drainage. Should they be found present, describe the practicality of avoiding their disturbance. If avoidance is not practicable, characterise the potential of the minerals to generate contaminated drainage and describe abatement measures that will be applied to avoid adverse impacts to surface and groundwater quality.	Sections 14.5.2, 14.6 and 14.7 Appendix O: Groundwater Technical Report, Sections 5, 11 and 12
11.47	Describe how the water quality objectives would be achieved, monitored and audited, and how environmental impacts would be avoided or minimised and corrective actions would be managed.	Sections 14.7 and 14.7.3 Appendix O: Groundwater Technical Report, Sections 12 and 13
11.52	Provide details of any proposed impoundment, extraction (i.e. volume and rate), discharge, use or loss of surface water or groundwater. Identify any approval or allocation that would be needed under the Water Act.	Sections 14.6.2 and 14.6.3 Chapter 3: Project Approvals Section 3.4.35 and Table 3.4 Appendix O: Groundwater Technical Report, Sections 2.1, 11.1, 11.2 1.7 and 11.2.2
11.54	Develop hydrological models as necessary to describe the inputs, movements, exchanges and outputs of all significant quantities and resources of surface water and groundwater that may be affected by the project. The models should address the range of climatic conditions that may be experienced at the site, and adequately assess the potential impacts of the Project on water resources. This should enable a description of the project's impacts at the local scale and in a regional context including proposed: (c) direct and indirect impacts arising from the project (d) impacts to aquatic ecosystems, including groundwater-dependent ecosystems and environmental flows.	Section 14.6.1 Appendix O: Groundwater Technical Report, Sections 8–10
11.55	Provide information on the proposed water usage by the project, including: (b) details of the quality and quantity of all water supplied to the site during the construction and operational phases based on minimum yield scenarios for water re-use, rainwater re-use and any bore water volumes (d) sufficient hydrogeological information to support the assessment of any temporary water permit applications.	Sections 14.5, 14.6.2.1 and 14.6.3.2 Appendix O: Groundwater Technical Report, Sections 6, 7, 10 and 11.1.6
11.58	Identify relevant Water Plans and Resources Operations Plans under the Water Act. Describe how the Project will impact or alter these plans. The assessment should consider, in consultation with the Department of Natural Resources and Mines, any need for: (a) a resource operations licence (b) an operations manual (c) a distribution operations licence (d) a water licence (e) a water management protocol.	Sections 14.3 and 14.5.6 Chapter 3: Project Approvals, Section 3.4.35 and Table 3.4 Appendix O: Groundwater Technical Report, Section 6.4.2
11.59	Identify other water users that may be affected by the proposal and assess the project's potential impacts on other water users.	Sections 14.5.6 and 14.6 Appendix O: Groundwater Technical Report, Sections 6.4 and 11
11.60	Identify and quantify likely activities involving the excavation or placement of fill that will be undertaken in any watercourse, lake or spring.	Section 14.6 Appendix O: Groundwater Technical Report, Section 11.1
11.62	Describe measures to minimise impacts on ground water resources.	Section 14.7 Appendix O: Groundwater Technical Report, Section 12
11.63	Provide a policy outline of compensation, mitigation and management measures where impacts are identified.	Section 14.7 Appendix O: Groundwater Technical Report, Section 12

14.3 Legislation, policy, standards and guidelines

This chapter has been prepared with consideration to key Commonwealth, State and local legislation, policies, standards and guidelines. Relevant legislation and policy are detailed in Table 14.2.

TABLE 14.2: REGULATORY CONTEXT

Legislation, policy or guideline	Relevance to the Project
Commonwealth	
Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act)	The Project was referred to the Australian Government Minister for the Environment in May 2017 and was subsequently deemed to be a 'controlled action' due to potentially significant impacts on listed threatened species and communities (Sections 18 and 18A of the EPBC Act). Controlled actions require assessment and approval under the EPBC Act. As such, the EIS includes an assessment of the Project's impacts on Matters of National Environmental Significance (MNES) as per the EPBC Act. As the project is not a coal seam gas development or large coal mine, groundwater is not required to be assessed under this Act.
State	
Environmental Protection Act 1994 (Qld) (EP Act)	The objective of the EP Act is to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains ecological processes on which life depends (i.e. ecologically sustainable development). The EP Act defines an environmental value (EVs) as: - A quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety - Another quality of the environment identified and declared to be an EV under an environmental protection policy or regulation. Further information regarding EVs is presented in Section 14.5.9.
Water Act 2000 (Qld) (Water Act)	The Water Act provides a framework for the following: - Sustainable management of Queensland's water resources by establishing a system for the planning, allocation and use of water, and the allocation of quarry materials and riverine protection - Sustainable and secure water supply and demand management for the South East Queensland (SEQ) region and other designated regions - Management of impacts on underground water caused by the exercise of underground water rights by the resource sector - Effective operation of water authorities. The Water Act covers water in a watercourse, lake or spring, underground water (or groundwater), overland flow water, or water that has been collected in a dam. The Project involves works that may intersect shallow groundwater units and, as such, the provisions of the Water Act apply.
Water Regulation 2016 (Water Regulation)	The Water Regulation is subordinate legislation made under the Water Act and prescribes administrative and operational matters for the Water Act. These matters include, but are not limited to: - Provide matters for the Minister's report on water plans - Prescribe the purpose and conditions for which a constructing authority may take water - Prescribes activities for which the taking of, or interfering with, water is authorised without an entitlement - Provide matters relating to water licences - Provide matters for water supply and demand management - Allow for seasonal water assignments and prescribe associated rules - Provide criteria for establishing water allocations and prescribe water allocation dealing rules - Prescribe requirements for decommissioning water bores - Provide for works that are accepted development and assessable development for the *Planning Act 2016* and prescribe the associated codes - Provide requirements for the construction and modification of levees - Make declarations about underground water taken to be water in a watercourse - Provide rules for managing underground water that isn't managed through a water plan.

Legislation, policy or guideline	Relevance to the Project
Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP Water and Wetland Biodiversity)	The EPP (Water and Wetland Biodiversity) is subordinate legislation to achieve the objective of the EP Act in relation to Queensland waters. The objective of the EPP (Water and Wetland Biodiversity) is achieved by the: ▶ Identification of EVs and management goals for Queensland (QLD) waters ▶ Stating water quality guidelines and water quality objectives to enhance or protect the identified EVs ▶ Provision of a framework for making consistent, equitable and informed decisions about Queensland waters ▶ Monitoring and reporting on the condition of QLD waters. EVs relevant to the Project are presented in detail in Section 14.5.9.

Water plans	Water plans have been developed under the Water Act to sustainably manage and allocate water resources in QLD. The *Water Plan (Moreton) 2007* and the *Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017* are relevant to the Project.
	The purposes of the water plans are to:
	▶ Define the availability of water in the plan area
	▶ Provide a framework for sustainably managing water and the taking of water
	▶ Identify priorities and mechanisms for dealing with future water requirements
	▶ Provide a framework for reversing, where practicable, degradation that has occurred in the natural ecosystems
	▶ Provide a framework for:
	  ▸ Establishing water allocations to take surface water
	  ▸ Granting and amending water entitlements for groundwater
	  ▸ Granting water entitlements for overland flow water.

Water Plan (Great Artesian Basin and Other Regional Aquifers) (GABORA) 2017	This plan applies to the following groundwater units of the groundwater study area:
	▶ Hutton Sandstone groundwater unit:
	  ▸ Gatton Sandstone
	  ▸ Koukandowie Formation.
	▶ Springbok Walloon groundwater unit:
	  ▸ Walloon Coal Measures.
	The plan suggests the groundwater study area is part of the Precipice groundwater unit (Woogaroo Subgroup); however, the groundwater study area is not expected to encounter the Woogaroo Subgroup based on the Project design therefore this unit has been excluded from the assessment.

Water Plan (Moreton) 2007	This plan is applicable to groundwater other than that included in the Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017. The Project is located within the Warrill–Bremer Alluvial Groundwater Management Area, as defined by this plan, which is applicable to alluvial sediments within the Bremer River sub-catchment to ensure management of groundwater from the alluvial in this area. This plan provides a framework for water entitlements/allocations to be managed. It includes the process for granting or amending interim resource operation licences, and interim water allocations for the construction of infrastructure to which the interim resource operation licences relate. The alluvial aquifers of the groundwater study area and consideration for construction water supply options are governed under this plan.
Water Plan (Logan Basin) 2007	The eastern portion of the Project is located within the plan area, specifically, within the Teviot Brook sub-catchment of the plan. Groundwater managed under this plan includes '*water in springs not connected to water which the Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017 applies*'. There are no mapped springs within the groundwater study area (refer Section 14.5.7); therefore this plan is not considered relevant to the Project.
ToR EIS information guideline—Water (2016)	The QLD Government's Department of Environment and Science (DES) has developed a guideline to assist in the development and assessment of water resources for EISs. This guideline was incorporated into the methodology, approach, and data sources for the groundwater impact assessment. The guideline is complementary to the Project-defined ToR by the Coordinator-General.

Legislation, policy or guideline	Relevance to the Project
Australia and New Zealand Guidelines for Fresh and Marine Water Quality (2018)	The objective of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (Australian and New Zealand Governments and Australian state and territory governments, 2018) is to provide authoritative guidance on the management of water quality in Australia and New Zealand. The guidelines include setting water quality and sediment quality objectives designed to sustain current, or likely future, community values for natural and semi-natural water resources. The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* provide: ▸ A platform for consistent water quality management and planning ▸ Technical support for Australia's *National Water Quality Management Strategy* and New Zealand's *National Policy Statement for Freshwater Management* ▸ Sound tools for governments and the community to assess and manage ambient water and sediment quality. The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* were used to assess groundwater quality in the groundwater study area.
National Health and Medical Research Council (NHMRC) and National Resource Management Ministerial Council's (NRMMC) *Australian Drinking Water Guidelines* (2018)	The *Australian Drinking Water Guidelines* (NHMRC & NRMMC, 2018) provide guidance to water regulators and suppliers on monitoring and managing drinking water quality. The *Australian Drinking Water Guidelines* provides details on the *Framework for Management of Drinking Water Quality*, which is a preventive management approach that encompasses all steps in water production from catchment to consumer, and aims to assure safe, good quality drinking water. The *Australian Drinking Water Guidelines* are used by state and territory health departments, local health authorities and water utilities. The *Australian Drinking Water Guidelines* were used to assess groundwater quality in the groundwater study area.

Application requirements for activities with impacts to water guideline (DES, 2019d)	The *Application requirements for activities with impacts to water guideline* is applicable to the following Environmentally Relevant Activities (ERAs):
	▸ Controlled/planned releases to water
	▸ Uncontrolled/unplanned releases to water
	▸ Changes to the quantity and quality of stormwater runoff from the site of the ERA
	▸ Indirect impacts
	  ▸ Disturbance to the bed or banks of waters
	  ▸ Turbidity due to disturbance or clearing of riparian vegetation during construction
	  ▸ Changes to groundwater formation characteristics
	  ▸ Changes to groundwater ecology (and surface water ecology).
	Based on the proposed works associated with the Project, this guideline is not considered relevant to groundwater in the groundwater study area.

Water Quality Guidelines (Qld) (DES, 2009)	The *Water Quality Guidelines* (Qld) (DES, 2009) provide the approach to determine guideline values for physical and chemical stressors. The guidelines indicate the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2018) includes default guidelines values; however, local water quality information is the first reference point and the water quality guideline values for physical and chemical stressors follow the hierarchy defined below: ▸ EPP (Water and Wetland Biodiversity) scheduled EVs and water quality objectives (WQOs) ▸ End of catchment anthropogenic pollutant reduction targets in Great Barrier Reef catchments ▸ QLD water quality guidelines (in the absence of EPP (Water and Wetland Biodiversity) scheduled EVs and WQOs ▸ Water monitoring protocols contained in the *Queensland Monitoring and Sampling Manual* (DES, 2018b). This assessment includes EVs and WQOs provided in the EPP (Water and Wetland Biodiversity), which is the priority source for water quality guideline values as they are developed based on local water quality conditions.

14.4 Methodology

14.4.1 Groundwater study area

The Project is located within the Ipswich City Council (ICC), Scenic Rim Regional Council (SRRC) and Logan City Council (LCC) local government areas (LGAs) in SEQ. The Project connects the adjacent Inland Rail projects of Helidon to Calvert (H2C) in the north-west and Kagaru to Acacia Ridge and Bromelton (K2ARB) to the south-east.

For the purposes of the assessment, the groundwater study area typically includes an area within 1 km either side of the alignment. It occurs across three broad areas: west of the Teviot Range (approximately Ch 00 km to Ch 38 km); the Teviot Range (Ch 38 km to Ch 51 km); and east of the Teviot Range (Ch 51 km to Ch 53 km). Figure 14.1 shows the groundwater study area and associated surface geology.

The groundwater study area also includes all areas associated with the Project that have the potential to directly or indirectly affect the groundwater environment, which was used to identify groundwater users, including registered bores and potential groundwater dependent ecosystems (GDEs).

14.4.2 Assessment methodology

To achieve the study scope and objectives outlined in the ToR, the groundwater impact assessment comprises two components:

- A description of the existing hydrogeological environment
- An assessment of the potential impacts of the Project on that environment.

A staged approach was adopted for development of the groundwater study to allow for compilation and assessment of sufficient data to:

- Address the groundwater requirements of the EIS submission
- Identify mitigation measures to be adopted in subsequent design, construction and operation.

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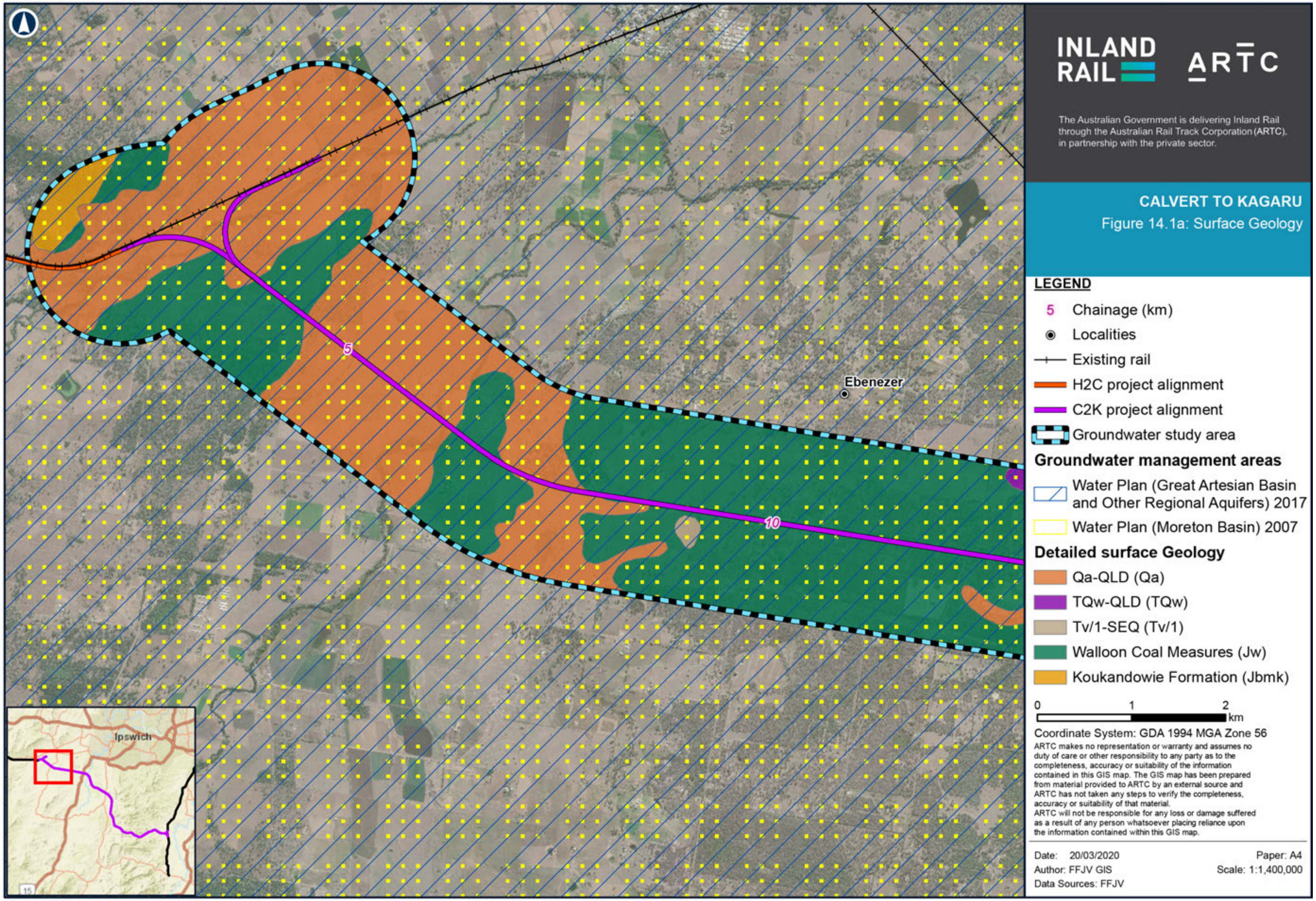

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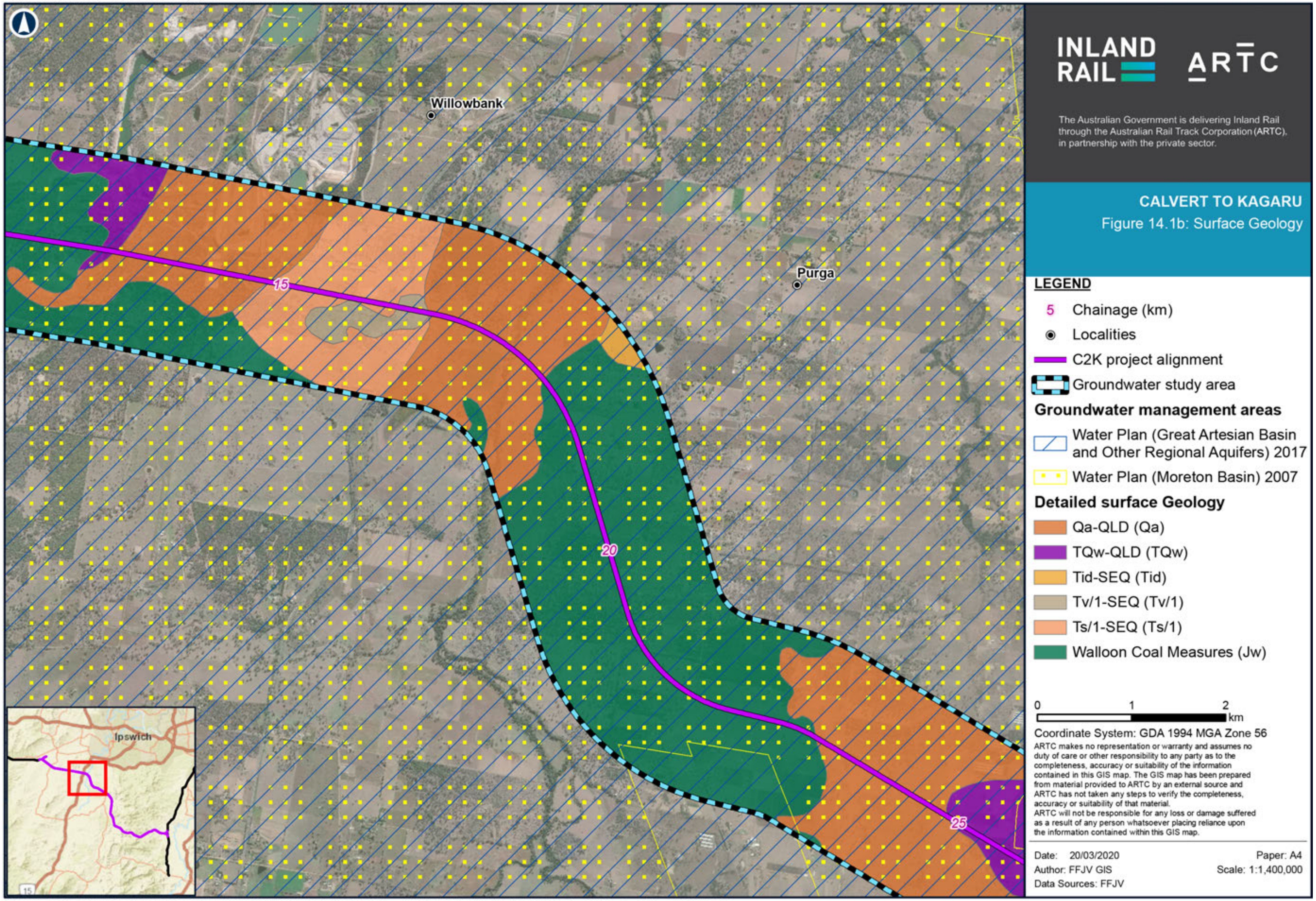

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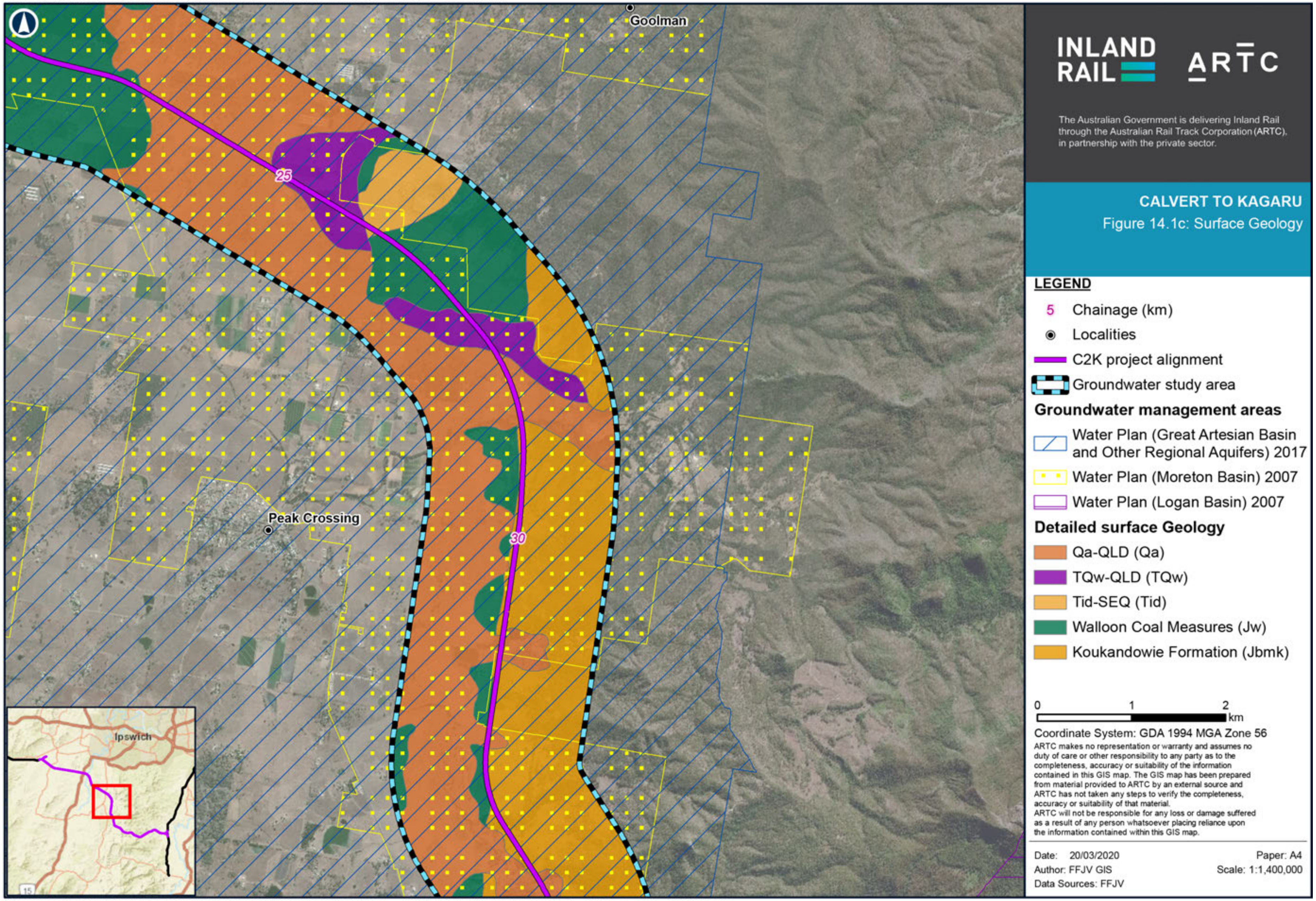

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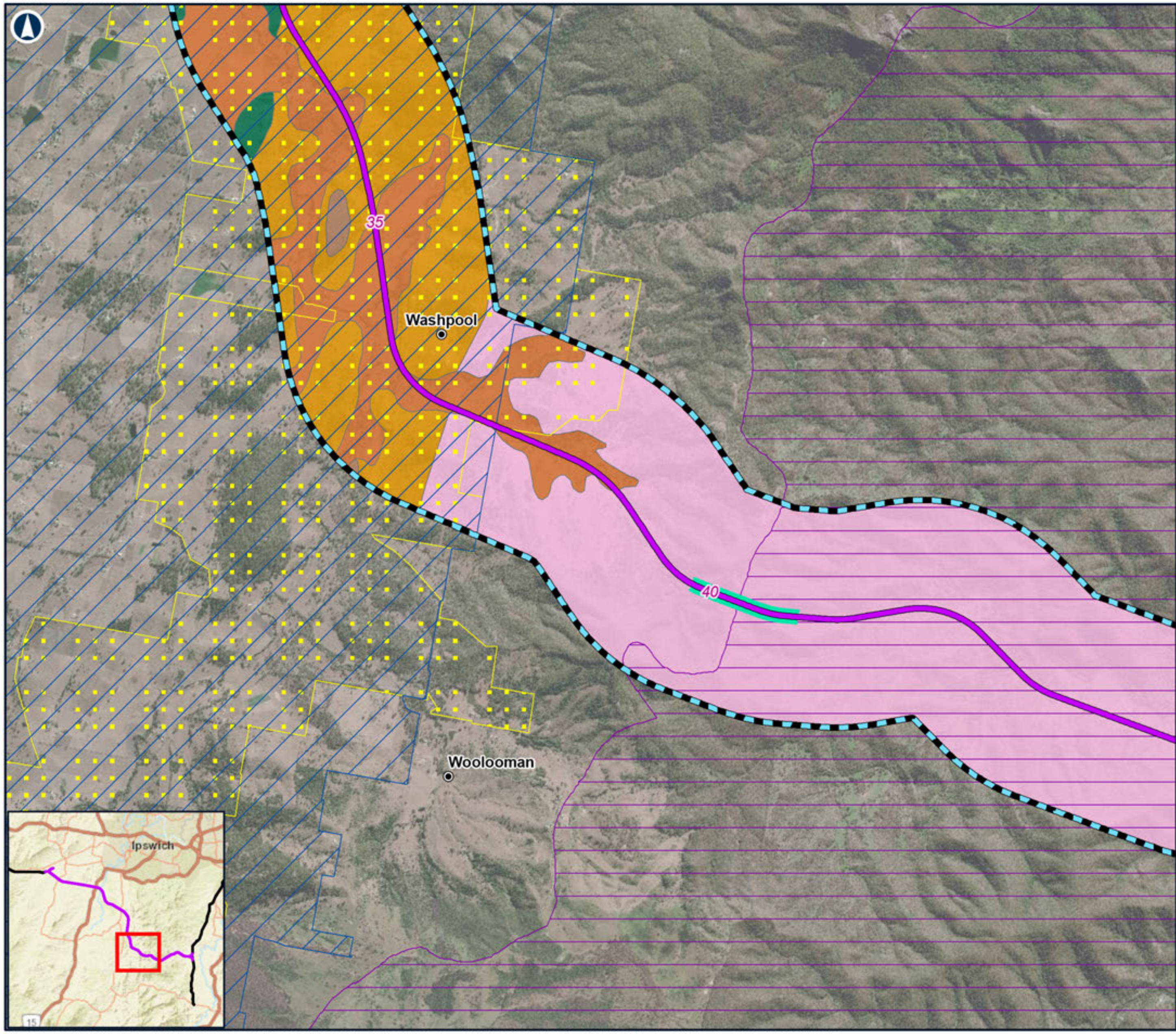

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CALVERT TO KAGARU

Figure 14.1d: Surface Geology

LEGEND

- 5 Chainage (km)
- Localities
- C2K project alignment
- Tunnel
- Groundwater study area

Groundwater management areas

- Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017
- Water Plan (Moreton Basin) 2007
- Water Plan (Logan Basin) 2007

Detailed surface Geology

- Qa-QLD (Qa)
- Tit-SEQ (Tit)
- Walloon Coal Measures (Jw)
- Koukandowie Formation (Jbmk)
- Gatton Sandstone (Jbmg)

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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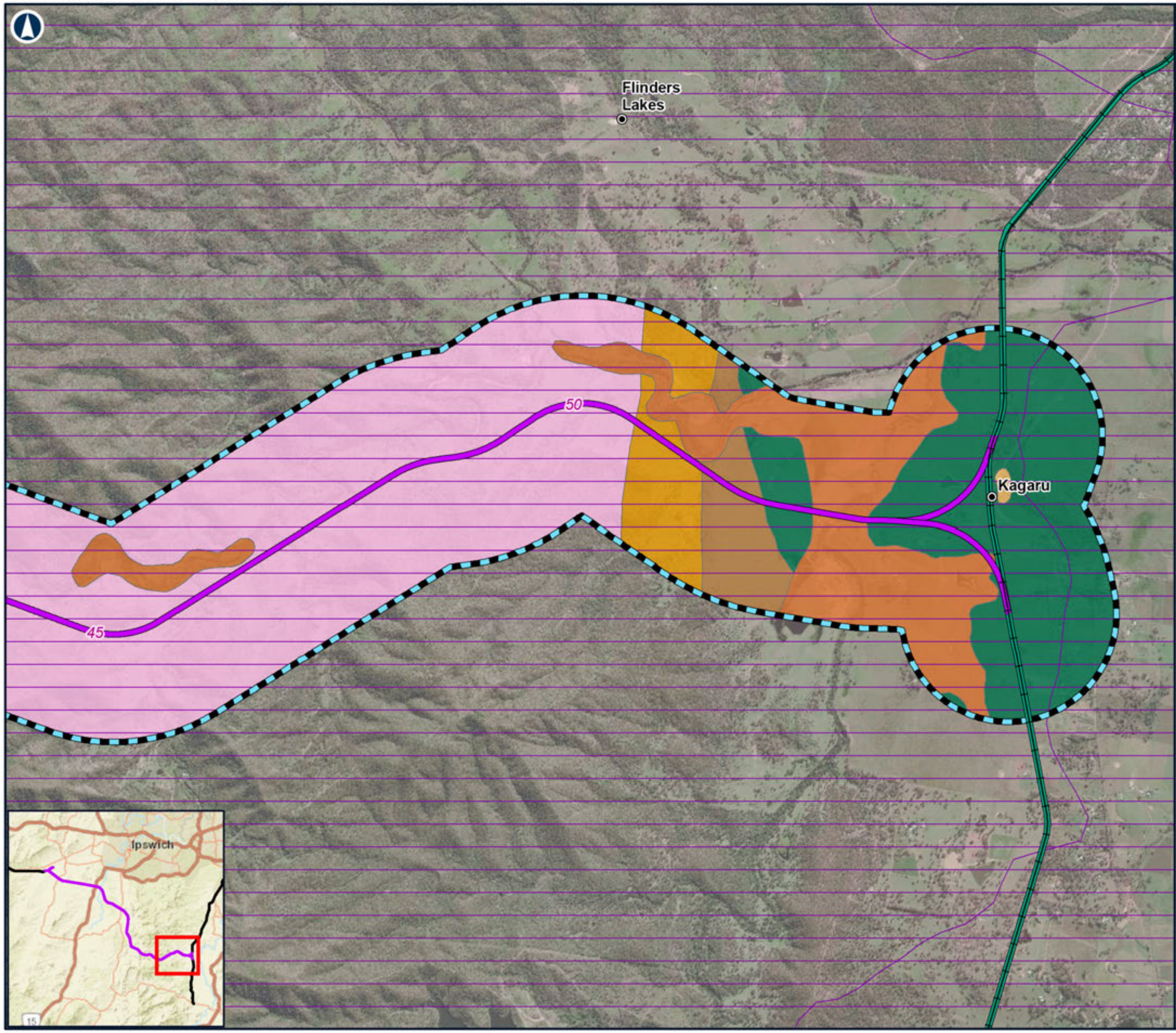

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CALVERT TO KAGARU

Figure 14.1e: Surface Geology

LEGEND

- 5 Chainage (km)
- Localities
- Existing rail
- C2K project alignment
- K2ARB project alignment
- Groundwater study area

Groundwater management areas

- Water Plan (Logan Basin) 2007

Detailed surface Geology

- Qa-QLD (Qa)
- Tv/2-SEQ (Tv/2)
- Heifer Creek Sandstone Member (Jbmkh)
- Walloon Coal Measures (Jw)
- Koukandowie Formation (Jbmk)
- Gatton Sandstone (Jbmg)

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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Each of the stages are described further below.

- **Stage 1—Desktop study**

  Available geological and groundwater data were reviewed to inform a detailed description of the existing hydrogeological regime, identification of groundwater EVs and development of a conceptual groundwater model. A review of publicly available databases, including registered groundwater bores and use, was performed.

  Data sources are discussed further in Section 14.4.3.

- **Stage 2—Geotechnical and hydrogeological site investigations**

  Geotechnical and hydrogeological site investigations along the rail alignment were undertaken by Golder Associates between April and December 2018. Findings to date are provided in the *Geotechnical Factual Report. Inland Rail Project— Calvert to Kagaru—Phase 2 Section 340* (Golder Associates, 2018) and the *Inland Rail Section 340—Calvert to Kagaru Preliminary Hydrogeological Interpretative Report—Feasibility Design Stage* (Golder Associates, 2019), which is included as Appendix A: Calvert to Kagaru Preliminary Hydrogeological Interpretive Report, in Appendix O: Groundwater Technical Report.

  Nine groundwater monitoring bores were installed and eight were developed in accordance with the *Minimum Construction Requirements for Water Bores in Australia* (National Uniform Driller Licensing Committee, 2012). Bore 340-1-BH2226 was not developed due to access issues.

  Groundwater monitoring bores are equipped with 50 mm diameter class 18 PVC screw-jointed pipes with 0.4 mm slotted screens and blank casing. A gravel pack (1 mm to 3 mm washed and graded gravel) was placed in the annulus of the borehole around the screen section, which was then sealed with a bentonite plug. The annular space above the bentonite plug was grouted to the surface where a protective monument or cover was installed.

  Dedicated pressure transducers with automated data logging capability were installed in eight of the nine groundwater monitoring bores for continuous groundwater level monitoring over a time (again Bore 340-1-BH2226 was not tested due to access issues). Measurements were recorded at hourly intervals and calibrated by manual static water level measurements.

  In-situ hydraulic testing using the slug test method was conducted in the eight completed groundwater monitoring bores. The recorded data allows for an estimation of hydraulic conductivity of the screened soil or rock material.

  One round of groundwater sampling was conducted at the eight completed monitoring bores for collection of baseline water quality, durability and salinity parameters. A total of nine samples were collected, with two samples collected at two depths from 340-1-BH2333. The analysed chemical parameters for each sample were as follows:

  - Major anions and cations (calcium, magnesium, sodium, potassium, chloride, fluoride, sulfate, carbonate and bicarbonate alkalinity, hardness)
  - pH, electrical conductivity (EC) and total dissolved solids (TDS)
  - Total and dissolved metals (arsenic, boron, barium, beryllium, cadmium, chromium, cobalt, copper, manganese, iron, nickel, lead, selenium, vanadium, zinc, mercury)
  - Nutrients (nitrate, nitrite, ammonia, reactive phosphorus, total nitrogen, total kjeldahl nitrogen (TKN) total phosphorus)
  - Sodium adsorption ratio.

  Findings from these investigations complement the desktop geological and hydrogeological reviews presented in Section 14.5.

- **Stage 3—Groundwater impact assessment**

  Potential short- and long-term impacts on groundwater (both local and regional) were assessed based on a review of proposed construction and rail operations activities and considering the current geological and hydrogeological setting.

  Results of the geotechnical modelling for the proposed Teviot Range tunnel were reviewed and interpreted to assess potential impacts on groundwater resources due to construction and operation of the tunnel.

- **Stage 4—Significance assessment**

  A qualitative significance assessment was undertaken of the identified potential short- and long-term groundwater impacts (as described in Chapter 4: Assessment Methodology). The sensitivity of the EV and the magnitude of the impacts are the key elements considered to determine significance. The sensitivity of the EV and the magnitude of the impacts were assessed via a significance matrix that defines appropriate significance classifications. These classifications are detailed in Chapter 4: Assessment Methodology.

The predictive modelling undertaken as a component of the geotechnical works has allowed for the assessment of potential impacts on groundwater resources based on sensitivity and magnitude criteria. The hierarchy of avoid, minimise, and mitigate then monitor has been applied in the significance assessment. Evaluation of significance classifications, with initial and proposed mitigation, was then performed, the results of which provide input into a Groundwater Monitoring and Management Program (GMMP).

- **Stage 5—Reporting**

  This groundwater chapter was prepared with factual site-specific and publicly available data, numerical modelling, and interpretation to assess the potential impacts of the Project on groundwater resources. This chapter is to be read in conjunction with Appendix O: Groundwater Technical Report.

Additionally, as part of the assessment methodology a cumulative impact assessment (CIA) was undertaken to identify developments in proximity to the Project in space and time, with potential to impose an additional/incremental impact on groundwater resources within the groundwater study area. That is, an assessment of developments from other existing, planned, or reasonably defined developments that may incrementally impact on the groundwater regime in addition to the Project. The CIA is discussed in Section 14.9 and in further detail within Chapter 22: Cumulative Impacts.

14.4.3 Data sources

Data used in this assessment includes interrogation and review of publicly available information and a Project-specific geotechnical assessment. Regional (catchment) scale studies have also been reviewed to describe the existing groundwater resources to allow for the assessment of the impact of the Project on current groundwater resources.

The description of the existing hydrogeological regime within the groundwater study area and the subsequent groundwater impact assessment is based on the following information sources in Table 14.3.

TABLE 14.3: DATA SOURCES

Data	Source
Hydrology/climate	▸ Historical Climate Database—Bureau of Meteorology (BoM) (**bom.gov.au/climate/data**) ▸ Appendix O: Groundwater Technical Report ▸ *Inland Rail Section 340—Calvert to Kagaru Preliminary Hydrogeological Interpretive Report—Feasibility Design Stage* (Golder Associates, 2019) (refer Appendix O: Groundwater Technical Report (Appendix A: Calvert to Kagaru Preliminary Hydrogeological Interpretive Report)) ▸ *Geotechnical Factual Report. Inland Rail Project—Calvert to Kagaru Section—Phase 2 Section 340* (Golder Associates, 2018) ▸ Queensland Globe datasets (**qldglobe.information.qld.gov.au**)
Soil types	▸ Appendix O: Groundwater Technical Report ▸ *Inland Rail Section 340—Calvert to Kagaru Preliminary Hydrogeological Interpretive Report—Feasibility Design Stage* (Golder Associates, 2019) (refer Appendix O: Groundwater Technical Report (Appendix A: Calvert to Kagaru Preliminary Hydrogeological Interpretive Report))
Geology/ hydrostratigraphy	▸ Appendix O: Groundwater Technical Report ▸ Department of Natural Resources, Mines and Energy (DNRME) Groundwater Database (accessed 14 January 2019) ▸ Queensland Globe datasets (**qldglobe.information.qld.gov.au**)
Groundwater levels and quality	▸ DNRME Groundwater Database (accessed 14 January 2019) ▸ Appendix O: Groundwater Technical Report ▸ *Clarence–Moreton Bioregional Assessment* (May 2014) ▸ *Geotechnical Factual Report. Inland Rail Project—Calvert to Kagaru Section—Phase 2 Section 340* (Golder Associates, 2018) ▸ Queensland Globe datasets (**qldglobe.information.qld.gov.au**)
Groundwater dependent ecosystems	▸ BoM *Groundwater Dependent Ecosystem Atlas* (GDE Atlas): **bom.gov.au/water/groundwater/gde/map.shtml** ▸ *Clarence–Moreton Bioregional Assessment* (May 2014) ▸ Queensland Globe datasets (**qldglobe.information.qld.gov.au**)

Data	Source
Groundwater use and management	▸ DNRME Groundwater Database (accessed 14 January 2019) ▸ Queensland Water Entitlements Database (DNRME) (accessed 12 August 2019) ▸ *Clarence–Moreton Bioregional Assessment* (May 2014) ▸ *Water Plan (GABORA) 2017* ▸ *Water Plan (Logan Basin) 2007* ▸ *Water Plan (Moreton) 2007* ▸ Appendix O: Groundwater Technical Report

14.5 Existing environment

14.5.1 Climate and rainfall

The groundwater study area has a hot and dry climate with warm-to-hot summers and mild-to-cool winters. Rainfall is seasonally distributed, with a distinct wet season, which occurs during the summer months of December through to February and an extended dry season from April through to September. The groundwater study area has an overall negative climate budget, which means that annual evaporation is greater than rainfall.

Long-term rainfall was assessed for the groundwater study area and the followings observations were identified:

- Drought condition from 1995 to 2006 is apparent in consecutive years of below-average rainfall
- At the break of drought, a period of generally above average rainfall was experienced between 2008 and 2011
- Since 2011, rainfall has been relatively stable compared to long-term averages, with the exception of a brief period of lower rainfall between 2013 and 2015.

Further information on climate and rainfall is provided in Section 4.4 in Appendix O: Groundwater Technical Report.

14.5.2 Hydrostratigraphy

The surface geology across the groundwater study area is illustrated in Figure 14.1. Much of the groundwater study area is located to the west of the Teviot Range (approximately Ch 0 to Ch 35) and is underlain by silty sandstone, mudstone and siltstone of the Jurassic-aged Walloon Coal Measures.

Relatively thin deposits of Quaternary alluvial sediments, including clays, silts, sands and gravels are associated with the primary surface water features in the groundwater study area, inclusive of Western Creek, Bremer River, Warrill Creek, and Purga Creek, which flow through the western extent of the groundwater study area. The alluvial sediments are considered limited in extent, both laterally and vertically, away from the watercourses.

Warrill Creek is supplemented by Moogerah Dam, which is a large reservoir on Reynolds Creek in the upper Warrill Creek catchment. It has a catchment area of 226 km^2 (25 per cent of the catchment area flows to Amberley). The dam has an uncontrolled spillway into Warrill Creek, which can result in recharge of the Warrill Creek Alluvium during significant rainfall events. Further information regarding Moogerah Dam is provided in Chapter 13: Surface Water and Hydrology.

The central portion of the groundwater study area (approximately Ch 35 to Ch 50) is underlain by the Gatton Sandstone formation, which forms the topographic high known as the Teviot Range.

The eastern extent of the groundwater study area (approximately Ch 50 to end) is underlain by the interbedded sandstones and siltstones of the Koukandowie Formation and Walloon Coal Measures, which are overlain in some parts by alluvial sediments associated with Teviot Brook.

The primary groundwater bearing units relevant to the Project are summarised in Table 14.4. The ability of these units to transmit groundwater is determined in large part by its permeability (or the hydraulic conductivity). The higher the permeability, the more readily it can transmit groundwater. An aquifer is a unit that transmits water relatively easily due to its higher permeability (for example sands and gravels, or fractured rock), compared to an aquitard that stores groundwater but cannot readily transmit water due to its low permeability (for example clays, silts and unfractured bedrock).

TABLE 14.4: GROUNDWATER OCCURRENCE WITHIN THE STUDY AREA

Hydrostratigraphic unit		Main occurrences	Approximate proportion of alignment	Thickness[1]	Lithology	Comments
Quaternary alluvium		Mainly west of Teviot Range. Associated watercourses include Bremer River, Warrill Creek and Purga Creek. Small deposit east of Teviot Range associated with Teviot Brook	32%	Up to approximately 30 m	Clay, silt, sand and gravel; in a generally fining upward sequence	Aquifer (unconfined)
Tertiary volcanics and intrusives		Minor occurrences west of Teviot Range (e.g. Ch 14.9 to Ch 16.6, and Ch 24.8 to Ch 26.2).	7%	Various	Basalts, rhyolite, dolerite and gabbro	Aquifer (unconfined)
Walloon Coal Measures		Mostly west of Teviot Range. Outcrops between watercourses and sub-crops beneath alluvial sediments. Small outcrop and sub-crop east of Teviot Range.	28%	400 to 600 m	Lithic and silty sandstone with interbedded mudstone and siltstone and numerous coal seams and carbonaceous coal shales	Aquifer/ Aquitard
Marburg Subgroup[2] (subdivided into the lower Gatton Sandstone and the upper Koukandowie Formation)	Koukandowie Formation	Parallel to, and abutting, the Teviot Range (i.e. immediately east and west)	12%	>1,000 m	Interbedded sandstone, siltstone, claystone and minor coal	Low permeability aquifer/ aquitard
	Gatton Sandstone	The Teviot Range. Includes proposed tunnel section.	21%		Medium- to coarse-grained sandstone	Low permeability aquifer/ aquitard

Table notes:

1. Values have been taken as the regional maximum thickness from Raiber et al. (2016); however, the aquifer thickness within the groundwater study area is thinner and shown in Figure 6 in Appendix O: Groundwater Technical Report.
2. Marburg Subgroup—undifferentiated relates to the subgroup in general and is not subdivided into the Koukandowie Formation or Gatton Sandstone.

14.5.3 Groundwater occurrence

The water table is typically a subdued version of topography, with the depth to groundwater increasing beneath topographic highs (for example the Teviot Range), and shallower groundwater in lower lying reaches (such as close to surface water drainage lines). The presence of shallow aquitards, surface water features, and groundwater extraction would locally affect depths to groundwater.

The water table occurs in the alluvial sediments or outcropping Walloon Coal Measures across much of the groundwater study area west, and east, of the Teviot Range. The Gatton Sandstone of the Teviot Range forms the upper (water table) aquifer in the central portion of the groundwater study area.

A summary of groundwater level data in the groundwater study area is provided in Table 14.5 and includes:

- Data from the DNRME groundwater database bores with recent results (i.e. 2017/2018)
- 2016 data for three monitoring bores installed during a preliminary geotechnical investigation (Jacobs–GHD 2016a)
- 2018 data available for eight monitoring bores installed along the alignment as part of the ongoing geotechnical investigation (and reported in Appendix O: Groundwater Technical Report (Appendix A: Calvert to Kagaru Preliminary Hydrogeological Interpretive Report)).

TABLE 14.5: GROUNDWATER LEVEL DATA

Bore ID	Aquifer	Groundwater elevation* (mAHD)	Depth to groundwater (mbNS)	Screen interval (mbNS)	Location
14310262	Western Creek Alluvium	42	6	10.7 to 18.3	100 m north-west of Western Creek. 1.2 km east north-east of Western Creek rail loop crossing Refer Figure 14.2a
14310144	Western Creek Alluvium	43	5	8.5 to 13.7	850 m north-west of Western Creek. 1.5 km northeast of Western Creek rail loop crossing Refer Figure 14.2a
14310066	Bremer River Alluvium	34	8.5	14.5 to 17.4	280 m north of Bremer River Crossing (Ch 6.3) Refer Figure 14.2a
14310245	Warrill Creek Alluvium	23	10	12 to 18.6	530 m west of Warrill Creek crossing at Ch 17.6 Refer Figure 14.2b
14310223	Walloon Coal Measures	34	20	84 to 96	500 m west of Purga Creek crossing at Ch 23.4. Screened below alluvial sediments Refer Figure 14.2b
14310224	Walloon Coal Measures	45.2	10.8	16 to 23	250 m south-west of Ch 27.8. Screened below alluvial sediments Refer Figure 14.2b
14310277	Purga Creek Alluvium	52.4	2.7	11.3 to 18	390 m east of Purga Creek, and 590 m west of Ch 31.2 Refer Figure 14.2c
BH-04	Koukandowie Formation	73.4	12.1	10.9 to 16.9	Approximately Ch 31.1 Refer Figure 14.2c
BH-05	Gatton Sandstone	82.6	16.9	18.97 to 24.97	Approximately Ch 44.8 Refer Figure 14.2e

Bore ID	Aquifer	Groundwater elevation* (mAHD)	Depth to groundwater (mbNS)	Screen interval (mbNS)	Location
BH-07	Gatton Sandstone	117.8	20.2	29.5 to 35.5	Approximately Ch 39.8 Refer Figure 14.2d
340-1-BH2101	Gatton Sandstone	146	72	112 to 124	Approximately Ch 40.0 Refer Figure 14.2d
340-1-BH2215	Alluvium	23	9	19 to 25	Approximately Ch 17.4 Refer Figure 14.2b
340-1-BH2220	Koukandowie Formation	39	9	16 to 25	Approximately Ch 25.4 Refer Figure 14.2b
340-1-BH2224	Walloon Coal Measures	65	9	16 to 25	Approximately Ch 35.2 Refer Figure 14.2d
340-1-BH2225	Alluvium	69	1	19 to 25	Approximately Ch 36.6 Refer Figure 14.2d
340-1-BH2226	Koukandowie Formation	Not available	Not available	17 to 26	Approximately Ch 37.2 Refer Figure 14.2d
340-1-BH2229	Koukandowie Formation	47	7	11 to 20	Approximately Ch 46.4 Refer Figure 14.2e
340-1-BH2233	Alluvium and Gatton Sandstone	23	9	16 to 25	Approximately Ch 52.8 Refer Figure 14.2e
340-1-BH2303	Gatton Sandstone	73	18	22 to 31	Approximately Ch 35.0 Refer Figure 14.2d

Table notes:

* Indicative recent groundwater elevation based on review of hydrographs
BH-0x series from 2016 preliminary geotechnical investigation (Jacobs–GHD, 2016a)
340-1-BH222x series from 2018 geotechnical investigation (Golder Associates, 2019)
mAHD = Australian Height Datum in metres
mbNS = metres below natural surface

Regional mapping indicates a mean groundwater depth of 5 m to 15 m in the Bremer River Basin alluvium for a wet period in 2008 to 2012 (Raiber et al., 2016). This is generally consistent with the limited 2018 data for alluvial aquifers indicating depths to groundwater of less than 10 m. It is expected that shallow groundwater in the alluvial sediments will typically occur in low-lying areas near to watercourses where fill/embankments and/or bridges are proposed, with no cuttings proposed through the alluvial sediments.

Regional-scale mapping of the Walloon Coal Measures indicates a potentiometric surface of around 40 mAHD likely to be expected in the groundwater study area, generally consistent with registered bores RN14310223 and RN14310224 data. In the main areas of outcrop from Ch 8 to Ch 13 and Ch 18 to Ch 23 (refer Figure 14.1), the water table is expected to be at least 5 mbNS and greater than 10 m below higher relief, based on the limited data available and topographical profile of the proposed alignment.

There is no DNRME groundwater level data available for the Koukandowie Formation and Gatton Sandstone (i.e. Teviot Range section) in the groundwater study area. However, three geotechnical bores were converted to monitoring wells during a preliminary geotechnical investigation in 2016 (Jacobs–GHD, 2016a). A groundwater depth of 12.1 mbNS was recorded in June 2016 at monitoring bore BH-04 (Koukandowie Formation), corresponding to an approximate groundwater elevation above the proposed base of cut in this location. It is possible, therefore, that cuts in the alignment from around Ch 29 to Ch 36 could intersect groundwater, although this is based on one data point only (BH-04).

Monitoring bores BH-05 at Ch 44.8 (refer Figure 14.2e), and BH-07 at Ch 39.8 western portal (refer Figure 14.2d) were screened in the Gatton Sandstone. At BH-05 the groundwater elevation indicates the potential for groundwater to be intersected by the proposed cut along this section of the alignment. The groundwater elevation at BH-07 was also higher than the floor elevation of the proposed western portal of the Teviot Range Tunnel, which indicates groundwater inflows will occur in this area, and throughout the tunnel section.

For assessment of potential groundwater inflows and drawdowns for the tunnel and portals, groundwater in the Gatton Sandstone was assumed to be unconfined with the groundwater level (water table) depicted as a subdued version of the Teviot Range topography (refer Appendix O: Groundwater Technical Report).

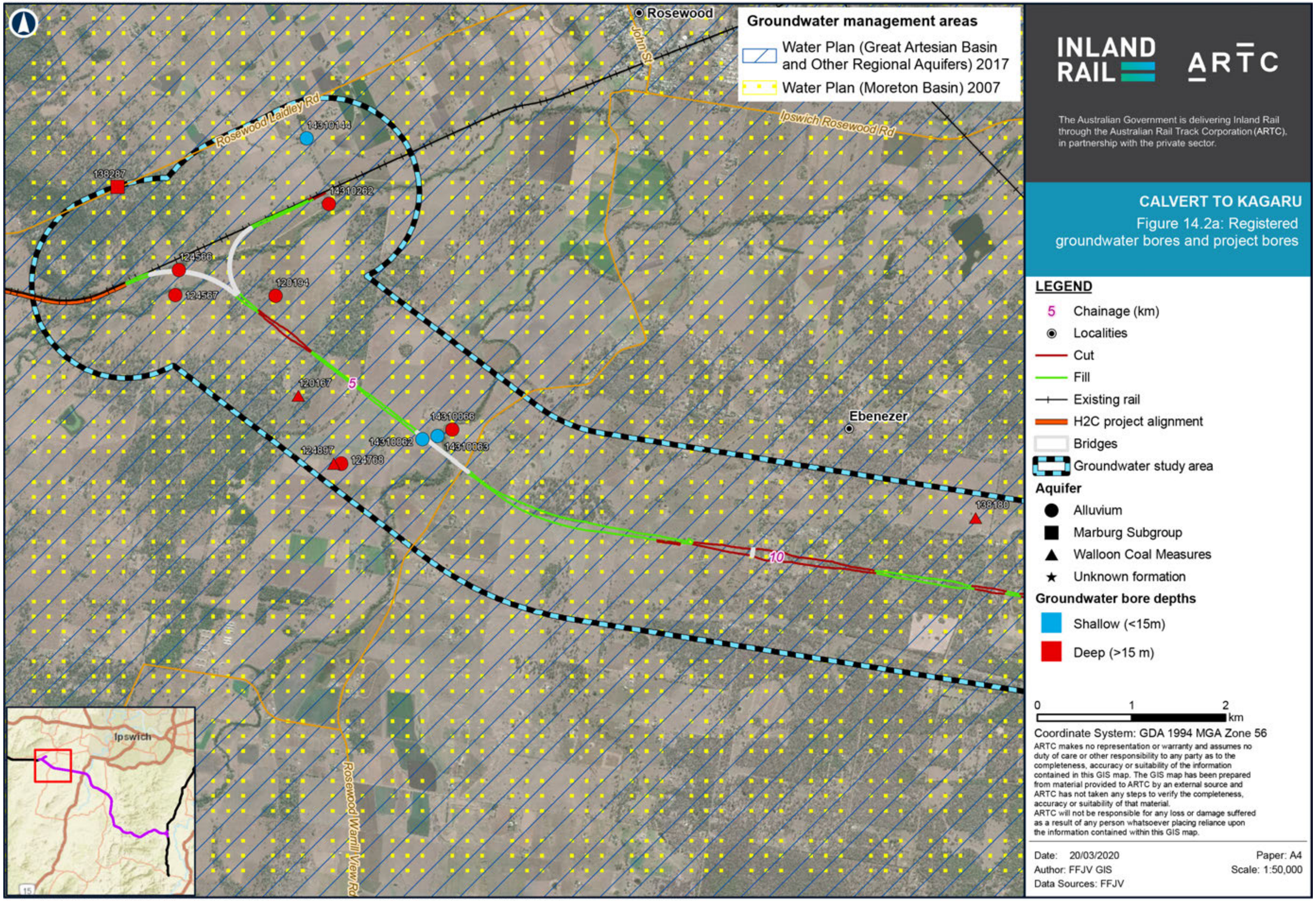
Where groundwater levels are above the base of cut elevations, consideration will be required with respect to potential geotechnical implications (such as wall failure and floor heave), salt residues caused by evaporation of low seepage rates, reduced groundwater levels and flow affecting groundwater users (that is at groundwater bores and GDEs), and the quality of groundwater discharge (for example to surface water courses). It is noted the 2018 geotechnical monitoring bores 340-1-BH2224 and 340-1-BH2303 (refer Figure 14.2d) were constructed near a proposed cutting, with all others targeting bridges (six bores) and the tunnel (one bore).

Intermediate and regional groundwater flow systems in alluvial sediments are inferred to be towards the north-east and north through the western part of the groundwater study area, following the associated rivers and creeks as they drain towards the Brisbane River. East of the Teviot Range, groundwater flow within the alluvial sediments is inferred to be northward through the groundwater study area as the Teviot Brook drains to the Logan River. Local groundwater flow systems are influenced by surface water–groundwater interaction where there is a hydraulic connection.

The regional potentiometric surface of the Walloon Coal Measures shows that groundwater flow is generally east and north-east towards the eastern margin of the Clarence–Moreton Basin (Raiber et al., 2016). As basin sediments thin and terminate against basement rocks, groundwater likely discharges to surface at the eastern margins and is expressed as discharge into the Bremer River or as wetlands and/or springs beyond the groundwater study area.

Mapping of Gatton Sandstone groundwater elevations indicate that regional groundwater flow is inferred to the north-east beneath the Bremer River Basin (Raiber et al., 2016). The potentiometric surface indicates that lower groundwater elevations correspond to alluvial sediments; this suggests that these act as regional discharge areas for the underlying Clarence–Moreton Basin sedimentary sequence. In the groundwater study area, the Gatton Sandstone outcrops as the Teviot Range where groundwater flow direction is influenced by a groundwater divide that coincides with the main ridge line. Deeper groundwater will follow regional flow directions, with shallow local groundwater flow influenced by discrete groundwater discharge areas.

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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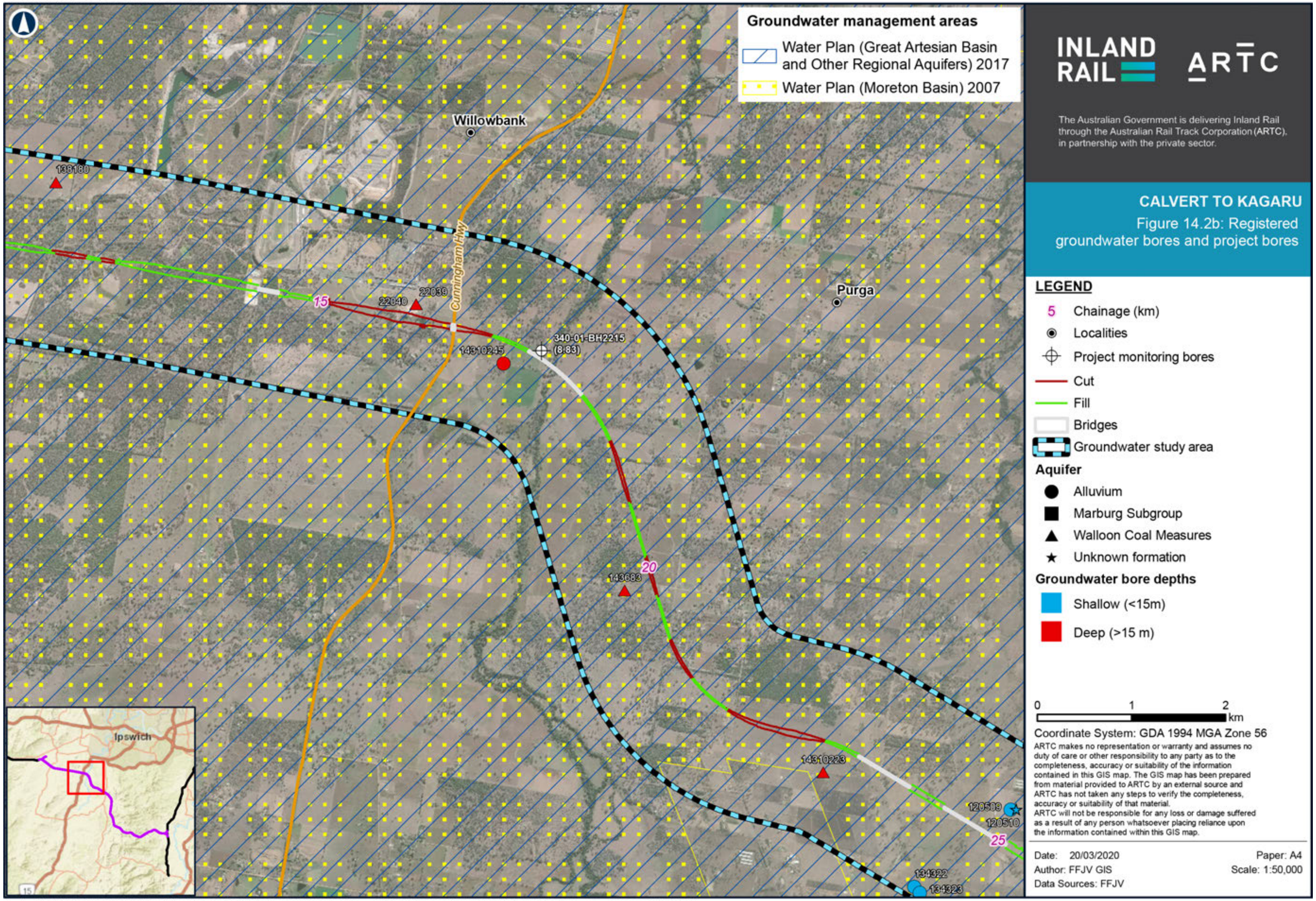

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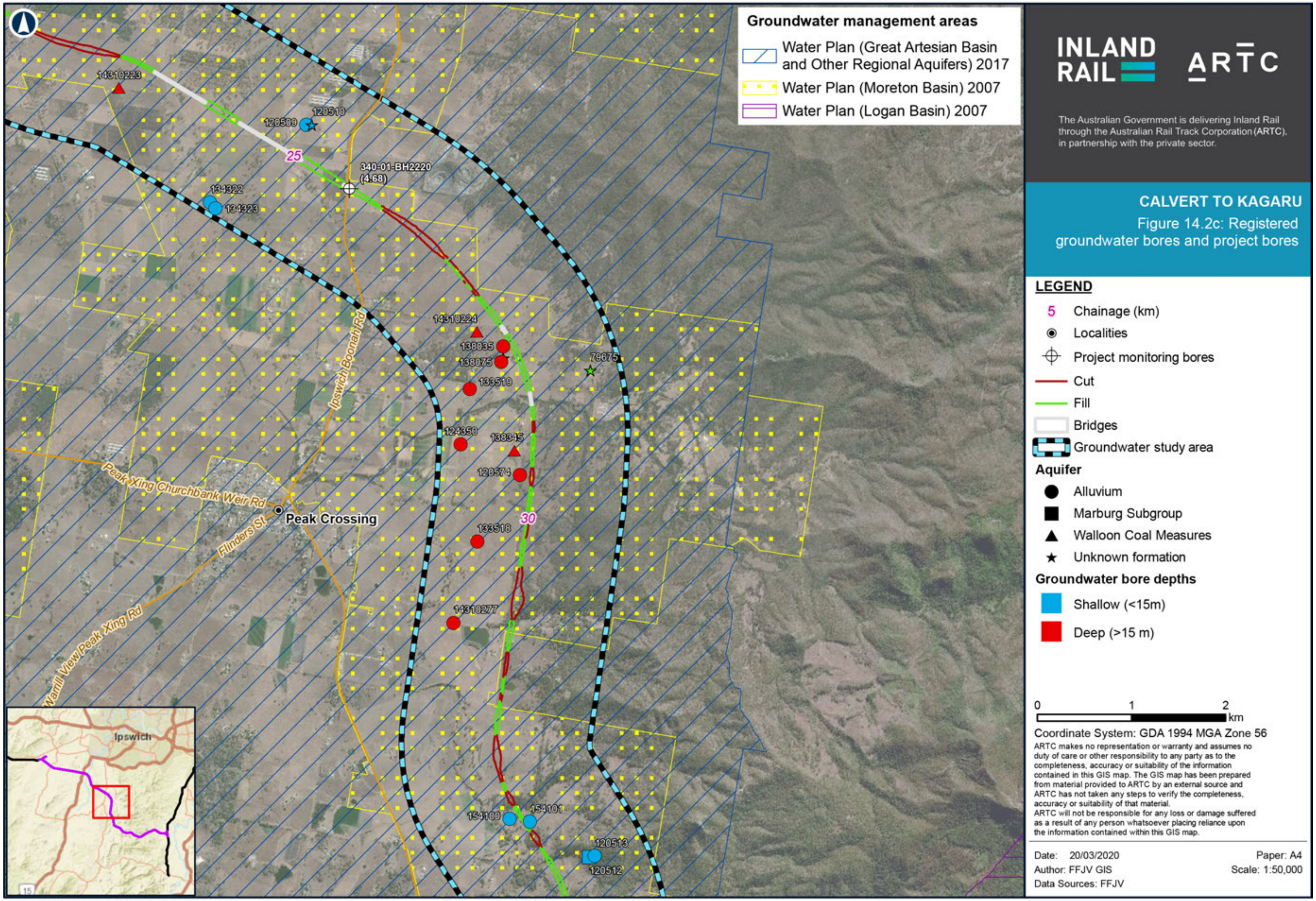

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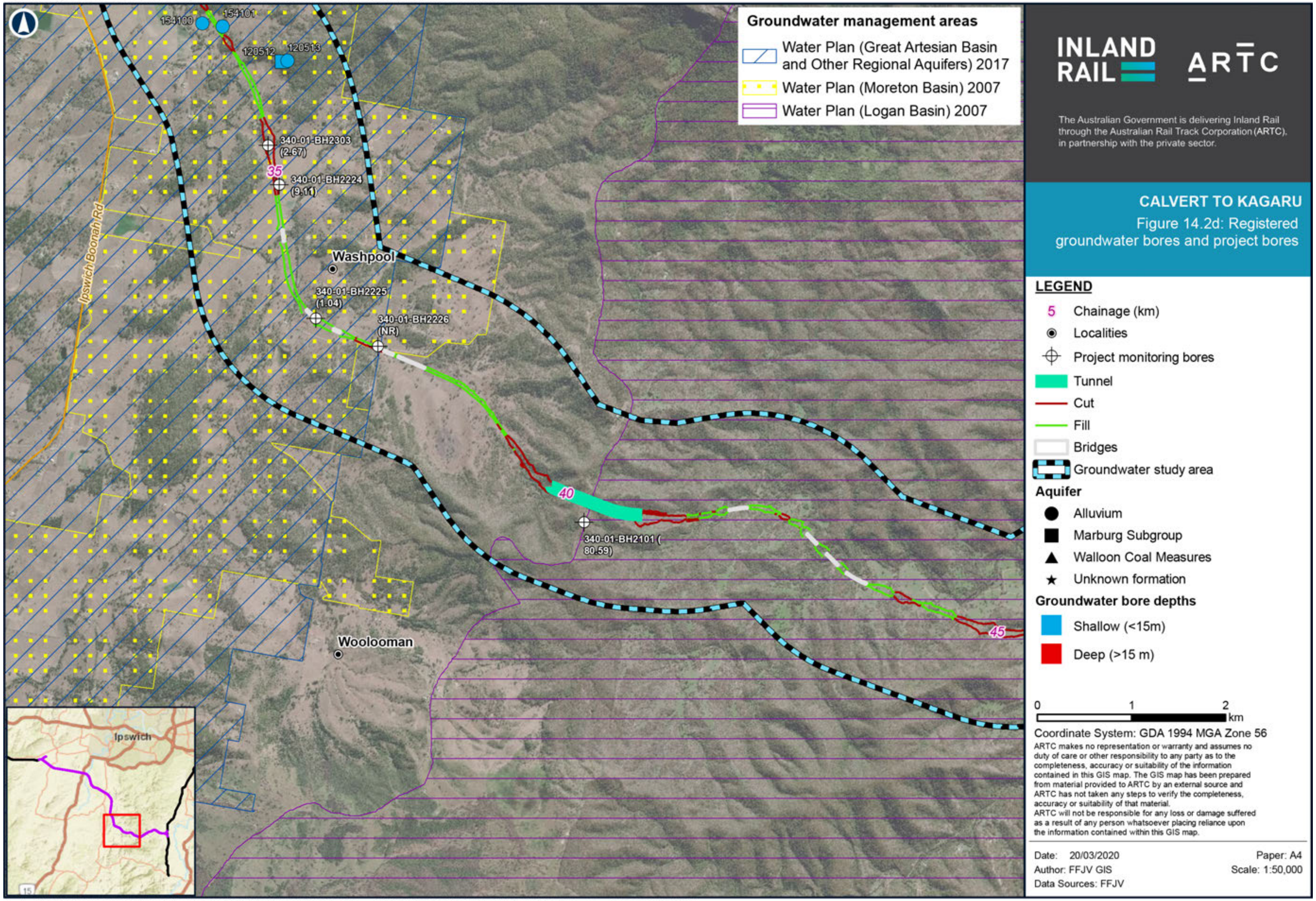

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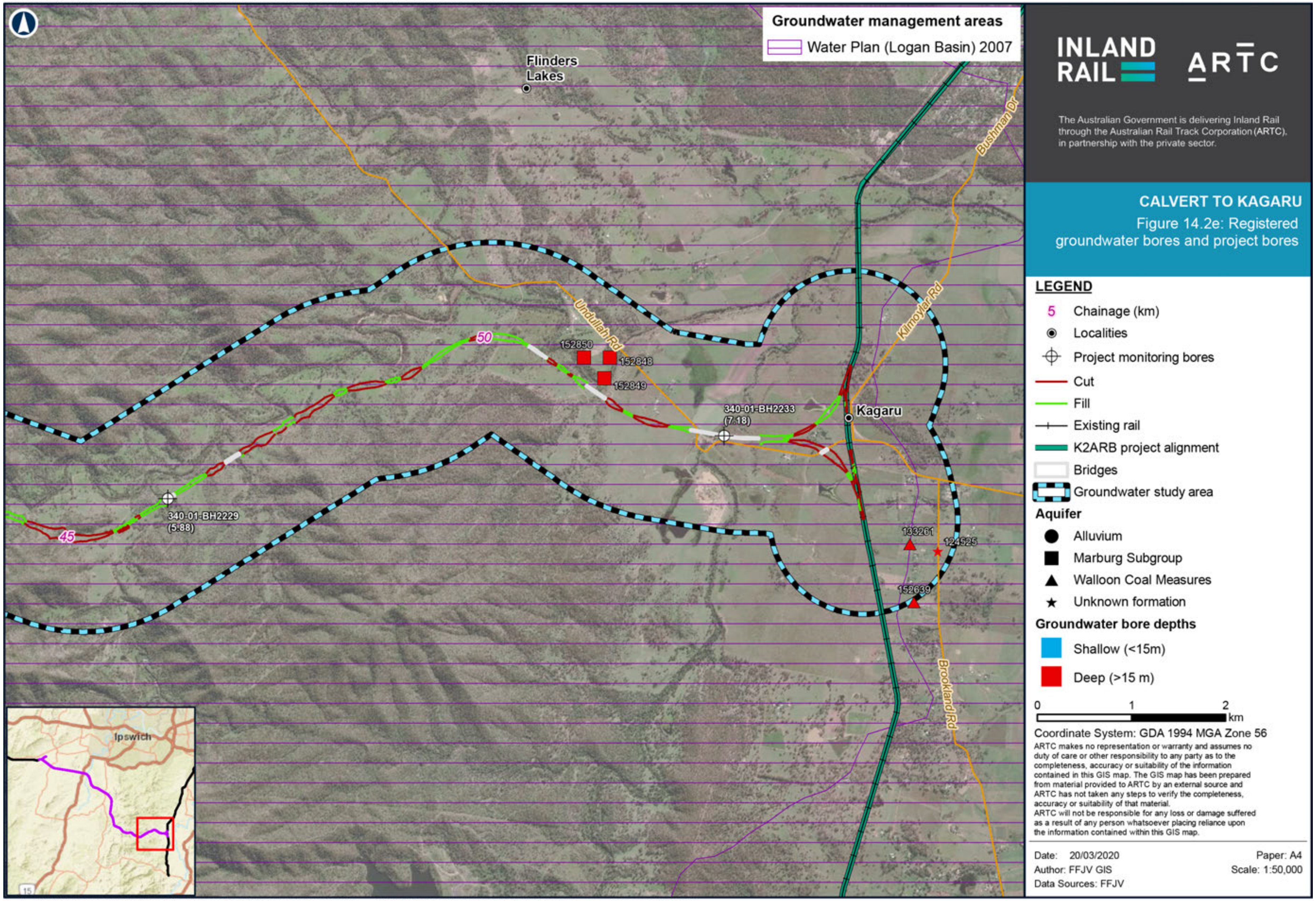

CALVERT TO KAGARU
Figure 14.2e: Registered groundwater bores and project bores

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14.5.4 Groundwater quality and yields

14.5.4.1 Groundwater quality

The quality of groundwater is often considered in terms of its salinity (or concentration of salt in water) and can be used to indicate the suitability of the water for various uses (for example, drinking water, stock, irrigation etc.). EC and/or TDS are typically used to indicate salinity. EC is a measure of how well an aqueous solution can carry an electrical current and reported as micro siemens per centimetre (µS/cm). This can be converted to an estimated TDS value by using a conversion factor. TDS (sometimes referred to as 'salinity') is an estimate of the mass of dissolved solids (salts) within the water and typically expressed as milligram per litre (mg/L). The higher the EC or TDS, the higher the salinity of the water. By way of comparison, a TDS of less than 500 mg/L is considered 'fresh', 1,000 to 2,000 mg/L is described as 'brackish' and 2,000 to 10,000 mg/L is 'saline'.

Groundwater in the alluvial sediments is generally fresher than the underlying sediments (primarily the Walloon Coal Measures in the groundwater study area). Groundwater in the Bremer River and Warrill River alluvium gradually becomes more saline (i.e. the quality decreases) down gradient, likely due to increasing influence of the underlying Walloon Coal Measures in the lower reaches (including within the groundwater study area) and longer residence time (that is, further from points of recharge). Groundwater quality is expected to vary seasonally, where rainfall events can flush the aquifer and result in lowered salinity.

Water quality in the bedrock sediments varies from fresh to saline across the region due to lithological variability, relative position in the basin, recharge processes, depth, and surface water interaction (Rassam et al., 2014).

An assessment of salinity and EC in the Clarence–Moreton Basin was provided by Rassam et al. (2014) based on multiple references and data sets. A summary is provided in Table 14.6, together with data from bores within the groundwater study area, where available.

TABLE 14.6: SUMMARY OF GROUNDWATER SALINITY—REGIONAL

	Salinity (milligrams per litre (mg/L)			EC (µS/cm)			
Aquifer unit	**Minimum**	**Mean**	**Maximum**	**Minimum**	**Mean**	**Maximum**	**Study area**
Alluvium (Bremer River and Warrill Creek)	~500	-	~6,350	500	2,508[#]	1,000	2,100; 2,200; and 2,300 µS/cm Purga Creek Alluvium 1,370 µS/cm (median) Bremer River Alluvium 9,650 µS/cm (median) Warrill Creek Alluvium 3,000 µS/cm (median) Western Creek Alluvium
Walloon Coal Measures	1,500	750[#]	19,475	3,000	8,554[#]	6,000	3,990 and 23,200 µS/cm
Koukandowie Formation	359	4,248	14,496	-	6,607	-	13,500 µS/cm (Koukandowie Formation)
Gatton Sandstone	333	6,452	24,294	-	9,971	-	300; 2,812 and 4,000 µS/cm (Marburg Subgroup – undifferentiated)

Table notes:

The table has been sourced from Rassam et al. (2014); however, the source cites various sources including Mckibbin (1995), Metagasco (2007) and Pearce et al. (2007). As a result, the mean appears to be higher than the minimum; however, this is a reflection of two difference data sources being used.

One groundwater monitoring event was completed across September and October 2018, as a component of the overall geotechnical investigations (July through October 2018), at eight of the geotechnical site investigation monitoring bores. This monitoring event provides a baseline water quality data set along sections of the alignment that could help to inform a future GMMP, as presented in Section 14.7.3. A summary of the laboratory results for EC and TDS is provided in Table 14.7.

TABLE 14.7: SUMMARY OF GROUNDWATER SALINITY—SITE INVESTIGATIONS

Bore ID	Formation sampled	TDS (mg/L)	EC (µS/cm)
340-1-BH2101	Gatton Sandstone	5,990	10,200
340-1-BH2215	Alluvium	487	782
340-1-BH2220	Koukandowie Formation	8,950	13,000
340-1-BH2224	Walloon Coal Measures	1,230	2,230
340-1-BH2225	Alluvium	1,720	2,250
340-1-BH2229	Koukandowie Formation	357	760
340-1-BH2233[1]	Alluvium	528	916
	Gatton Sandstone	2,780	4,290
340-1-BH2303	Gatton Sandstone	1,150	2,020

Table notes:
1. BH2233 was sampled at 10 mbNS and 23 mbNS

Source: Golder Associates (2018)

TDS and EC ranges are generally consistent with the findings of Rassam et al. (2014) for the wider Clarence–Moreton Basin and show the same variability for the various formations. Samples were collected from two depths at bore 340-1-BH2233, which is identified in Appendix O: Groundwater Technical Report as being screened across alluvium and underlying Gatton Sandstone. The samples collected using a manual bailer seem to suggest distinct TDS/EC values in the bore profile, possibly coinciding with the two groundwater systems/aquifers.

14.5.4.2 Groundwater yields

It is likely that yields from bores in the alluvium will vary considerably across the groundwater study area due to the variable extent and nature of alluvial sediments, which can vary from coarse gravels to silty clays.

Regional studies have reported yields from the Walloon Coal Measures to be, on average, 0.5 litres per second (L/sec) with a maximum recorded of 5 L/sec (Rassam et al., 2014). In general, yields from bedrock sediments in the groundwater study area are likely to be relatively low, but dependent on the lithology intersected (sandstone, siltstone, mudstone etc.) and frequency, size, and interconnectivity of fractures.

Individual bore yield estimates will also be affected by the available drawdown, bore construction, and capacity of the pump used during testing.

Yields are generally low for bores in the groundwater study area, with all but two outliers below 1.6 L/sec (i.e. 80 per cent). The outliers were for a bore in the Purga Creek Alluvium (4.38 L/sec) and Western Creek Alluvium (12.6 L/sec). A summary of yields by aquifer is provided in Table 14.8.

TABLE 14.8: STUDY AREA BORE YIELDS

		Yield (L/sec)		
Aquifer unit	No. of bores	Minimum	Mean	Maximum
Alluvium	8	0.25	2.85	12.60
	6[1]	0.25	0.97	1.60
Walloon Coal Measures	9[2]	0.13	0.43	1.23
Marburg Subgroup (Undifferentiated)	4	0.13	0.53	1.00

Table notes:
1. Two 'outliers' removed
2. One unknown aquifer considered likely to be Walloon Coal Measures

14.5.4.3 Groundwater quality summary

Available groundwater quality data in the groundwater study area was tabulated into Table 14.9 to compare the quality of the aquifers within the groundwater study area. As a general overview of water quality in each aquifer zone, the analytical results were compared with the *Australian Drinking Water Guidelines* (NHMRC & NRMMC, 2018) and the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG, 2018) for livestock drinking water guidelines. Analytes identified as exceeding guideline values include:

- TDS exceeds the *Australian Drinking Water Guidelines* and ANZG livestock drinking water guidelines across all aquifers
- Hardness exceeds the *Australian Drinking Water Guidelines* within the Walloon Coal Measures
- Chloride exceeds the *Australian Drinking Water Guidelines* in all aquifers
- Sulfate exceeds the *Australian Drinking Water Guidelines* in the Western Creek alluvium and Walloon Coal Measures
- Sodium exceeds the *Australian Drinking Water Guidelines* in all aquifers
- Calcium exceeds the ANZG livestock drinking water guidelines in the Walloon Coal Measures
- Zinc exceeds the *Australian Drinking Water Guidelines* in the Warrill Creek alluvium.

TABLE 14.9: COMPARISON OF GROUNDWATER QUALITY DATA TO GUIDELINE VALUES IN THE GROUNDWATER STUDY AREA

	Guidelines		Bremer River Alluvium (n = 7)			Warrill Creek Alluvium (n = 3)			Western Creek Alluvium (n = 5)			Walloon Coal Measures (n = 2)		
Parameter	ANZG* (2018)	ADWG** (2018)	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max	Median
Physiochemical														
Electrical conductivity (µS/cm)	-	-	990	4,858	1,370	983	11,000	9,650	646	11,400	3,000	3,990	23,200	13,595
pH value (pH units)	-	6.5–8.5	7.2	8.3	7.9	7.3	7.4	7.4	6.7	8.0	7.4	7.6	7.6	7.6
Turbidity (NTU)	-	-	1	347	169	22	1427	94	149	1,239	694	20	84	52
Hardness as CaCO3 (mg/L)	4,000	6,000	305	1,800	529	311	3,540	3,237	187	2,140	965	279	6,540	3,410
Alkalinity (mg/L)	-	-	340	554	438	292	598	395	117	1150	504	172	651	412
Sodium adsorption ratio	-	-	1.3	10	1.8	2	7.1	7.1	1.2	18	2.7	19	20	19.5
Total Dissolved Solids (mg/L)	2,000[b]	600	527	2,630	792	539	6,040	5,690	293	7,120	1,638	2,250	16,000	9,125

Parameter	Guidelines		Bremer River Alluvium (n = 7)			Warrill Creek Alluvium (n = 3)			Western Creek Alluvium (n = 5)			Walloon Coal Measures (n = 2)		
	ANZG* (2018)	ADWG** (2018)	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max	Median
Dissolved anions														
Bicarbonate (mg/L)	-	-	415	676	518	355	727	479	143	1,380	615	207	788	498
Carbonate (mg/L)	-	-	0.9	8.1	3.1	0.6	1.7	1.2	3.7	6.9	5.3	1.4	3	2.2
Chloride (mg/L)	-	250	100	1,362	213	143	3,460	3,393	117	3,180	720	956	9,500	5,228
Fluoride (mg/L)	2	1.5	0.07	0.25	0.1	0.04	0.11	0.08	0.1	0.25	0.13	0.1	0.2	0.15
Sulfate as SO4 (mg/L)	1,000	250	1	30	6.5	3.7	46	44.6	1	741	5.95	10	822	416
Dissolved cations														
Sodium (mg/L)	-	180	70	402	88	79.5	965	923.8	37.4	1,890	175.4	783	3,490	2,137
Potassium (mg/L)	-	-	1	5.8	1.9	0.9	8.2	7.7	0.6	4.8	2.1	3.9	33	18.45
Iron (mg/L)	-	0.3	-	-	0.01[a]	-	-	-	-	-	0.01[a]	-	-	0.01[a]
Calcium (mg/L)	1,000	-	20	366	99	66.8	725	632.2	32.6	262.6	104	49	1,010	530
Magnesium (mg/L)	-	-	47	216	68	35	421	403.6	25.8	462	113	38	976	507
Nutrients														
Phosphate (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrogen (mg/L)	-	-	1	30	3.2	1.3	24.8	10	1.3	6	1.5	2.5	25	13.75
Dissolved metals														
Zinc (mg/L)	20	3	0.01	0.03	0.025	0.05	4.8	0.54	0.32	0.53	0.425	-	-	0.01[a]
Aluminium (mg/L)	5	0.2	0.05	0.05	0.05	0.05	0.08	0.065	0.02	0.07	0.045	0.05	0.05	0.05
Boron (mg/L)	5	4	0.02	0.02	0.02	-	-	0.04[a]	-	-	0.34[a]	0.43	0.54	0.485
Copper (mg/L)	0.5	2	0.01	0.03	0.03	0.01	0.03	0.02	-	-	0.03[a]	-	-	0.03[a]

Table notes:

Data source: Section 9.3 Livestock Drinking Water Guidelines (ANZG, 2018); Table 10.6 Guideline values for physical and chemical characteristics (NHMRC and NRMMC, 2018)

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

** *Australian Drinking Water Guidelines* (NHMRC & NRMMC, 2018)

a. Only single data value available

b. Most conservative guideline value out of the range provided in Table 9.3.3 of *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*.

14.5.5 Hydraulic properties

A summary of hydraulic conductivity values is provided in Table 14.10 for units relevant to the groundwater study area, based on:

- A review of aquifer parameters and pumping test data carried out by Raiber et al. (2016) for hydrostratigraphic units in the Clarence–Moreton Basin
- A further review of hydrogeological parameters by Golder Associates (2018)
- Site-specific slug tests conducted in October and November 2018 at eight groundwater monitoring bores constructed during the geotechnical site investigation.

TABLE 14.10: SUMMARY OF HYDRAULIC CONDUCTIVITY VALUES

	Literature review (Raiber et al., 2016)		Literature review (Golder Associates, 2019)		Slug tests (Golder Associates, 2018)	
Formation	No. of bores	Hydraulic conductivity (m/day)	No. of tests	Hydraulic conductivity (m/day)	No. of tests[1]	Hydraulic conductivity (m/day)
Alluvium	193	0.09 to 1,500	96	0.09 to 1,470	2	0.01 to 0.85
Walloon Coal Measures	7	0.5 to 17.2	79	0.0002 to 0.95	1	0.20 to 0.54
Marburg Subgroup (undifferentiated)	8	0.03 to 5.8		-	-	-
Marburg Subgroup: Koukandowie Formation	-	-	26	0.004 to 0.82	2	0.007 to 1.7
Marburg Subgroup: Gatton Sandstone	2	1.1 to 4.9	80	0.00009 to 0.071	1	0.0001 to 0.0003

Table notes:
1. Results for seven bores included. 34001-BH2233 screened across two formations not included.

All formations exhibit a wide range of hydraulic conductivity values, typical of fractured aquifer systems and the heterogeneity of alluvial sediments.

It is expected that hydraulic conductivities in the upper portions of the alluvium, most relevant to the Project scope, will be at the lower end range provided in Table 14.10 due to a fining-upwards sequence of gravels and coarse sands at the base, and fine-grained flood-plain sediments at the top.

14.5.6 Groundwater users

14.5.6.1 Registered bores

A desktop survey of registered groundwater bores was conducted via a search of the DNRME groundwater database (undertaken online 14 January 2019). This provides information on the location, depths and aquifer of registered bores. Where licensed groundwater extraction exists for registered bores these are identified, noting that no entitlement (permit to take water) is required for domestic and stock watering use.

A total of 65 groundwater bores were identified within 1 km either side of the proposed rail alignment. Of the 65 identified, 43 are reported as existing and 22 reported as abandoned. It should be noted that bores constructed prior to 2002 were not required to be registered with DNRME and, as a result, the DNRME groundwater database is not a complete record of bores within the groundwater study area; however, it is the most accurate and recent information available publicly. A groundwater bore survey will be required during the detailed design phase to capture all groundwater bores within the groundwater study area.

Key attributes for the 43 registered bores are included in Table 14.11 and bore locations in proximity to the alignment are depicted in Figures 14.2a–e.

14.5.6.2 Groundwater entitlements

Part of the groundwater study area is managed under either the *Water Plan (GABORA) 2017* or *Water Plan (Moreton) 2007*. The QLD water entitlements database (DNRME) (accessed 12 August 2019) was reviewed for bores with extraction licences (licences are only required for bores with extraction other than domestic and stock watering purposes) for bores within either Plan. The database search indicated there were no such bores within 1 km of the Project. Therefore, the Project is not expected to impact on existing water plans.

Groundwater users in the groundwater study area taking groundwater for purposes other than stock or domestic from aquifers managed under either water plan (GABORA or Moreton) at the commencement of the groundwater management plans are authorised to continue taking groundwater. No licences have been issued to such bores in the groundwater study area. Therefore, a groundwater survey and property inspections can determine if any authorised users are located in the study area.

TABLE 14.11: EXISTING REGISTERED GROUNDWATER BORES WITHIN 1 KM EITHER SIDE OF RAIL LINE

Bore ID	Use	Drilled depth (mbNS)	Bore depth (mbNS)	Screen top (mbNS)	Screen base (mbNS)	Aquifer	Yield (L/s)	Quality
14310144	-	18.59	12.8	8.5	13.7	Western Creek Alluvium	-	Brackish to saline
14310262	Water resources investigation / subartesian monitoring	19.8	19.2	10.7	18.3		-	-
124566	Water supply	18	18	12.5	17.8		3	Fresh
124567	Water supply	21	21	12	20.9		1	Fresh
120194	Water supply	22	22	16.2	21.7		12.6	Fresh
14310062	-	15.24	14.4	13.4	14.3	Bremer River Alluvium	-	Slightly brackish
14310063	-	13.71	12.2	11.3	11.9		-	Fresh to slightly brackish
14310066	-	18.89	16.8	14.5	17.4		-	Fresh to slightly brackish
124768	Water supply	18	18	12	18		1.25	Brackish
14310245	Subartesian monitoring	19.6	19.6	12	18.6	Warrill Creek Alluvium	-	Brackish to saline
134322	Water supply	14.7	14.7	7.5	14.7		-	-
134323	Water supply	14.7	14.7	11.4	14.3		-	-
14310277	Water resources investigation/ subartesian monitoring	19	18	11.3	18	Purga Creek Alluvium	-	Slightly brackish
133518	Water supply	17.1	17.1	11.4	-		1.6	Slightly brackish (2,200 µS/cm)
154100	Water supply	14.6	14.6	3	-		0.6	Slightly brackish (2,300 µS/cm)
154101	Water supply	11.5	11.5	10	11		0.25	Slightly brackish (2,100)
120509	Water supply	11	11	8.5	11		1.37	Brackish
120513	-	10	10	7.6	10		-	Fresh
124350	Water supply	17.4	17.4	5	17.4		4.38	-
120574	Water supply	18	18	12	18	Sandy Creek Alluvium[1]	0.75	-
133519	Water supply	17	17	14	17		1.9	-
138035	Water supply	29	28.9	23	28.9		-	Brackish
138075	Water supply	23	21.2	7	21.2		-	Brackish
14310223	Subartesian monitoring	100	97.4	85.4	97.4		-	Brackish to saline

Bore ID	Use	Drilled depth (mbNS)	Bore depth (mbNS)	Screen top (mbNS)	Screen base (mbNS)	Aquifer	Yield (L/s)	Quality
14310224	Subartesian monitoring	24	23	16	23	Walloon Coal Measures	0.25	Brackish
124897	Water supply	32	32	24	32		0.31	Brackish
133261	Water supply	30.3	30.3	18.3	30.3		0.29 (coal) 0.41 (gravel)	Potable to brackish
138180	Water supply	147	147	135	147		0.65 (sandstone) 0.14 (coal)	Brackish to saline
22039	-	87.78	-	66	-		-	Salty
22040	-	195.07	-	46.77	-		-	-
120167	Water supply	57	57	45	57		0.35	Brackish
138345	Water supply	120	32	20	32		1.23	Brackish (3,700 µS/cm)
143683	Water supply	30	30	18	30		0.4	Brackish
152639	Water supply	30	30	13	30-		0.13 to 0.88	Brackish
138287	Water resources investigation	38	38	28	34	Koukandowie Formation	-	Saline (13,500 µS/cm)
152848	Water supply	36.7	36	22.6	28.6	Marburg Subgroup[2]	0.13	Brackish (4,000 µS/cm)
152849	Water supply	24.5	18.1	11.1	17.1		0.5	Fresh (300 µS/cm)
152850	Water supply	30	28.8	16	27.8		1 to 2	Good
120512	Water supply	10	10	8	10		0.5	Brackish (2,812 µS/cm)
79675	Water supply	-	-	-	-	-	-	Fresh
120510	Water supply	12.9	12.9	9.9	12.9	-	-	Slightly brackish
138034	-	-	-	-	-	-	-	-
124525	Water supply	59	59	15 47	21 59	Coal	0.23 to 0.47	Potable

Table notes:
1 Possibly equivalent to Upper Tributary of Purga Creek
2 Includes Koukandowie Formation (upper unit) and Gatton Sandstone (lower unit)
'-' Data not reported
mbNS metres below Natural Surface

14.5.7 Groundwater dependent ecosystems

The *GDE Atlas* (BoM, 2020) was developed as a national dataset of Australian GDEs. The *GDE Atlas* contains information about:

- Aquatic ecosystems: reliant on the surface expression of groundwater and includes surface water systems (freshwater only), which may have a groundwater component (i.e. rivers, springs and wetlands)
- Terrestrial ecosystems: reliant on the subsurface presence of groundwater and includes all vegetation ecosystems
- Subterranean ecosystems: such as caves and aquifer ecosystems.

It is important to note that the *GDE Atlas* mapping is from two broad sources:

- National assessment—national-scale assessment based on a set of rules that describe potential for groundwater/ecosystem interaction and available GIS data
- Regional studies—more detailed assessment by states and/or regional agencies using approaches included field work, analysis of satellite imagery and application of rules/conceptual models.

The identification of potential GDEs in the *GDE Atlas* does not confirm that the ecosystem is groundwater dependent; this is confirmed by undertaking an ecological investigation to identify the location, extent and source of the GDE. Ground truthing of GDEs was not possible due to land access conditions therefore the modelled extent of the aquatic GDEs are accepted as true presence, and thus form a potentially sensitive receptor.

14.5.7.1 Aquatic groundwater-dependent ecosystems

Numerous watercourses traversing the groundwater study area are designated as moderate potential GDEs from regional studies (as defined in the *GDE Atlas*) including Western Creek, Bremer River, Warrill Creek, Purga Creek and Teviot Brook. The potential GDEs are described as wetlands '*supplied by alluvial aquifers with near-permanent flow*'.

No springs were observed during ecological field assessments for the Project associated with surface water or identified from the *GDE Atlas* (BoM, 2020) within the study area. Noting this, several first order streams intersect the Project alignment and may be associated with natural springs.

14.5.7.2 Terrestrial groundwater-dependent ecosystems

Within the groundwater study area, to the west and east of the Teviot Range, several moderate, potential terrestrial GDEs from regional studies (as defined in the *GDE Atlas*) are either intersected or are close to the proposed alignment. These are described as wetlands or riparian vegetation '*supplied by alluvial aquifers with near-permanent flow*'.

Low and moderate potential terrestrial GDEs (from regional studies) have been identified within the Teviot Range portion of the groundwater study area. These GDEs are generally described as wetland vegetation supplied by low-porosity sedimentary rock with intermittent flow. Wetlands supplied by alluvial aquifers with near permanent flow (eastern flank) and riparian vegetation supplied by sedimentary rocks with saline flow (western flank) are also indicated.

14.5.8 Surface water–groundwater interaction

The groundwater study area is located within the Clarence–Moreton bioregion assessment area where strong evidence of interaction between groundwater and surface water has been reported (Raiber et al., 2016). This supposition is based on several lines of evidence including assessment of groundwater and surface water quality, streamflow time-series data, groundwater hydrographs and streambed elevation.

It is anticipated that there will be interaction between watercourses and shallow groundwater in the associated alluvial sediments at some locations, particularly where drainage channels are more deeply incised and groundwater levels are shallow. The degree of interconnection will vary laterally due to local variations in alluvial sediment lithology, underlying bedrock geology and drainage channel morphology, as well as seasonally due to changes in groundwater elevations.

At times, watercourses may change from gaining systems (receiving baseflow from shallow groundwater) to losing systems (with surface water locally recharging the alluvial sediments).

An assessment of surface water–groundwater interaction in the Bremer River Basin found that hydraulic connection between the aquifer and river was relatively poor and of limited lateral extent (Raiber et al., 2016). This was thought to be linked to the broad valley of the Bremer River and limited depth of incision into the underlying alluvial sediments, with upper sections typically fine-grained clay rich floodplain sediments.

Details on existing and constructed waterbodies adjacent to the alignment is provided in Chapter 13: Surface Water and Hydrology.

14.5.9 Groundwater environmental values

The quality of QLD waters (including water in rivers, streams, wetlands, lakes and groundwater) is protected under the EPP (Water and Wetland Biodiversity). It provides a framework for identifying the EVs and establishing water quality guidelines and objectives to enhance or protect QLD waters.

This section identifies and describes groundwater-related EVs within the groundwater study area. For the purposes of this assessment the 'values', as defined in the EPP (Water and Wetland Biodiversity), are those attributes of the groundwater systems within the groundwater study area that are sufficiently important to be protected or enhanced.

The following relevant sub-areas of the EPP (Water and Wetland Biodiversity) were identified in accordance with Schedule 1:

- The western part of the groundwater study area (Ch 0 to Ch 40): in the Bremer River area, part of the Brisbane basin, with relevant EVs described in Bremer River environmental values and water quality objectives (Department of Environment and Resource Management (DERM), 2010a)
- The eastern part of the groundwater study area (Ch 40 to Ch 56): in the Logan River area, part of the South Coast basin, with relevant EVs described in Logan River environmental values and water quality objectives (DERM, 2010b).

EVs for groundwater to be protected or enhanced in the groundwater study area, as prescribed by Schedule 1 (EPP (Water and Wetland Biodiversity)), are listed in Table 14.12.

TABLE 14.12: ENVIRONMENTAL VALUES OF GROUNDWATER

Environmental value	Definition
Aquatic ecosystems	'*A community of organisms living within or adjacent to water, including riparian or foreshore area*' (EPP (Water and Wetland Biodiversity). The intrinsic value of aquatic ecosystems, habitat and wildlife in waterways and riparian areas. For example, biodiversity, ecological interactions, plants, animals, key species (such as turtles, platypus, seagrass and dugongs) and their habitat, food and drinking water. Waterways include perennial and intermittent surface waters, groundwaters, tidal and non-tidal waters, lakes, storages, reservoirs, dams, wetlands, swamps, marshes, lagoons, canals, natural and artificial channels and the bed and banks of waterways.
Irrigation	Suitability of water supply for irrigation. For example, irrigation of crops, pastures, parks, gardens and recreational areas.
Farm water supply/use	Suitability of domestic farm water supply, other than drinking water. For example, water used for laundry and produce preparation.
Stock watering	Suitability of water supply for production of healthy livestock.
Drinking water supply	Suitability of raw drinking water supply. This assumes minimal treatment of water is required, for example, coarse screening and/or disinfection.
Industrial use*	Suitability of water supply for industrial use—for example food, beverage, paper, petroleum and power industries. Industries usually treat water supplies to meet their needs.

Table notes:
* For Logan River area only (i.e. eastern part of study area)

Stock watering, drinking water and aquatic ecosystems were identified as the only EVs of groundwater relevant to the groundwater study area (refer Appendix O: Groundwater Technical Report).

14.5.10 Conceptual hydrogeological model

Key aspects of the hydrogeological regime within the groundwater study area are summarised below, and a conceptual understanding of the hydrogeology along the proposed alignment west of the Teviot Range is provided in Figure 14.3.

14.5.10.1 Main hydrostratigraphic units

The Project is anticipated to encounter the Walloon Coal Measures and alluvial sediments in low-lying areas between Ch 0.0 and Ch 22.9, and between Ch 53.2 and Ch 56.2 km (refer Figure 14.1).

The main occurrences of alluvial sediments are up to 30 m thick and associated with the Bremer River, Warrill Creek and Purga Creek, and graded from finer to coarser grained sands and gravels with depth. It is expected that the interbedded sandstone, mudstone and siltstone of the Walloon Coal Measures will be confined where they are overlain by alluvial sediments, but will form the upper unconfined (water table) aquifer where they crop out between drainage lines (refer Figure 14.3).

The Project is anticipated to encounter the interbedded sandstones, siltstones and claystones of the Marburg Subgroup (Koukandowie Formation/Gatton Sandstone) in the Teviot Range between Ch 22.9 and Ch 53.2. At the section of the alignment where the Teviot Range tunnel is proposed to be located (between Ch 39.5 and Ch 41.3) the medium-to-coarse grained Gatton Sandstone is locally exposed at the surface or blanketed by a thin layer of soils (refer Figure 14.1).

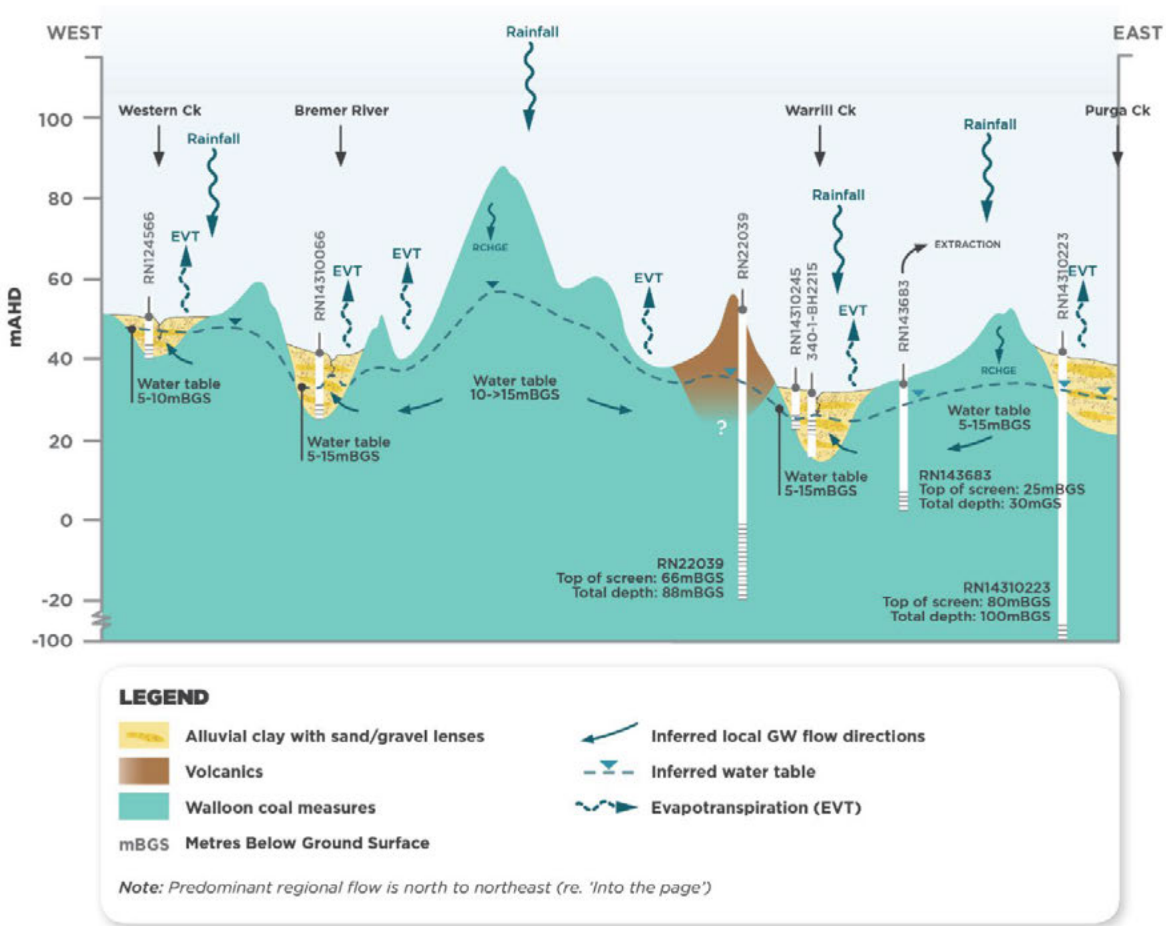

FIGURE 14.3: CONCEPTUAL HYDROGEOLOGICAL MODEL

14.5.10.2 Levels and flow

The water table is typically a subdued version of topography, with the depth to groundwater increasing beneath topographic highs (for example the Teviot Range) and shallower in lower lying reaches (such as close to surface water drainage lines).

The water table occurs in the alluvial sediments or outcropping Walloon Coal Measures across much of the groundwater study area west and east of the Teviot Range (refer Figure 14.3). The Gatton Sandstone of the Teviot Range comprises the upper (water table) aquifer in the central portion of the groundwater study area.

Depths to groundwater in alluvial sediments are anticipated to be between 5 mbNS and 15 mbNS, and typically less than 10 mbNS based on limited data for the groundwater study area. Intermediate and regional groundwater flow systems in alluvial sediments will be north-east and north through the study area, following surface drainage. Local groundwater flow systems will be influenced by surface water–groundwater interaction where there is a hydraulic connection.

Regional-scale mapping indicates groundwater levels of around 40 mAHD in the Walloon Coal Measures, with the water table expected to be at least 5 mbNS and greater than 10–15 mbNS in higher relief areas of outcrop (refer Figure 14.3). The regional potentiometric surface of the Walloon Coal Measures shows that groundwater flow is generally east and north-east towards the eastern margin of the Clarence–Moreton Basin (Raiber et al., 2016). Local groundwater flow will be controlled by topography and interaction with the overlying alluvial sediments.

A maximum water table depth of approximately 60 mbNS was estimated beneath the topographic high forming a groundwater divide (refer Appendix O: Groundwater Technical Report). Regional groundwater flowpaths are north-east beneath the Bremer River Basin (Raiber et al., 2016) with regional-scale mapping of the potentiometric surface (confined groundwater elevation) indicating alluvial sediments act as regional discharge areas for the underlying rock aquifers.

Local groundwater flow direction will be controlled by a groundwater divide coinciding with the main ridge line. Deeper groundwater will follow regional flowpaths with shallow, local groundwater flow paths potentially influenced by discrete groundwater discharge areas expressing as surface features.

14.5.10.3 Recharge

Recharge to alluvial or colluvial materials will be via throughflow in the aquifers from up hydraulic gradient of the groundwater study area (that is, from the south) via direct infiltration of rainfall and by seepage from ephemeral streams during periods of flow following rainfall. Sub-cropping rock below permeable alluvium may also act as a source of recharge where upward vertical hydraulic gradients are present.

Recharge via direct infiltration of rainfall will occur to rock formations along ridgelines where the formations are exposed at the surface or blanketed by a thin layer of soil. Locally perched groundwater may exist where more permeable weathered rock or soils are underlain by low permeable rocks. Throughflow from up hydraulic gradient of the groundwater study area (that is, generally from the south) is also a recharge mechanism in the bedrock aquifers.

Monthly average evaporation exceeds monthly average rainfall and, therefore, direct infiltration of rainfall to groundwater is unlikely during dry periods, when light rainfall events will be absorbed as soil moisture and lost to evapotranspiration. Recharge is likely to occur in response to higher or more continuous rainfall events and overall net recharge rates at the site are expected to be low.

14.5.10.4 Discharge

In areas with alluvial or colluvial materials, discharge out of the groundwater study area is as throughflow of groundwater to the north within the alluvial aquifers. Other discharge mechanisms include evaporation and transpiration from vegetation growing in the creek beds and along the banks, seepage to the underlying units (following flood events) and groundwater extraction.

Discharge mechanisms from the bedrock aquifers are throughflow out of the groundwater study area towards the north, via leakage into the underlying and/or adjacent aquifers, evaporation and transpiration, and as groundwater extraction.

14.6 Potential impacts

14.6.1 Groundwater modelling

A summary of the numerical predictive modelling undertaken to assess potential groundwater ingress and drawdowns associated with a free draining (unlined) Teviot Range tunnel, portals, and cuts is provided in the subsections below; further details are provided in Appendix O: Groundwater Technical Report and the *Inland Rail Section 340—Calvert to Kagaru Preliminary Hydrogeological Interpretative Report—Feasibility Design Stage* (Golder Associates, 2019), which is included as Appendix A: Calvert to Kagaru Preliminary Hydrogeological Interpretive Report, to Appendix O: Groundwater Technical Report.

Based on this methodology and the extent of available data it is considered that the models are Class 1 under the *Australian Groundwater Modelling Guidelines* (Barnett et al., 2012). The guidelines define a Class 1 model as a tool to provide an initial assessment of a problem, which is subsequently refined and improved to higher classes as additional data is gathered (often from further monitoring).

The numerical simulations undertaken in part for this study are considered to be suitable for developing coarse relationships between groundwater extraction locations and rates and associated impacts (Barnett et al., 2012). Further, these models are considered an initial assessment of the Project on groundwater resources. The numerical model will be updated with additional information gathered during the detail design phase.

14.6.1.1 Design assumptions

Preliminary analysis of groundwater inflows and drawdown associated with the drained tunnel and portal cuts are reported as part of the preliminary hydrogeological interpretative assessment (refer Appendix O: Groundwater Technical Report).

Modelling was carried out to support the design, and included the following assumptions:

- Tunnel and portal cuts permanently drained
- Modelled portal cuts and tunnel alignment between Ch 39.15 and Ch 41.35, with tunnel between Ch 39.86 and Ch 40.86
- No lining or grouting works for higher permeability zones associated with faults or increased fracture intensity
- Rock is considered practically impermeable beyond 50 m below the tunnel invert
- Groundwater levels used in the model derived from correlation between topography and water level shown in Figure 14.4.

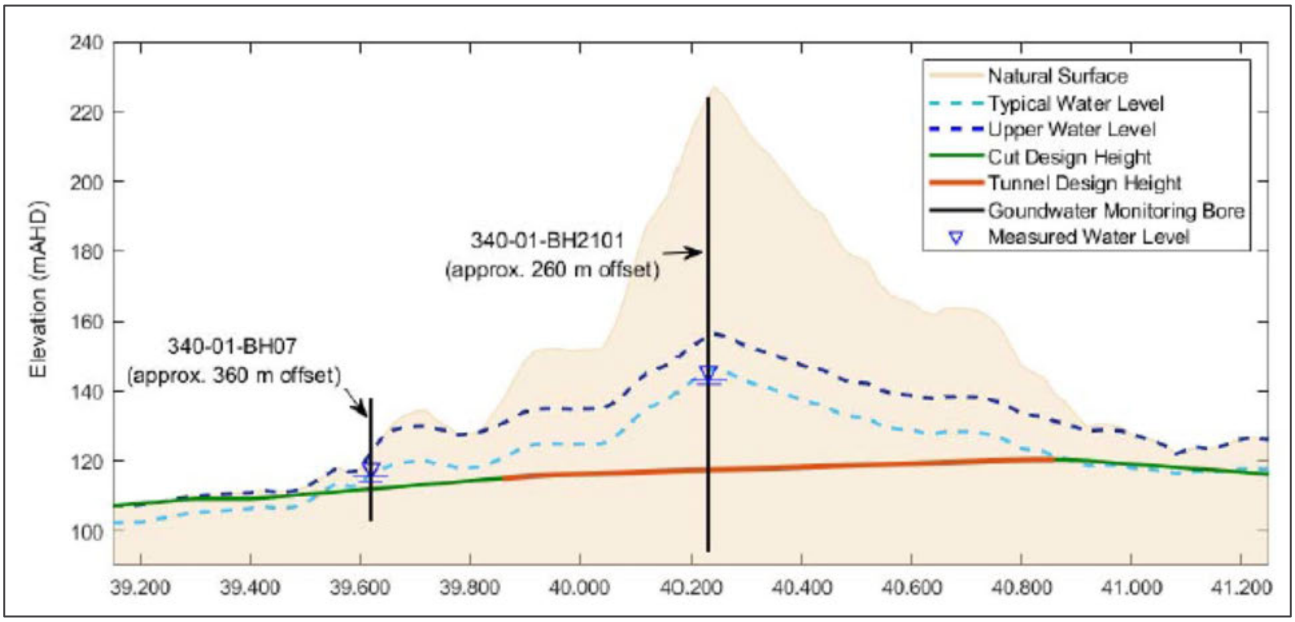

FIGURE 14.4: ESTIMATES OF GROUNDWATER LEVELS PRIOR TO TUNNEL CONSTRUCTION

Source: Golder Associates (2019)

14.6.1.2 Methodology

Groundwater inflows and drawdown were estimated using the Perrochet analytical method and a numerical modelling approach using SEEP/W.

The analytical method allowed simulation of transient discharge into the tunnel, and development of a cross-sectional steady-state numerical model using SEEP/W allowed comparison with results from the analytical method. Assumptions for each method are included in Appendix O: Groundwater Technical Report and summarised below.

Inflow and drawdown analysis using the Perrochet method was based on assumptions including:

- Tunnel excavation will start from west to east at construction rate of 4 m per day over 250 days
- Water inflows to drained tunnel sections along entire length of the tunnel, divided into 20 m intervals
- Homogeneous and isotropic hydraulic characteristics above and below tunnel invert
- Groundwater recharge at a constant rate along the length of tunnel
- Gatton Sandstone with horizontal hydraulic conductivity of 1 x 10^{-8} m/s (8.6. x 10^{-4} m/day).

The inflow and drawdown analysis using the cross-sectional SEEP/W groundwater model was based on assumptions including:

- Modelled cross section at Ch 40.24 km where rock thickness above tunnel crown is maximum
- Three geological units: highly weathered rock, moderately weathered rock and fresh rock
- Constant head boundaries 5 km north and south of the tunnel
- Recharge applied to surface (top boundary) of the model, with rates adjusted to match inferred groundwater levels. Calibrated recharge rates between 1.46 and 3.65 mm/year.
- A regional groundwater flow divide based on the correlation between groundwater level and ground surface elevation
- Horizontal hydraulic conductivity of 5.8 x 10^{-8} m/s (5 x 10^{-3} m/day) to match inferred groundwater levels
- Anisotropy ratio of 100 (horizontal to vertical).

Calibration of the model and changes to model parameters (such as hydraulic conductivity and recharge) were based on matching inferred groundwater levels that were estimated from limited site-specific groundwater data and relied on correlation between groundwater level and ground surface elevation.

Uncertainty analysis was also undertaken for predicted long-term drawdown. Potential effects of pre-existing groundwater levels 10 m higher than base case, and the presence of three higher permeability structural features were assessed. Applying elevated groundwater levels to the model allows an assessment of the effects of climatic conditions and an adequate assessment of potential impacts of the Project on water resources.

Based on this methodology and the extent of available data it is considered that the models are Class 1 under the Australian Groundwater Modelling Guidelines (Barnett et al., 2012). These models are considered an initial assessment of the Project on groundwater resources. The numerical model will be updated with additional information gathered during the detail design phase.

14.6.1.3 Teviot Range tunnel and portals

The Perrochet analytical method was used to predict long-term drawdown due to drainage of the tunnel and portal cuts. Figure 14.5 depicts the predicted drawdown extent and resulted in a 5 m drawdown estimated to extend to approximately 400 m perpendicular to the tunnel, with drawdown contours offset from tunnel alignment (i.e. greater to the south) due to topographic effects and inferred initial condition groundwater levels.

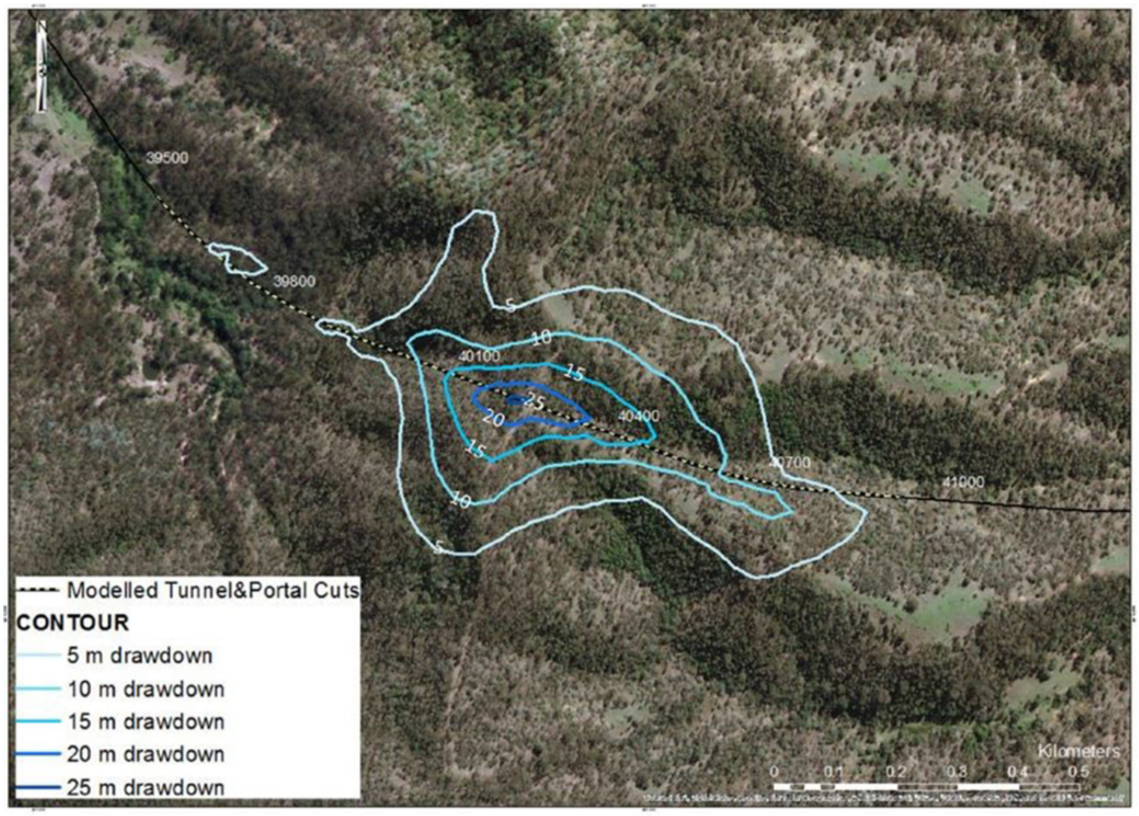

FIGURE 14.5: PREDICTED WATER TABLE DRAWDOWN EXTENT DUE TO DRAINAGE OF THE TUNNEL

Source: Golder Associates (2019)

Long-term drainage was anticipated to reduce groundwater levels below the ridge, to the tunnel invert elevation. This was considered to have the potential to impact deep-rooted trees in areas of lower topography near portal cuts and to the north and south of the tunnel (Golder Associates, 2019).

Cross-sectional drawdown estimates were generally comparable between the Perrochet and SEEP/W methods (refer Figure 14.6).

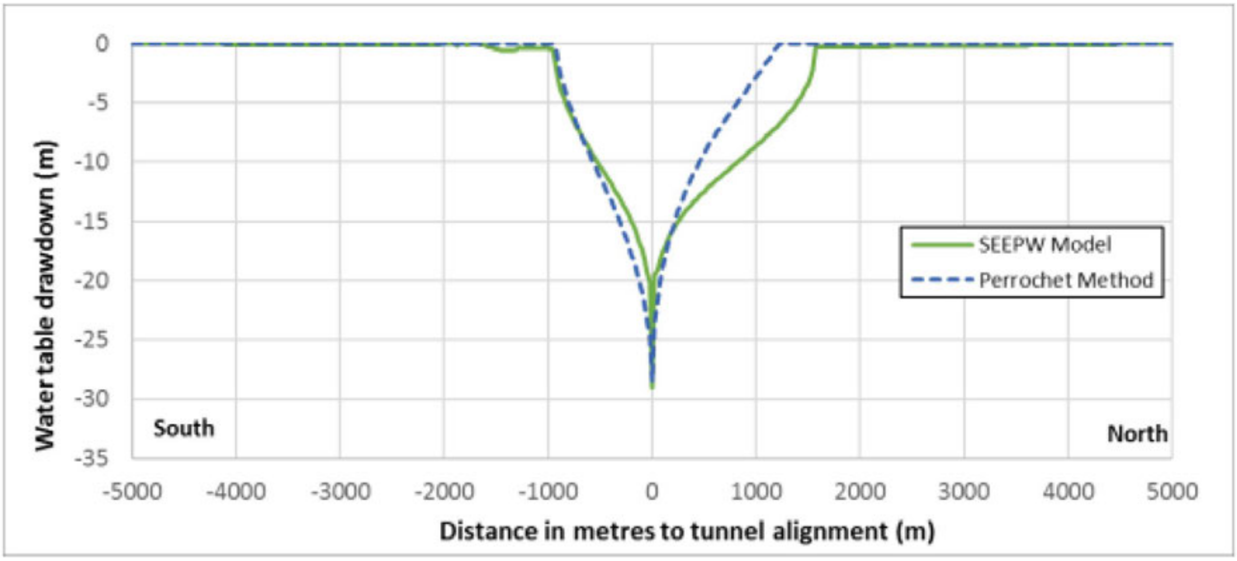

FIGURE 14.6: MODELLED DRAWDOWN COMPARISON

Source: Golder Associates (2019)

Uncertainty analysis was also undertaken for predicted long-term drawdown based on the Perrochet analytical method. Potential effects of pre-existing groundwater levels 10 m higher than base case, and the presence of three higher permeability structural features were assessed. The three scenarios considered were:

- Scenario 1: Elevated groundwater levels (+10 m), no structural feature -5 m drawdown contour extends out to approximately 700 m perpendicular to tunnel alignment
- Scenario 2: Base case groundwater levels, three structural features—estimated drawdown develops along the modelled structural zones
- Scenario 3: Elevated groundwater levels (+10 m), three structural features—estimated drawdown develops along the modelled structural zones.

Drawdown extents are shown in Figure 14.7 (Scenario 1), Figure 14.8 (Scenario 2) and Figure 14.9 (Scenario 3), respectively.

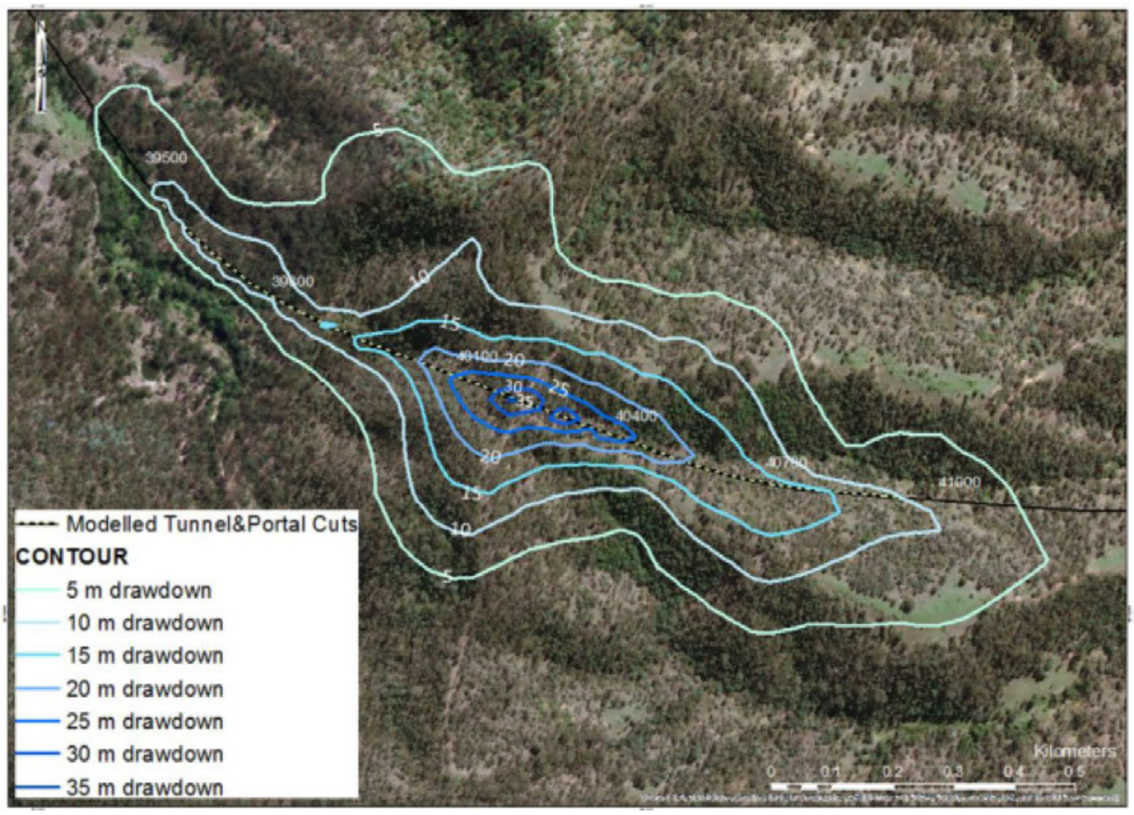

FIGURE 14.7: SCENARIO 1: PREDICTED DRAWDOWN EXTENT

Source: Golder Associates (2019)

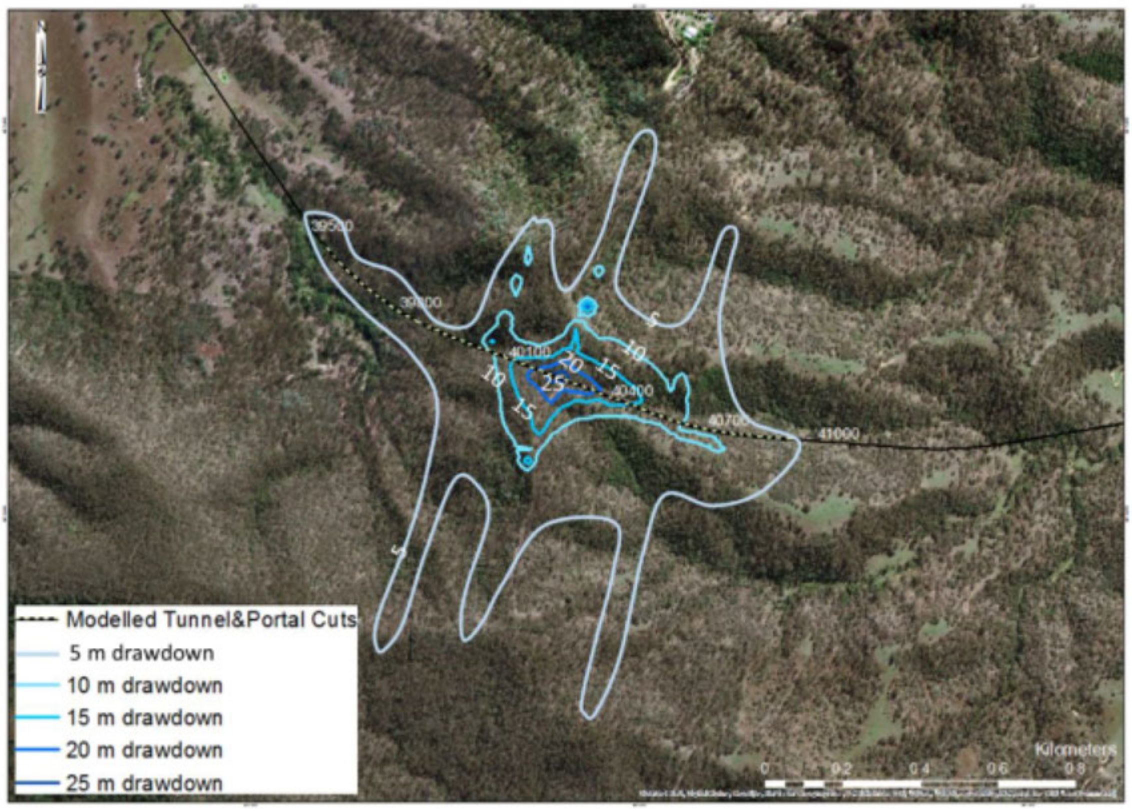

FIGURE 14.8: SCENARIO 2: PREDICTED DRAWDOWN EXTENT

Source: Golder Associates (2019)

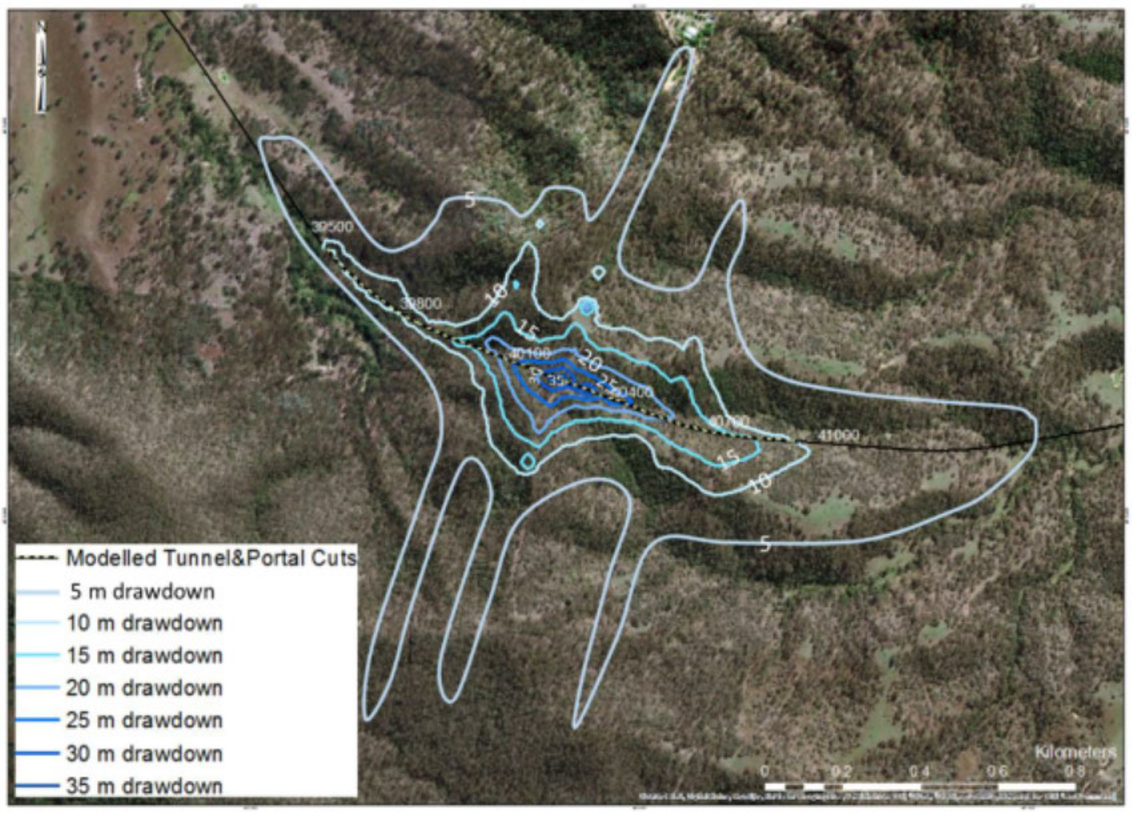

FIGURE 14.9: SCENARIO 3: PREDICTED DRAWDOWN EXTENT

Source: Golder Associates (2019)

Long-term inflow rates of up to 0.01 L/s were estimated per 100 m sections of the tunnel using the Perrochet analytical model. The long-term inflow into Ch 40.24 km was computed by the SEEP/W model to be 0.014 L/s per 100 m, comparable to the 0.01 L/s estimated over the same 100 m interval by the analytical method.

Overall, the long-term inflow rate was estimated to be 0.1 L/s for the 1 km long tunnel section. Short-term inflows of 0.6 L/s were estimated by the analytical method to indicate potential inflow rates to be managed during construction of the tunnel. Higher flow rates over short durations (i.e. weeks to months) might be encountered where locally higher permeability features are encountered (Golder Associates, 2019).

Long-term seepage flows of 0.02 L/s at the western portal and 0.01 L/s at the eastern portal were estimated by the analytical method.

Overall, a base case long-term inflow rate in the order of 0.11 L/s was estimated for the combined tunnel and portal sections (Golder Associates, 2019).

Uncertainty analysis was also undertaken for tunnel inflows. Potential effects of pre-existing groundwater levels 10 m higher than the base case, and the presence of three higher permeability structural features were assessed. The three additional scenarios considered were:

- Scenario 1: Elevated groundwater levels (+10 m), no structural feature—giving long-term flow rate of 0.17 L/s
- Scenario 2: Base case groundwater levels, three structural features—giving long-term flow rate of 0.13 L/s
- Scenario 3: Elevated groundwater levels (+10 m), three structural features—giving long-term flow rate of 0.23 L/s.

14.6.1.4 Cuts along the alignment

Preliminary assessment is provided in Appendix O: Groundwater Technical Report, using an analytical solution with the purpose of estimating potential groundwater inflows into slope cuts along the alignment to inform the design.

Groundwater inflows were considered at 20 cut sections along the alignment, where groundwater was inferred to be intersected.

Inflows were estimated at 1 year and 50 years (i.e. long-term) after construction. The results are detailed in Appendix O: Groundwater Technical Report and summarised by geological unit in Table 14.13.

TABLE 14.13: ESTIMATED SEEPAGE RATES FOR PROJECT CUTS (GOLDER ASSOCIATES, 2019)

	Seepage rate along cut length (L/sec)					
	1 year after construction				Long-term seepage rate	
Geology	**<0.1 L/sec**	**0.1 L/sec**	**0.2 L/sec**	**0.8 L/sec**	**< 0.1 L/sec**	**0.1 L/sec**
Alluvium	-	-	1	1	1	1
Walloon Coal Measures	3	-	2	-	5	-
Koukandowie Formation	4	-	1	-	5	-
Gatton Sandstone	6	2	-	-	8	-
Totals	**13**	**2**	**4**	**1**	**19**	**1**

All long-term seepage rates were estimated to be 0.1 L/sec or less, with most seepage rates one year after construction also estimated to be 0.1 L/sec or less. The higher seepage rate estimates were generally associated with slope cuts through alluvium (assumed higher permeability) or due to longer cut lengths.

While potential drawdown impacts associated with cuts along the alignment were not assessed in Golder Associate's hydrogeological interpretive report (Golder Associates, 2019), drawdown estimates were considered in Appendix O: Groundwater Technical Report and are discussed later in Section 14.6.

14.6.1.5 Model limitations

The preliminary hydrogeological interpretative report (Golder Associates, 2019 within Appendix O: Groundwater Technical Report) described the following limitations for the Teviot Range tunnel and portal modelling:

- The Perrochet method does not allow for anisotropy of models, although vertical hydraulic conductivities are expected to be considerably lower than horizontal hydraulic conductivity values used
- No account for groundwater recharge parallel to the tunnel alignment, limiting spatial extent of recharge zones and, therefore, potential overestimate of groundwater drawdown zone
- Materials assumed to be saturated only, with effects of variable saturation on groundwater flow and recharge not considered
- Uncertainty analysis indicated the extent and location of structurally affected zones could significantly affect inflow and drawdown associated with the tunnel.

The following limitations were noted in Appendix O: Groundwater Technical Report in relation to modelling for cuts along the alignment:

- Impervious base to cuts may have resulted in underestimates of flow rates
- Rainfall effects on seepage rates not considered
- Structural features not included
- Seepage from perched groundwater not included in analysis.

The implication of the model limitations is that groundwater inflow has been potentially underestimated due to applying an impervious base, not including structural features that may act as conduit and not including seepage from a perched aquifer. Rainfall effects on seepage have not been included, which can potentially result in underestimating seepage during periods of high rainfall and overestimating seepage during periods of low rainfall. However, limitations are within the range of a Class 1 model, as defined by the *Australian Groundwater Modelling Guidelines* (Barnett et al., 2012). The model is an adequate tool for preliminary assessment of groundwater inflow and refinement (from further groundwater monitoring) will increase the reliability of the model for the detailed design phase.

14.6.2 Construction-phase potential impacts

14.6.2.1 Water resources

Loss or damage to existing landholder bores

Registered and unregistered bores within, or near, the disturbance footprint of the Project have the potential to be damaged or lost during construction, or to become inaccessible during construction (refer Figures 14.2a–e). Liaison will occur with all potentially affected landholders to ensure that potential damage to, destruction of, or loss of access to, all bores is identified. Once detailed design has been undertaken and ground truthing of bores has occurred, potential risks can be confirmed, and mitigation measures developed in conjunction with the affected landholder.

Embankments

Surface loading from embankments can cause compaction of compressible materials (that is, alluvial sediments) leading to increased groundwater levels (i.e. mounding) upstream of the embankment and reduction in groundwater levels downstream of the embankment. Compaction will also reduce the ability of the aquifer material to transmit shallow groundwater (i.e. reduction in aquifer's hydraulic properties and damming effect). This can result in more frequent and prolonged inundation of low-lying ground, particularly during times of higher groundwater levels (for example, following significant rainfall recharge events).

The potential significance of the impact is dependent on the embankment (i.e. height), compressibility of the underlying materials (i.e. clay, silt and sand content of the alluvial sediments) and depths to groundwater.

Depths to groundwater in the alluvial sediments are typically greater than 5 m and, therefore, the potential for impacts is reduced. The potential for mounding and damming of groundwater may be greater in areas of shallower groundwater in alluvial sediments local to active channels (such as Bremer Creek, Warrill Creek and Purga Creek) although bridges are typically proposed in these areas.

Although there is the potential for embankments to locally affect groundwater levels and/or the hydraulic properties of the aquifers across some sections of the alignment (as described above), it is anticipated that ongoing and future field investigations will inform detailed design and mitigation measures required (if any).

Subsidence/settlement

Early drawdown effects due to seepage into cuttings and the tunnel has the potential to cause settlement of compressible materials, and damage to buildings or other structures within areas of settlement.

The greatest potential occurs where groundwater is shallow, soils are compressible, and buildings/structures are nearby. In such locations, either embankments or bridges are typically proposed.

Deep cuttings in high relief areas are typically in more competent bedrock sediments with depths to groundwater in the order of 20 m, and so the risk of settlement is reduced. Reduced groundwater levels due to dewatering and/or seepage into the tunnel are not considered to present a risk of settlement due to the competent sedimentary bedrock material being tunnelled (that is, Gatton Sandstone).

Overall, the potential for settlement and damage to buildings and properties due to subsidence from drained cuttings and the tunnel is considered to be low. It is anticipated that the potential for settlement will be confirmed as part of ongoing geotechnical investigations and will inform final design to mitigate potential impacts (if any).

Dewatering

Reduced groundwater levels from dewatering during construction of cuts and the Teviot Range tunnel has the potential to impact groundwater users (e.g. registered bores and surface water flows). Details are discussed in detail in Appendix O: Groundwater Technical Report and the findings summarised here.

The tunnel will be approximately 1,015 m long with the maximum cover of rock above the tunnel of approximately 90 m. The tunnel excavated cross section is approximately 135 m^2 and the internal space requirements are driven by ventilation requirements.

Maximum drawdowns are unlikely to exceed 0.5 m at 200 m from cuttings, based on the limited data currently available and using the Theis analytical solution to approximate drawdown away from a cut.[1] A summary of deep cut sections and nearby registered bores is provided in Table 14.14. A review of the location and construction of deep cut sections and registered bores suggests there is limited potential for unacceptable impacts to groundwater levels. Ongoing and further field investigations (for example deep cuts anticipated to intersect groundwater and, in particular, cuts near registered bores RN138180 and RN22040, and RN120512 and RN120513) are anticipated to confirm that risks posed to registered bores are acceptable. If this is not the case, works will be completed during subsequent phases (i.e. detailed design and early works) to develop mitigation and management strategies that achieve acceptable residual risks.

1. Preliminary estimate using this approximation: cutting floor 5 m below water table, hydraulic conductivity of 5 m/d, storage coefficient of 0.1 (unconfined aquifer) and stabilised drawdown at 365 days.

TABLE 14.14: DEEP CUT AND REGISTERED BORE SUMMARY

Deep cut chainage	Length (m)	Minimum base of cut elevation[1] (mAHD)	Registered bores	Comment[2]
9.7–10.2	437.0	55	RN120194—Alluvium; ~250 m from cut; ground surface 50.5 mAHD; screened 9–22 mBGS.	Cut and bore in different aquifers. Ground elevation at bore is below base of cut elevation. Negligible potential for groundwater levels at RN120194 to be affected by seepage into this cut.
10.3–10.5	261.7	65	No registered bores within 1 km. Nearest bore RN138180— Walloon Coal Measures; ~1.6 km from cut; ground surface 72.1 mAHD; top of screen 135 mBGS; depth of bore 147mBGS.	Distance from cut and depth of screen for nearest bore (compared to base of cut) indicate no potential for impact to groundwater levels at registered groundwater bores.
15.5–16.2	723.6	35	RN22039 – Walloon Coal Measures; ~180 m from cut; ground surface 58.7 mAHD; top of screen 66 mBGS; depth of bore 87.8 m.	Depth of bores suggests limited potential for groundwater level impact at RN22039 and RN22040. Confirmation of final cut design, bore location, bore construction, and groundwater levels at cut and/or bore would further refine assessment.
			RN22040—Walloon Coal Measures; ~180 m from cut; ground surface 58.7 mAHD; top of screen 47 mBGS; depth of bore 195 m.	
			RN14310245 – Alluvium; ~360 m from cut; ground surface 23.8 mAHD; screened 12–19 mBGS.	Cut and bore in different aquifers. Ground elevation at bore is below base of cut elevation. Risk of unacceptable impact to groundwater levels at RN14310245 is negligible.
30.7–31.0	308.6	65	RN133518—Alluvium; ~540 m from cut; ground surface 52.2 mAHD; top of screen 11 mBGS; depth of bore 17 m.	Cut and bore in different aquifers and ground elevation at bore is below base of cut elevation. Risk of unacceptable impact to groundwater levels at RN133518 is negligible.
			RN14310277—Alluvium; ~600 m from cut; ground surface 55 mAHD; screened 11–18 mBGS.	Cut and bore in different aquifers. Ground elevation at bore is below base of cut elevation. Risk of unacceptable impact to groundwater levels at RN14310277 is negligible.
32.5–32.6	70.6	65	RN154100—Alluvium; ~360 m from cut; ground surface 59.9 mAHD; top of screen 3 mBGS; depth of bore 15 m.	Cut and bore in different aquifers. Ground elevation at bore is below base of cut elevation. Risk of unacceptable impact to groundwater levels at RN154100 and RN154101 is negligible.
			RN154101—Alluvium; ~500 m from cut; ground surface 62.6 mAHD; screened 10–11 mBGS.	
34.5–34.8	301.9	70	RN120512—Marburg Subgroup; ~750 m from cut; ground surface 104.2 mAHD; depth of bore 10 m	Distance from cut suggests limited potential for unacceptable impact to groundwater levels at RN120512 and RN120513. Confirmation of final cut design, bore location, bore construction, and groundwater levels at cut and/or bore would further refine assessment.
			RN120513—Alluvium; ~750 m from cut; ground surface 112.2 mAHD; top of screen 4 mBGS; depth of bore 10 m.	

Deep cut chainage	Length (m)	Minimum base of cut elevation[1] (mAHD)	Registered bores	Comment[2]
43.9–44.0	146.7	80	No registered bores within 1 km.	No potential for impact to groundwater levels at registered groundwater bores.
44.8–45.1	364.6	70		
46.7–46.9	57.0	60		
47.3–47.4	128.6	57		
47.8–47.9	42.0	55		
49.1–49.2	58.8	55		
51.6–51.6	19.2	45	RN152848—Marburg Subgroup; ~430 m from cut; ground surface 35.5 mAHD; screened 25–27 mBGS.	Ground elevation at bore is below base of cut elevation. Risk of unacceptable impact to groundwater levels at RN152848, RN152849 and RN152850 is negligible.
			RN152849—Marburg Subgroup; ~180 m from cut; ground surface 34 mAHD; top of screen 14 mBGS; depth of bore 18 m.	
			RN152850—Marburg Subgroup; ~470 m from cut; ground surface 34.2 mAHD; top of screen 18 mBGS; depth of bore 29 m.	
53.6–53.7	65.9	45	No registered bores within 1 km.	No potential for impact to groundwater levels at registered groundwater bores.
53.8–53.9	95.3	40		

1. Approximate elevation from GIS analysis
2. Approximate bore elevation from BoM NGIS (**bom.gov.au/water/groundwater/ngis**)

The potential aquatic and terrestrial GDEs in the groundwater study area are largely associated with groundwater supplied by alluvial aquifers and occur lower lying topography. The base of deep cuts is above the elevation of potential GDEs and therefore the risk of reduced groundwater levels from free-draining cuts are not anticipated at these lower lying potential GDEs.

Preliminary estimates of groundwater inflows and drawdowns have been carried out to inform assessment of the potential to construct the Teviot Range tunnel and portals as permanently drained structures (Golder Associates, 2019). There are no registered bores within the predicted area of drawdown extent; however, there are a number of potential aquatic and terrestrial GDEs within the predicted drawdown extent. Ongoing and further investigations are anticipated to confirm that risks posed to potential GDEs are acceptable (refer Appendix O: Groundwater Technical Report). If this is not the case, works will be completed during subsequent phases (i.e. detailed design and early works) to develop mitigation and management strategies that achieve acceptable residual risks.

Vegetation removal and surface disturbance

The disturbance footprint defined in Project design has aimed to minimise clearing extents to that required to construct and operate the works. The disturbance footprint is considered negligible against the recharge surface area of the aquifers that underlay the Project. Consequently, there is likely to be little impact on the groundwater resources.

Bridge pilings

Changes to groundwater levels may occur during installation of pilings for bridge construction. Due to the design (such as diameter, depth and spacing of piles), the scale of groundwater being impeded would be negligible, relative to the scale of the groundwater flow system, and any such changes will be localised and small in magnitude.

Construction water supply

Groundwater quality indicates it can only be sourced for earthworks and track works; however, groundwater is not the only, or preferred, source of construction water for the Project.

Water will be required for dust control, site compaction and reinstatement during construction. Overall quantities of water have been estimated to be 950 megalitres (ML) total for earthworks and trackworks, including material conditioning and dust suppression. ARTC recognises water sourcing and availability is critical to supporting the construction program for the Project. Sources of construction water (including potable water demand) will be finalised as the construction approach is refined during the detailed design (post-EIS) and will be dependent on:

- Climatic conditions in the lead up to construction
- Confirmation of private water sources made available to the Project by landholders under private agreement
- Confirmation of access agreement with local governments for sourcing of mains water.

Initial consultation with Seqwater has indicated the water supply options discussed in Chapter 13: Surface Water and Hydrology may be available for Project use; however, discussions will be ongoing as the Project progresses.

The hierarchy of preference for accessing of construction water is generally anticipated to be as follows:

a) Commercial water supplies where capacity exists: existing infrastructure, well-understood water systems, available water volumes known, existing (in place) licences

b) Public surface water storages (e.g. dams and weirs)

c) Permanently flowing watercourses

d) Privately held water storages (e.g. dams or ring tanks, under private agreement)

e) Existing registered and licensed bores

f) Treated water (e.g. from wastewater treatment plants, coal seam gas fields, or desalination plants)

g) Drilling of new bores (least preferred option).

An assessment of the suitability of each source will need to be made for each construction activity requiring water, based on the following considerations:

- Legal access
- Volumetric requirement for the activity (e.g. site offices require potable water)
- Water quality requirement for the activity
- Source location relative to the location of need.

The current estimated water demand is expected to be met using existing water sources; however, further options may need to be investigated depending on engagement with water resource owners.

An appropriate quality of water will be sourced for each use. For instance, non-potable water is suitable for soil conditioning and dust suppression, while potable water must be sourced for the construction offices and amenities. Prior to sourcing any construction water, the necessary approvals and licences will be obtained.

Where water is not available, it will be transported to the site via tanker truck and stored in temporary storage tanks. Potable water for human consumption will be supplied via bottled water or potable water tanks. Non-potable wash water will be supplied using trailer-mounted storage tanks. Portable toilet facilities will be used where existing infrastructure is unavailable and sewage pump out services used to remove waste offsite.

The buying or sharing of groundwater from existing water licence, entitlement or permit is an option to be considered in the instance bore water is selected as a preferred source of construction water.

Temporary water permits in accordance with the Water Act could provide a suitable water supply option for the construction phase of the proposal. Water permits are issued for temporary projects having a foreseeable conclusion date and anticipated to have short-term impacts on the resource. Normally, water permits are granted up to a maximum timeframe of three years and cannot be renewed, transferred or amended. However, the viability of this option will need to be reviewed during the pre-construction phase to confirm the volume, if any, of available allocations to support the temporary permit.

If a temporary water permit is warranted during construction, the licensed volume is expected to be within the allowable extraction limits for the relevant Water Plan. Therefore, the Project is not expected to impact on, or alter, the identified relevant Water Plans or other plans under the Water Act outside of their designated use and objectives.

Refer to Chapter 6: Project Description and Chapter 13: Surface Water and Hydrology for more detailed discussions about construction water resource and supply.

14.6.2.2 Water quality

Contamination

During the construction phase, there is the potential for contamination to groundwater from:

- Accidental spills and leaks of hydrocarbons (oils, fuels and lubricants) and other chemicals associated with plant and equipment
- Water mixtures and emulsions related to washdown areas.

Leaching of contaminated embankment fill could impact groundwater quality and affect EVs. The Project proposes to source embankment fill from cut volumes. Any impacts would be local to embankments and limited in extent due to the disturbance footprint.

Acid rock drainage/acid sulfate soils

The intersection of sulfide-bearing rocks in cuts and the Teviot Range tunnel or use of sulfide-bearing materials in embankment fill could present an acid rock drainage (ARD) risk following exposure of the rocks to oxygen and subsequent runoff, which could impact on EVs, i.e. aquatic GDEs and groundwater users. ARD occurs when sulfide minerals are exposed to air and water. This process is accelerated through excavation activities, which increase rock exposure to air, water and microorganisms. The resulting drainage may be neutral-to-acidic with dissolved heavy metals and significant sulfate levels. Potential acid sulfate soils (PASS) also present a risk though excavation of cuts in soils susceptible to acid forming conditions.

Based on the surface geology traversed by the rail alignment, the following is noted:

- Alluvium—generally low risk due to young age and lack of sulfide minerals
- Main range volcanics—the tertiary main range volcanics are considered low risk given their primary mineralogy is sulfide poor
- Sedimentary units—the Jurassic age Walloon Coal Measures, Koukandowie Formation and Gatton Sandstone, in which cuts and tunnel are proposed, may host disseminated sulfide minerals (i.e. pyrite).

Rainfall infiltration into cuttings with sulfide-bearing minerals above the saturated zone may also pose an ARD risk even if the entire cut is in the unsaturated zone (above groundwater).

Bridge pilings

A rotary drill rig will be used to drill-bored piers, with prefabricated reinforcement cages lowered into the pile before a wet concrete slurry is placed via tremmie or pumping. The alkaline wet concrete slurry may affect groundwater quality (for example pH and salinity) immediately adjacent to the piles while curing occurs (that is, drying and hardening of the concrete).

There is potential for groundwater quality mixing across aquifers (e.g. more saline water mixing/ intersecting with fresher water); however, it is anticipated that due to the piling method of driven precast or cast-in-place foundations, any such changes are likely to be temporary, localised and small given the small contact areas of piling surfaces and groundwater compared to the scale of the groundwater flow systems.

Discharge of groundwater, dewatering activities/seepage

Groundwater inflows to cuttings, portals, and the Teviot Range tunnel will require appropriate management. Further, evaporation of the estimated low groundwater seepage rates into cuts (refer Section 14.6.1.4) may lead to salt residue on the faces of some cuts and the potential for increased salinity of discharge water in the short-term immediately following a 'first flush' rainfall event.

Stormwater will be diverted away from the tunnel and any water that falls within the tunnel portals will be captured by purpose-built sumps and not directed through the tunnel. Any water collected inside the tunnel (groundwater, washdown, firefighting etc.) will be collected via drainage pits throughout the tunnel and connected longitudinally by a drainage pipe. Collected water will be conveyed via gravity to the tunnel collection sumps located at the western portal. This water will likely be processed through a water treatment plant, which will include hydrocarbon separation. The collection sump will also likely include a 'first flush' tank that will collect the first quantity of water, which is expected to contain the majority of pollutants. Any separated pollutants will be held for collection by a licensed waste contractor. Provision has been made for the collection and treatment of water from the tunnel. The extent of treatment of the water from the tunnel will depend greatly on the quality of the groundwater ingress.

Water treatment facilities are likely to include:

- Screening treatment
- Detention tanks
- Aeration/flocculation tanks
- Chemical treatment (if warranted)
- Water pumping facilities
- Sludge storage.

The potential effects of discharging groundwater seepage to receiving waterbodies have been assessed in Chapter 13: Surface Water and Hydrology and were not considered further as part of the groundwater study.

14.6.3 Operational-phase potential impacts

Many of the potential impacts with respect to groundwater are considered temporary in nature and primarily associated with the construction phase of the Project. Impacts on groundwater resources during the operation phase of the Project are considered limited to groundwater seepage from ongoing dewatering of the tunnel and the management of that dewatering.

14.6.3.1 Water resources

Access to landholder bores

There are several registered bores located within, or near to, the disturbance footprint of the Project. Bores within the Project footprint will be decommissioned to enable construction of the Project. The potential exists for these to become inaccessible, or more difficult to access, due to the railway line blocking previous access route or no access being available if within exclusion zones associated with the operating rail corridor.

Embankments

Surface loading from embankments can cause a damming effect due to increased groundwater levels and/or reduced ability to transmit groundwater through compressed shallow sediments (i.e. due to reduced hydraulic conductivities). Depths to groundwater in the alluvial sediments are typically greater than 5 m and thicknesses of the main alluvial channels greater than 15 m thick. The risk is therefore considered low; however, shallower groundwater may be present locally (with depths of 1 m to 3 m also measured in the groundwater study area). It is anticipated that ongoing and future geotechnical investigations and assessment of embankment loading of alluvial sediments will confirm site conditions and inform final design to mitigate this potential risk.

Dewatering/seepage

Lowered groundwater levels due to long-term seepage into cuts and the Teviot Range tunnel have the potential to impact groundwater users (e.g. registered bores, surface water flows and potential GDEs).

Maximum drawdowns due to seepage at cuttings are unlikely to exceed 0.5 m at 200 m from cuttings[2], based on the limited data currently available. As discussed in Section 14.6.2, there is limited potential for unacceptable impacts at registered bores based on comparison of deep cut floor elevations and the construction and/or location of registered bores. Confirmation of final cut design, bore location, bore construction and groundwater levels at cuts and/or registered bores would further refine the assessment; in particular for registered bores RN138180 and RN22040, and RN120512 and RN120513 nearby cuts.

Preliminary estimates of groundwater inflows and drawdowns have been carried out to inform assessment of the potential to construct the Teviot Range tunnel and portals as permanently drained structures (Golder Associates, 2019). There are no registered bores within the predicted drawdown extent of the tunnel and portals; however, there are a number of potential aquatic and terrestrial GDEs within the predicted drawdown extent. The predicted drawdown extent is defined in Section 14.6.1.3. Ongoing and further investigations are anticipated to confirm that risks posed to potential GDEs are acceptable. Should this not be the case, works will be completed during subsequent phases (i.e. detailed design and early works) to develop mitigation and management strategies that achieve acceptable residual risks.

It is currently assumed that cuttings, portals, and the Teviot Range tunnel will be free draining and dewatering effects will be ongoing and long term. Ongoing and further investigations, and groundwater monitoring will inform detailed design and construction to mitigate potential impacts to groundwater.

Bridge pilings

Bridge pilings may change local groundwater flow patterns. Due to the design (such as diameter, depth and spacing of piles), the scale of groundwater being impeded would be negligible relative to the scale of the groundwater flow system, and any such changes will be localised and small in magnitude.

14.6.3.2 Water quality

Discharge of dewatering activities

Long-term groundwater inflows to free draining cuttings, portals and the Teviot Range tunnel would require appropriate management. Further, evaporation of the estimated low groundwater seepage rates into cuts (refer Section 14.6.1.4) may lead to salt residue on the faces of some cuts and the potential for increased salinity of discharge water in the short-term immediately following a ‘first flush’ rainfall event.

The potential effects of discharging groundwater seepage to receiving waterbodies have been assessed in Chapter 13: Surface Water and Hydrology and was not considered further as part of the groundwater study.

2. Preliminary estimate using Theis approximation: cutting floor 5 m below water table, hydraulic conductivity of 5 m/d, storage coefficient of 0.1 (unconfined aquifer) and assumed steady state at 365 days

14.7 Mitigation

14.7.1 Design considerations

The mitigation measures presented in Table 14.15 have been incorporated into the Project design. These design measures have been identified through collaborative development of the design and consideration of environmental constraints and issues. These design measures are relevant to both construction and operational phases of the project.

TABLE 14.15: INITIAL MITIGATION MEASURES OF RELEVANCE TO GROUNDWATER

Aspect	Initial design measures
Water resources	The Project is generally located within the Southern Freight Rail Corridor, which was gazetted as a future rail corridor in 2010. The design has been developed to use the existing rail corridor protection and minimise land severance and impacts to natural and rural landscapes to the greatest extent possible. The alignment (both lateral and vertical) has been designed to minimise earthworks, reducing the potential to impact water resources (for example dewatering of cuttings and embankment placement). The design of culverts and embankment have developed to minimise pre-loading and compaction of alluvial sediments. This will reduce the risk of altering shallow groundwater levels and recharge patterns. The current embankment designs allow for openings (i.e. culverts and bridge spans) near creeks and rivers to assist with flow.
Water quality	The disturbance footprint defined in design has aimed to minimise clearing extents to that required to construct and operate the works.

14.7.2 Proposed mitigation measures

To manage Project risks during construction, a number of mitigation measures have been proposed for implementation in future phases of project delivery, as presented in Table 14.16. These proposed mitigation measures have been identified to address Project-specific issues and opportunities, address legislative requirements, accepted government plans, policy and practice.

Table 14.16 identifies the relevant project phase, the aspect to be managed, and the proposed mitigation measure, which is then factored into the assessment of residual significance in Table 14.19.

Chapter 23: Draft Outline Environmental Management Plan provides further context and the framework for implementation of these proposed mitigation and management measures.

TABLE 14.16: GROUNDWATER MITIGATION MEASURES

Delivery phase	Aspect	Proposed mitigation measures
Detailed design	Water resources	▸ Undertake additional investigations and assessment of potential drainage/dewatering impacts associated with the tunnel through the Teviot Range, portals and deep cut sections to further refine current understanding, inform detailed design, identify potential for impacts to and mitigation measures for groundwater users. This will also inform requirements for monitoring during construction and potentially operation. ▸ Refine seepage analysis for deep cuts to inform detailed design (for example drainage blanket specifications, shotcrete and weep hole specifications). ▸ Review the proposed groundwater monitoring network to ensure locations are accessible during pre-construction, construction, commissioning and operation of the Project. Continue collection of baseline groundwater monitoring data (levels and quality) to confirm seasonal variation and inform detailed design and the development of the final Groundwater Monitoring and Management Plan (GMMP). Include monitoring at any additional bores identified during the development of the GMMP to establish a comprehensive monitoring regime prior to construction and operation. ▸ Engage with relevant landholders to confirm the location of existing bores, identification/confirmation of new monitoring bore locations, and procure access agreements to existing registered groundwater bores included in the GMMP. ▸ Confirm (i.e. physical survey or ground truth) the location of registered and unregistered bores that may be lost due to construction or operation of the Project and engage with licensed users to determine an appropriate mitigation strategy. ▸ Undertake field 'truthing' of identified potential aquatic and terrestrial GDEs within the groundwater study area that can potentially be impacted by the Project and confirm their status. ▸ Confirm sources for construction water requirements via consultation with relevant stakeholders (including landholders/occupants) prior to construction. Appropriate approvals and agreements will be sought for the extraction of water. Where private water sources are used for construction, monitoring will be undertaken during extraction to ensure volumes and conditions stipulated by licence requirements and/or private landholder agreements are met.
	Water quality	▸ Undertake detailed geotechnical investigations at deep cut sections to inform design and location specific construction management of groundwater. ▸ Risks associated with dewatering (i.e. water table lowering) and environmental management requirements during construction are identified through appropriate baseline groundwater monitoring, modelling and analysis.
Pre-construction	Water resources	▸ Continue collection of baseline groundwater monitoring data (levels and quality) to confirm seasonal variation and inform detailed design and the development of the GMMP. Include monitoring at any additional bores identified during the development of the GMMP to establish a comprehensive monitoring regime prior to construction and operation.
	Water quality	▸ Undertake site inspections prior to the construction of cuts, including visual examination of surface outcrops for sulfide minerals or evidence of sulfide mineralisation. Use the information from these inspections to inform the management of potential acid rock drainage (ARD) from cuttings prior to Project works.
Construction and commissioning	Water resources	▸ Implement the CEMP and the construction GMMP with appropriate groundwater-level and quality-monitoring criteria based on the baseline groundwater monitoring, modelling analysis and regulatory requirements; with make-good arrangements with the owners of groundwater bores as necessary. ▸ Opportunities to re-use/recycle groundwater water drawn from tunnel and cuttings, where encountered, are identified and implemented where feasible during construction.

Delivery phase	Aspect	Proposed mitigation measures
Construction and commissioning (continued)	Water quality	▸ Vehicle and plant maintenance will be undertaken in suitable bunded hardstand areas, to minimise the risk of contaminants from incidental spills or leaks from entering aquifers via infiltration or surface runoff. ▸ Personnel involved in ground-disturbing works are familiar with hazardous spill management procedures. ▸ Spill kits will be available at all work fronts and laydown areas in the event of a spill or leak. All vehicles and machinery will have dedicated spill kits. These refuelling locations will be equipped with on-site chemical and hydrocarbon absorbent socks/booms and spill kits. ▸ Chemical and dangerous goods storage areas will be located in appropriately designed facilities, such as bunded areas, sealed or lined surfaces, hardstand areas, or storage within containers. Storage of chemicals, oils, fluids and other hazardous substances will be in accordance with the appropriate safety data sheets and relevant Australian Standards. These measures would minimise the risk of contaminants from incidental spills or leaks from entering aquifers via infiltration or surface runoff. Where possible, laydown areas and storage areas will be located away from creeks, rivers and sensitive receptors such as existing groundwater bores or known GDEs. ▸ Imported fill material will be clean, certified contaminant free and be required to comply with regulatory guidelines for the intended use. ▸ Material won from site will be tested and assessed for suitability prior to use within proximity to potential groundwater infiltration sites. ▸ Any excavated material that is suspected to contain sulfides will be stockpiled, lined and covered, and managed to minimise rainfall infiltration and leaching. Where possible, treatment and onsite reuse are preferred to off-site disposal. A case-by-case assessment of the suitability of material for treatment and reuse will be required. ▸ Routine sampling of discharge waters from the deep cuts intersecting groundwater will be undertaken to assess the potential for ARD processes taking place. Screening of the seepage water onsite for pH (trending down) and EC (trending up) and comparison to the baseline groundwater monitoring program results/trends will allow for indication of ARD processes. Further laboratory analyses for the key analytes pH, TDS, EC, TSS, alkalinity, and dissolved metals will validate the presence or absence of ARD potential. ▸ If ARD-contaminated discharge water is found to be generated from the deep cuts, this water will need to be impounded in ponds and neutralised via treatment with hydrated lime or dilution prior to release into the surrounding catchment or other discharge mechanism. ▸ Implement the construction GMMP. ▸ Any groundwater supply and/or monitoring that require decommissioning will be undertaken in accordance with the *Minimum Construction Requirements for Water Bores in Australia—Edition 3* (National Uniform Drillers Licensing Committee, 2012).
Operation	Water resources	▸ Implement operational phase GMMP.
	Water quality	▸ Appropriate controls are to be in place to prevent environmental incidents including leaks/spills from refuelling activities and locomotive operations and to protect the environment in the event of an incident. ▸ In the event of a spill, all necessary actions will be taken to contain the spill and ARTC emergency response protocols will be followed. ▸ Teviot Range tunnel and potential deep cut seepage water will be monitored and discharged in accordance with the surface water monitoring framework and the Surface Water Management Plan as confirmed during detailed design. ▸ Groundwater quality will be monitored in accordance with the operational phase GMMP, assessed against trigger levels and contingency measures followed (as required). ▸ Any groundwater supply and/or monitoring bores that are decommissioned will be undertaken in accordance with the *Minimum Construction Requirements for Water Bores in Australia—Edition 3* (National Uniform Drillers Licensing Committee, 2012).

14.7.3 Groundwater monitoring and management program

The GMMP provides for an ongoing assessment of the potential impacts identified in Section 14.6. The GMMP incorporates principles of performance assessment and adaptive management and a structured, iterative process for decision making. The GMMP will be assessed and updated after each phase of works (pre-construction/baseline, construction, and operation) so that the GMMP for subsequent phases is based on the outcomes of the previous phase.

The indicative pre-construction/baseline GMMP's primary objective is to develop a robust baseline dataset from which all subsequent monitoring will be assessed against to identify impacts. This dataset will also inform the proposal-specific WQO trigger values. The pre-construction/baseline GMMP will be developed and implemented during the detailed design stage to inform proposal-design aspects and ensure a suitable groundwater baseline dataset is established before starting any works.

The baseline/pre-construction dataset is to be the reference dataset for future groundwater monitoring and, as such, may be supplemented with existing groundwater data inclusive of, but not limited to, representative data from local councils, recent studies, etc. The baseline dataset will be compiled, and the construction GMMP developed, prior to the commencement of the construction phase of the proposal.

The pre-construction (baseline) GMMP is discussed in the following subsections. The construction phase GMMP will be developed prior to commencement of construction. Groundwater baseline monitoring should commence as soon as practicable to provide information on seasonal variation. The baseline monitoring program will be completed in enough time prior to commencement of construction works to allow for assessment of the data, including trends, develop groundwater level and quality thresholds (warning and action levels) and inform the development of the construction phase GMMP.

An indicative network of monitoring bores in proximity to the deep cuts is summarised in Table 14.17. In addition to the existing bores, it may be beneficial to install dedicated environmental monitoring bores in areas where materials will be stored and in locations identified to intersect groundwater, in order to provide adequate coverage up and down the hydraulic gradient of these areas. The monitoring network will be subject to landholder negotiations and access and will be refined during the detailed design phase.

14.7.3.1 Groundwater level monitoring

Groundwater levels for bores within the indicative minimum network are to be monitored using automated pressure transducers/level loggers to record measurements at least every six hours. This is particularly required to establish the baseline groundwater dataset from which potential impacts can be assessed during construction and operation of the Project.

Manual measurements on all bores is proposed monthly during establishment of the baseline groundwater dataset as this will be the basis of comparison for the Project. Pressure transducer data will be downloaded on a bimonthly basis, during the baseline program, to coincide with quality monitoring, as discussed below. The baseline groundwater monitoring program will be continuously ongoing so as to account for natural (seasonal) or anthropogenic fluctuations of groundwater levels prior to construction. This is pertinent for the alluvial sediments, in particular, as the water levels in these sediments are key to the design, construction, and operation of the Project.

In addition, the baseline groundwater level dataset will allow for identification of outside influences on groundwater levels. This information is important to capture to allow for discernibility between the impacts of the Project and those from non-project influences.

The baseline monitoring program will be completed in sufficient time prior to commencement of construction works to allow for assessment of the data, including trends, to develop groundwater level thresholds (warning and action levels); the construction phase GMMP will also be developed at this time. Groundwater level measurements are to remain ongoing in the transition from detailed design into construction.

After completion of the baseline monitoring program, and with consideration of the final detailed design, the frequency and location of level measurements can be reviewed and amended for suitability to achieve the objectives of the groundwater monitoring program for the construction stage of the Project. The shallow aquifer data will be considered together with regular surface water level monitoring data to inform the local hydraulic connectivity between surface water and shallow groundwater in the disturbance footprint.

TABLE 14.17: INDICATIVE MINIMUM GROUNDWATER MONITORING NETWORK

Chainage (km)	Bore ID	Deep cut chainage (km)	Aquifer	Screen interval (mbgl)
1.6	RN120194	9.7–10.2	Alluvium	16.2–21.7
12.0	RN138180	10.3–10.5	Walloon Coal Measures	135.0–147.0
16.0	RN22039	15.5–16.2	Walloon Coal Measures	Unknown
16.0	RN22040	15.5–16.2	Walloon Coal Measures	Unknown
Ch 17.6	RN14310245	15.5–16.2	Alluvium	17.1–18.6
29.6	RN133518	30.7–31.0	Alluvium	11.1–17.1
Ch 31.2	RN14310277	30.7–31.0	Alluvium	17.0–18.0
33.2	RN154100	32.5–32.6	Alluvium	8.3–14.3
33.4	RN154101	32.5–32.6	Alluvium	6.7–11.2
34.0	RN120512	34.5–34.8	Marburg Subgroup—undifferentiated	8.0–10.0
34.0	RN120513	34.5–34.8	Alluvium	7.6–10.0
51.4	RN152848	51.6–51.6	Marburg Subgroup—undifferentiated	22.6–28.6
51.4	RN152849	51.6–51.6	Marburg Subgroup—undifferentiated	11.1–17.1
51.4	RN152850	51.6–51.6	Marburg Subgroup—undifferentiated	16.0–27.8
Ch 31.1	BH-04	30.7–31.0	Koukandowie Formation	10.9–16.9
Ch 44.8	BH-05	-	Gatton Sandstone	18.97–24.97
Ch 39.8	BH-07	-	Gatton Sandstone	29.5–35.5
Ch 40.0	340-1-BH2101	-	Gatton Sandstone	112–124
Ch 17.4	340-1-BH2215	-	Alluvium	19–25
Ch 25.4	340-1-BH2220	-	Koukandowie Formation	16–25
Ch 35.2	340-1-BH2224	-	Walloon Coal Measures	16–25
Ch 36.6	340-1-BH2225	-	Alluvium	19–25
Ch 37.2	340-1-BH2226	-	Koukandowie Formation	17–26
Ch 46.4	340-1-BH2229	-	Koukandowie Formation	11–20
Ch 52.8	340-1-BH2233	-	Alluvium and Gatton Sandstone	16–25
Ch 35.0	340-1-BH2303	-	Gatton Sandstone	22–31

14.7.3.2 Groundwater quality monitoring

The baseline groundwater monitoring program is to include the indicative bores in Table 14.17, at a minimum, to characterise the local groundwater quality prior to construction activities. The quality data collected during the baseline program will be used to assess potential impacts of the Project on local groundwater resources through all stages of the Project. Groundwater quality samples are to be collected for field and laboratory analyses on a bimonthly basis (to coincide with the manual groundwater level measurement baseline program).

The baseline groundwater quality program will be continuously ongoing to account for and allow characterisation of natural (seasonal) and/or anthropogenic variation prior to commencement of construction activities. This is especially applicable to the shallow aquifers hydraulically connected to surface water, as after the dry season (negligible recharge) a first-flush/flow of recharge to these sediments can result in markedly different quality from data collected within and after the wet season. In addition, the baseline quality dataset will indicate the potential for ARD prior to construction works and inform the suitability of local groundwater suitability for construction water purposes.

Field parameters to be collected during sampling include pH, EC, temperature, redox potential, and dissolved oxygen. The following analytical suite is suggested for laboratory analyses for the baseline groundwater quality dataset and is considered sufficient to identify potential ARD and suitability of groundwater for construction water purposes:

- pH, EC and TDS
- Major anions (bicarbonate, chloride, sulfate)
- Major cations (calcium, magnesium, sodium, potassium and silicon)
- Dissolved and total metals (aluminium, arsenic, boron, cadmium, chromium, copper, manganese, lead, nickel, selenium, molybdenum, silver, zinc, iron, and mercury)
- Nutrients (ammonia, nitrite, nitrate, total nitrogen, total phosphorus)
- The baseline monitoring program will be completed in sufficient time, prior to commencement of constructions works, to allow for assessment of the data, including trends, to develop groundwater quality trigger levels (warning and action levels); the construction phase GMMP will also be developed at this time. Groundwater quality monitoring events are to remain ongoing between project phases.

After completion of the baseline monitoring program, and with consideration of the final detailed design, the frequency and location of groundwater quality sample events can be reviewed and amended for suitability to achieve the objectives of the groundwater monitoring program for the construction stage of the Project. The shallow aquifer data will be considered together with regular surface water quality monitoring data to inform the local hydraulic connectivity between surface water and shallow groundwater in the disturbance footprint.

Groundwater quality data (post-baseline) will be analysed for trends and compared to the baseline dataset to identify potential impacts of the Project on groundwater quality.

Groundwater monitoring and sample collection will be conducted in accordance with recognised groundwater sampling guidelines such as *Monitoring and Sampling Manual* (DES, 2018b) and *Groundwater Sampling and Analysis—A Field Guide* (Sundaram et al., 2009) unless an updated version is available prior to commencement of the baseline monitoring program.

14.7.3.3 Data management and reporting

The following data and reporting requirements would be implemented:

- All groundwater data will be validated with suitable quality assurance and quality control (QA/QC) protocols applied
- Monitoring data will be assessed on a quarterly basis, initially, to identify trends and compare to trigger levels (baseline and pre-construction)
- After baseline, where consecutive data points for the same bores over a six-month period indicate divergence from the baseline trends or previous data, consideration of verification sampling to confirm the accuracy of the data will be undertaken and the bore data will be further investigated to determine appropriate actions. This may include more rigorous monitoring or trigger a re-assessment of impacts/or mitigation measures.
- Reporting will be completed on an annual basis and present the assessment of water levels and water quality trends, including hydrographs and hydrochemical plots. The annual assessment will recommend if the location and frequency of monitoring needs to be modified to ensure the objectives of the monitoring plans for the relevant stage of the Project are achieved.

14.7.4 Summary

A summary of the monitoring and requirements of the GMMP is presented in Table 14.18.

TABLE 14.18: SUMMARY OF GMMP REQUIREMENTS

GMMP requirements	Pre-construction (baseline)	Construction	Operation
Groundwater level monitoring	- Pressure transducers/level loggers record measurements six hourly intervals - Pressure transducer data downloaded every two months - Manual measurements monthly	Subject to DNRME/DES approval of the GMMP	Subject to DNRME/DES approval of the GMMP
Groundwater quality monitoring	- Every two months	Subject to DNRME/DES approval of the GMMP	Subject to DNRME/DES approval of the GMMP
Reporting	- Quarterly data comparison - Annual reporting	Subject to DNRME/DES approval of the GMMP	Subject to DNRME/DES approval of the GMMP

14.8 Impact assessment

As discussed in Section 14.4.2, a qualitative impact assessment using the significance assessment approach has been adopted for evaluating potential impacts to groundwater resources from the Project, as described in Section 14.6 and Chapter 4: Assessment Methodology.

A summary of the significance assessment is provided in Table 14.19.

For each of the potential impacts discussed in Section 14.6, the initial significance assessment was undertaken on the assumption that the design considerations (or initial mitigation measures) factored into the Project design (refer Table 14.19) have been implemented.

Proposed mitigation measures, including those listed in relevant subplans (including the GMMP), were then applied as appropriate to the phase of the Project to reduce the level of potential impact and are detailed in Section 14.7 (refer Table 14.16).

The residual significance level of the potential impacts was then reassessed after mitigation and management measures were applied. The pre-mitigated significances were compared to the residual significance for each potential impact on groundwater values to assess the effectiveness of the mitigation and management measures.

14.8.1 Temporary impacts

Many of the potential impacts with respect to groundwater are considered temporary in nature and primarily associated with the construction phase of the Project. The likelihood of a material impact on current groundwater conditions and users is considered to be low.

Final construction design, engineering controls and monitoring are generally considered to be adequate to mitigate potential impacts to groundwater. However, it is noted that additional investigations and assessment of potential drainage/dewatering impacts associated with the Teviot Range tunnel and deep cut sections is proposed to further refine current understanding and inform detailed design and reduce potential impacts.

14.8.2 Long-term impacts

The main potential long-term impacts identified beyond the construction stage are:

- Changes to groundwater levels and flow associated with loading from embankments and ongoing dewatering/draining of the Teviot Range tunnel and deep cuts
- Management of discharge from dewatering/drainage of the Teviot Range tunnel and deep cuts.

Final construction design, engineering controls and monitoring are generally considered to be adequate to mitigate potential impacts to groundwater. However, it is noted that additional investigations and assessment of potential drainage/dewatering impacts and potential loading impacts near significant embankments is proposed, to further refine current understanding, inform detailed design, and refine the long-term monitoring approach.

TABLE 14.19: SIGNIFICANCE ASSESSMENT SUMMARY FOR GROUNDWATER

Potential impact	Phase	Initial significance[1]			Application of proposed mitigation measures presented in Table 14.16, by aspect[2]	Residual significance[3]	
		Sensitivity	Magnitude	Significance		Magnitude	Significance
Loss of registered bores (through destruction, damage or lack of access)	Construction	Moderate	Moderate	Moderate	Water resources (pre-construction and construction)	Low	Low
	Operations		Moderate	Moderate		Low	Low
Subsidence/consolidation due to groundwater extraction, dewatering or loading	Construction	Moderate	Moderate	Moderate	Water resources (detailed design, pre-construction, construction) Water quality (pre-construction)	Low	Low
	Operations		Low	Low	-	Low	Low
Altered groundwater levels (increase or decrease) affecting groundwater users (incl. impacts due to embankments and seepage to cuts)	Construction	Moderate	Moderate	Moderate	Water resources (detailed design, pre-construction, construction)	Moderate	Moderate
	Operations		Moderate	Moderate		Moderate	Moderate
Reduced groundwater levels affecting groundwater users—due to drained tunnel (Teviot Range tunnel)	Construction	Moderate	High	High	Water resources (detailed design, pre-construction, construction)	Moderate	Moderate
	Operations		High	High		Moderate	Moderate
Altered groundwater flow regime	Construction	Moderate	Low	Low	-	Low	Low
	Operations		Low	Low	-	Low	Low
Contamination or water quality degradation of vulnerable groundwater resources requiring remediation (spills or induced flow, bore hole intersections. Upwards leakage along pile/soil interface.)	Construction	Moderate	High	High	Water quality (detailed design, pre-construction, construction)	Moderate	Moderate
	Operations		Low	Low	-	Low	Low
ARD from cuts and tunnel impacts on EVs (i.e. GDEs)	Construction	Moderate	Moderate	Moderate	Water quality (pre-construction, construction)	Low	Low
	Operations		Low	Low	-		
Vegetation removal and surface alteration affecting recharge/discharge, increasing associated salinity risks	Construction	Moderate	Moderate	Moderate	Water resources (pre-construction)	Low	Low
	Operations		Low	Low	-	Low	Low

Table notes:
1. Includes implementation of initial mitigation measures specified in Table 14.15
2. Proposed mitigation measures and controls, as identified in Table 14.16
3. Assessment of residual significance after the initial and additionally proposed mitigation measures have been applied

14.9 Cumulative impacts

Cumulative impacts are the successive, incremental and combined impacts of an activity when added to other existing or planned projects and activities (IFC, 2013). For the Project, a CIA was undertaken where potential groundwater impacts of the Project were assessed together with existing or planned surrounding activities (as outlined in Section 14.4.2).

It is noted that no cumulative impacts on agricultural groundwater users are anticipated as no potentially significant effects were identified for individual groundwater bores carried out as part of this groundwater study (refer Section 14.6). For a full assessment of cumulative impacts refer Chapter 22: Cumulative Impacts.

14.9.1 Surrounding projects and timeline relationships

Due to the localised potential groundwater impacts associated with the alignment, only applicable projects and operations (with potential impacts on groundwater) in Table 14.20 have been considered for this CIA. Other projects are considered too distant compared to the localised nature of potential groundwater impacts, and/or the scope of the surrounding projects were such that there is negligible potential to impact on groundwater.

TABLE 14.20: APPLICABLE PROJECTS AND OPERATIONS CONSIDERED FOR THE CIA

Project and proponent	Location	Description	EIS status	Timeline	Relationship to the Project
Kagaru to Acacia Ridge and Bromelton (K2ARB) (ARTC)	Rail corridor from Kagaru to Acacia Ridge and Bromelton	Enhancing and connecting the existing rail corridor (approximately 49 km) from north-east of Kagaru to Acacia Ridge and from south of Kagaru to Bromelton	Project Feasibility	Construction: 2023 to 2025 Operation: >50 years	Potential overlap of construction finalisation for C2K and commencement for K2ARB
Helidon to Calvert (H2C) (ARTC)	Rail alignment from Helidon to Calvert	- 47 km single-track dual-gauge freight rail line to accommodate double stack freight trains up to 1,800 m long - 850 m tunnel through the Little Liverpool Range - Construction of rail infrastructure, culverts, bridges, viaducts and crossing loops - Connection to the existing West Moreton Railway Line - Ancillary works including road and public utility crossings and realignments	EIS in preparation	Construction: 2021 to 2026 Operation: >50 years	Potential overlap of construction finalisation for H2C and commencement for C2K

14.9.2 Assessment of potential cumulative impacts

Cumulative impacts to groundwater would most likely occur where multiple projects intersect and/or abstract groundwater from the same shallow aquifer units. Due to the localised nature of potential groundwater impacts associated with this Project, only the adjacent Inland Rail projects (H2C and K2ARB) were included in the groundwater cumulative impact assessment.

The potential cumulative impacts associated with groundwater are considered to be changes in groundwater levels and changes in groundwater quality. As these potential impacts are highly localised in nature, the potential for cumulative impacts associated with the Project is considered to be of low significance.

Further information on the potential cumulative impact of the Project relating to groundwater aspects is presented in Chapter 22: Cumulative Impacts.

14.10 Conclusion

A significance assessment was carried out for identified potential impacts on groundwater resources in terms of groundwater levels, groundwater flow, and water quality.

The significance of impacts is considered low to moderate across the majority of the proposed alignment based on the assumption that the recommended mitigation measures are adopted.

Potentially moderate impacts to groundwater users and receptors were identified due to lowering of groundwater levels associated with permanent seepage from a free draining (unlined) Teviot Range tunnel and deep cuts. It is expected that pre-EIS investigations to inform detailed design, and subsequent refinement of the monitoring approach, will result in adequate management of the potential impacts identified, which will be confirmed by ongoing and further investigations and assessment of hydrogeological conditions at key sections:

- Significant embankments overlying alluvial sediments with shallow groundwater
- Drawdowns and inflow rates to deep cuts intersecting groundwater
- Teviot Range tunnel.

The CIA undertaken as part of the groundwater assessment identified a low significance due to the physical distance of each project from the Calvert to Kagaru Project and the proposed adoption and implementation of recommended mitigation measures. This is further discussed in Chapter 22: Cumulative Impacts.

An indicative groundwater monitoring program is outlined in Appendix O: Groundwater Technical Report and Chapter 23: Draft Outline Environment Management Plan to provide an ongoing assessment of the potential impacts of the Project on the identified groundwater EVs.