CHAPTER 13

Groundwater

INLAND RAIL

INLAND RAIL—BORDER TO GOWRIE ENVIRONMENTAL IMPACT STATEMENT

ARTC

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

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13.1 Introduction

The purpose of this chapter is to assess potential impacts to groundwater resources and users resulting from construction and operation of the Inland Rail Border to Gowrie Project (the Project). Where potential impacts have been identified, mitigation measures are proposed to avoid or minimise the magnitude of those impacts.

The key objectives of this groundwater assessment are to:

- Establish existing groundwater resources, values and conditions within the impact assessment area (defined in Section 13.4.1), using a combination of published information and data collected from groundwater investigations conducted to inform the reference design and Environmental Impact Statement (EIS)
- Identify key Project impacts on groundwater environmental values (EVs) within the impact assessment area
- Identify mitigation measures and controls that have been factored into the design, or otherwise implemented during the reference design phase for the Project
- Identify mitigation measures and controls that will be implemented during future phases of the Project to further reduce the magnitude of potential impacts
- Evaluate the significance of the impacts of the Project on groundwater environmental values within the impact assessment area, with and without the application of mitigation measures during future phases of the Project
- Provide an assessment of the potential for cumulative impacts to groundwater resources as a result of the Project, in combination with other projects.

This chapter should be read in conjunction with Appendix R: Groundwater Technical Report.

13.2 Terms of Reference requirements

This chapter has been prepared to address sections of the ToR of relevance to groundwater. A compliance check of this chapter against each of the relevant components of the ToR is presented in Table 13.1. Compliance of the draft EIS against the full ToR is documented in Appendix B: Terms of Reference Compliance Table.

TABLE 13.1 COMPLIANCE AGAINST RELEVANT SECTIONS OF THE TERMS OF REFERENCE

Groundwater Terms of Reference requirements		Draft EIS section
Existing environment		
11.36	Identify the water related environmental values and describe the existing surface water and groundwater regime within the impact assessment area and the adjoining waterways in terms of water levels, discharges and freshwater flows.	Section 13.6.1 Section 13.6.4 Section 13.6.7 Chapter 12: Surface Water and Hydrology Appendix P: Surface Water Quality Technical Report
11.37	Identify the environmental values of groundwater within the Project area and immediately downstream that may be affected by the Project, including any human uses of the water and any cultural values.	Section 13.6.7 Chapter 12: Surface Water and Hydrology Appendix P: Surface Water Quality Technical Report
11.38	At an appropriate scale, detail the chemical, physical and biological characteristics of surface waters and groundwater within the area that may be affected by the Project. Include a description of the natural water quality variability within the impact assessment area associated with climatic and seasonal factors, and flows.	Section 13.6.4 Appendix R: Groundwater Technical Report Chapter 12: Surface Water and Hydrology Appendix P: Surface Water Quality Technical Report
11.39	Describe any existing and/or constructed waterbodies adjacent to the proposed alignment.	Section 13.6.1
11.40	Undertake a landowner bore survey to identify the location and source aquifer of licensed groundwater extraction in areas potentially impacted by the Project (e.g. near cuttings and bridges).	Section 13.6.5

	Groundwater Terms of Reference requirements	Draft EIS section
Water quality: impact assessment		
11.41	The assessment of impacts on water will be in accordance with the Department of Environment and Science (DES) Information guideline for an environmental impact statement – ToR Guideline – Water, where relevant, located on the DES website	Section 13.3, Table 13.2
11.44	Where significant cuttings are proposed, identify the presence of any sulphide minerals in rocks with potential to create acidic, metalliferous and saline drainage. If 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 groundwater quality.	Section 13.7 Section 13.7.5 Section 13.9
Water quality: mitigation measures		
11.47	Describe how the water quality objectives (WQOs) identified above would be achieved, monitored and audited, and how environmental impacts would be avoided or minimised and corrective actions would be managed.	Section 13.7.5 Section 13.9
11.48	Describe appropriate management and mitigation strategies and provide contingency plans for:	-
	a) potential accidental discharges of contaminants and sediments during construction and operation	Section 13.7.5 Section 13.9
	d) management of acid sulfate soils and acid producing rock and associated leachate from excavations and disturbed areas.	Section 13.7.5 Section 13.9
Water resources: impact assessment		
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, Water Supply (Safety and Reliability) Act 2008 or Planning Act.	Section 13.7 Section 13.7.5 Chapter 3: Legislation and Project Approvals Process Chapter 12: Surface Water and Hydrology
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:	-
	a) changes in flow regimes from structures and water take	Section 13.7.1 Table 13.15 Table 13.18
	c) direct and indirect impacts arising from the Project	Section 13.7.1
	d) impacts to aquatic ecosystems, including groundwater dependent ecosystems and environmental flows.	Section 13.7.1

Groundwater Terms of Reference requirements		Draft EIS section
11.55	Provide information on the proposed water usage by the Project including details about:	Also refer to Chapter 5: Project Description Chapter 12: Surface Water and Hydrology
	a) the estimated supply required to meet the demand for construction and full operation of the Project, including timing of demands	Section 13.7 Section 13.7.5 Section 13.9
	b) the quality and quantity of all water supplied to the site during the construction and operational phases based on minimum yield scenarios for water reuse, rainwater reuse and any bore water volumes	Section 13.7 Section 13.7.5 Section 13.9
	d) sufficient hydrogeological information to support the assessment of any temporary water permit applications.	Section 13.7 Section 13.7.5 Section 13.9 Table 13.15
11.56.	Describe proposed sources of water supply given the implication of any approvals required under the Water Act. Estimated rates of supply from each source (average and maximum rates) must be given and proposed water conservation and management measures must be described.	Section 13.7 Section 13.7.5 Chapter 5: Project Description Chapter 12: Surface Water and Hydrology
11.57	Determination of potable water demand must be made for the Project, including the temporary demands during the construction period. Include details of any existing town water supply to meet such requirements. Detail should also be provided to describe any proposed on-site water storage and treatment for use by the site workforce.	Section 13.7 Section 13.7.5 Chapter 5: Project Description Chapter 12: Surface Water and Hydrology
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 Department of Natural Resources, Mines and Energy (DNRME), 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.	Section 13.3 Section 13.7 Chapter 3: Legislation and Project Approvals Process Chapter 12: Surface Water and Hydrology
11.59	Identify other water users that may be affected by the proposal and assess the Project's potential impacts on other water users.	Section 13.6.5 Section 13.7 Section 13.7.5
Water resources: mitigation measures		
11.62	Describe measures to minimise impacts on surface water and ground water resources.	Section 13.8 Section 13.9
11.63	Provide a policy outline of compensation, mitigation and management measures where impacts are identified.	Section 13.7.5 Section 13.9

13.3 Policies, standards and guidelines

A summary of the groundwater related policies and plans that are of relevance to the Project and this assessment are included in Table 13.2.

Legislation of relevance with respect to this groundwater assessment is as follows:

- *Water Act 2007* (Cth)
- *Water Act 2000* (Qld) (Water Act)
- *Environmental Protection Act 1994* (Qld) (EP Act)

The relevance of these items of legislation and the Project's compliance with each is discussed in Chapter 3: Legislation and Project Approvals Process.

TABLE 13.2 SUMMARY OF POLICY, PLANS, AND GUIDELINES

Policy, plan or guideline	Relevance to the Project
Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP Water and Wetland Biodiversity)	Under the EP Act, the EPP Water and Wetland Biodiversity achieves the objectives of the Act in relation to Queensland waters. This policy provides: ▸ Identification of EVs and management goals for Queensland groundwaters ▸ Identification of State water quality guidelines and water quality objectives (WQOs) to enhance or protect the EVs. Groundwater resources within the impact assessment area occur within two river basins with identified EVs and WQOs under the EPP Water and Wetland Biodiversity. These basins are: ▸ Queensland Border Rivers catchment from Ch 30.6 km (NS2B) to Ch 117.0 km ▸ Condamine River Basin from Ch 117.0 km to Ch 206.9 km.
Healthy Waters Management Plans (HWMPs)	HWMPs are a key planning mechanism to improve the quality of Queensland waters under the EPP Water and Wetland Biodiversity. HWMPs provide an ecosystem-based approach to integrated water management. The HWMPs provide: ▸ Identification and mapping of environmental values (EVs), desired levels of aquatic ecosystem protection and management goals for Queensland waters ▸ WQOs under the *National Water Quality Management Strategy* (National Health and Medical Research Council and National Resource Management Ministerial Council (NHMRC & NRMMC), 2011). to protect the EVs. The relevant HWMPs for the Project include: ▸ Ch 30.6 km (NS2B) to Ch 117.0 km: within the boundaries of the Border Rivers catchment. The relevant EVs for the impact assessment area are described in the *Healthy Waters Management Plan: Queensland Border Rivers and Moonie River Basins* (DES, 2019a). ▸ Ch 117.0 km to Ch 206.9 km: within the boundaries of the Condamine–Balonne River catchment. The relevant EVs for the impact assessment area are described in the *Healthy Waters Management Plan: Condamine River Basin* (DES, 2019b).
Basin Plan 2012 (Basin Plan)	The Basin Plan is a Commonwealth instrument, made under subparagraph 44(3)(b)(i) of the *Water Act 2007* (Cth), that provides a framework to manage the water resources of the Murray–Darling Basin and sets out limits for sustainable use of surface water and groundwater in each water resource plan area. The impact assessment area is located within the Condamine and Balonne (groundwater unit GW21) and the Border Rivers and Moonie (groundwater unit GW19) water resource plan area, which are covered by the Basin Plan.
Water Plans	Water sharing plans were developed under the Water Act to sustainably manage and allocate water resources in Queensland. The plans apply to water in watercourses and lakes, water in springs, overland flow water, and groundwater, and allow for identification of availability of water options for Project uses. Three water sharing plans are relevant to the Project: ▸ *Water Plan (Border Rivers and Moonie) 2019* ▸ *Water Plan (Condamine and Balonne) 2019* ▸ *Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017*.

Policy, plan or guideline	Relevance to the Project
	These plans specifically apply to the following groundwater units located within the impact assessment area: - Border Rivers Fractured Rock - Border Rivers Alluvium - Sediments above the Great Artesian Basin (GAB) - Condamine Alluvium - Condamine Fractured Rock - Upper Condamine Basalts (i.e. Main Range Volcanics) - Kumbarilla Beds - Walloon Coal Measures (WCM).
Water guidelines	Various water guidelines were applied in assessing EVs and potential impacts. These are as follows: - *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC & ARMCANZ), 2018) - *Australian Drinking Water Guidelines* (NHMRC & MNRMMC, 2011)—Updated October 2017, viewed 3 September 2018, **nhmrc.gov.au/guidelines-publications/eh52** - *EIS information guideline—Water 2016* (DES, 2016a) Further details are provided in Appendix R: Groundwater Technical Report.

13.4 Methodology

13.4.1 Impact assessment area

An impact assessment area has been established to delineate the spatial extent for the groundwater assessment. The impact assessment area for groundwater is generally defined as the area within a 1 km distance of the centre line of the proposed Project alignment.

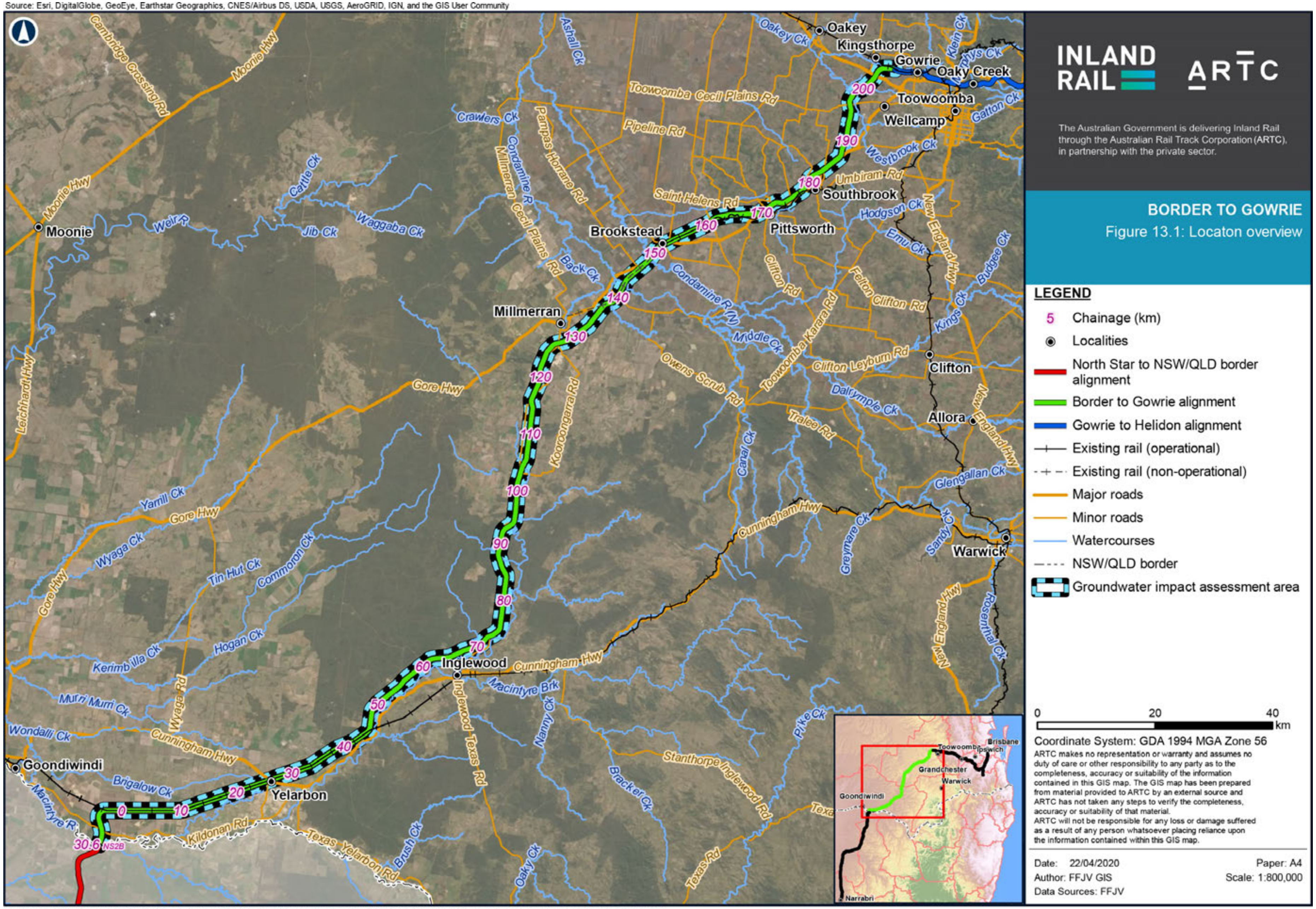
In some instances, due to a paucity of available groundwater data, the impact assessment area has been increased to appropriately characterise certain EVs (i.e. 5 km distance for groundwater dependant ecosystems (GDEs), Section 13.6.6). Where an extension of the impact assessment area was warranted to sufficiently address the ToR, the impact assessment area has been defined within that section of the chapter.

The Project footprint is wholly within the impact assessment area. The Project footprint has been established to encompass all permanent infrastructure required for the Project. Permanent infrastructure features include the new rail track, bridges and drainage structures, level crossings, road realignments, possible upgrades to adjacent roads and infrastructure, a rail maintenance access road, fencing and signage.

The Project footprint also includes land required on a temporary basis to enable construction of the Project, including for construction laydown, stockpile and storage areas, temporary erosion control structures, concrete batching and access track(s).

The impact assessment area and Project location are presented in Figure 13.1.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: LUC/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_ARTC_Fig13.1_Location_Overview_v4.mxd Date: 23/04/2020 13:57

13.4.2 Assessment methodology

A staged approach has been adopted for the groundwater assessment for the Project. This methodology allows for the compilation and assessment of sufficient data to address the groundwater requirements of the ToR and the provision of recommendations for impact avoidance and mitigation through the reference design and future Project phases. Stages adopted for the groundwater study include:

- Stage 1—Desktop study
- Stage 2—Reference design phase investigations
- Stage 3—Groundwater impact assessment
- Stage 4—Significance assessment.

Details of each stage are summarised below and described in greater detail in Appendix R: Groundwater Technical Report.

13.4.2.1 Desktop study

Available geological and hydrogeological literature and data were reviewed to establish a detailed description of the existing hydrogeological regime and identification of groundwater EVs. Interrogation of publicly available databases, including the Department of Natural Resources, Mines and Energy (DNRME) Groundwater Database, was undertaken to identify registered groundwater bores within the impact assessment area and corresponding groundwater level and quality data. In addition, published studies and reports of relevance to the impact assessment area were reviewed to further inform the understanding of regional geological and hydrogeological characteristics. Data sources accessed for this assessment are specified in Section 13.4.3.

13.4.2.2 Hydrogeological investigations

Groundwater investigations were undertaken over the period May to November 2018, concurrent with geotechnical investigations that were completed to inform development of the reference design.

Direct impacts by new freight rail infrastructure on groundwater resources are typically associated with locations of deep cuts and bridge piling works. Project monitoring bores were primarily located near proposed bridge structures and deep cuttings (> 10 m) to reflect this risk and to provide site-specific groundwater data within areas considered most likely to be affected by the Project. The site-specific groundwater data collected was used to further refine and describe the existing hydrogeological regime.

The scope and findings of the groundwater investigations are discussed in Section 13.5.

13.4.2.3 Groundwater impact assessment

Potential impacts on the existing groundwater regime, at local and regional scales, were identified and assessed based on a review of planned construction and rail operation activities with respect to the current geological and hydrogeological environment.

Groundwater numerical modelling was performed for the Project in the form of two-dimensional (2-D) cross sectional models in locations where deep cuttings (> 10 m) are proposed as part of the reference design. The predictive modelling was used to inform development of the reference design for the Project in terms of potential drawdown and seepage rates in locations where deep cuttings may be required. Modelling results were reviewed and interpreted to assess potential impacts on groundwater resources from the Project.

A discussion of the modelling results is provided in Section 13.7.1, with further detail provided in provided in Appendix R: Groundwater Technical Report.

13.4.2.4 Significance assessment

Potential impacts on groundwater resources have been assessed using a qualitative significance assessment method. For groundwater, the significance of an impact depends on the sensitivity of the groundwater EVs (i.e. the quality of the environment to be impacted) and the magnitude (i.e. intensity, duration and potential spatial extent) of the identified potential impact. Determination of the sensitivity of the groundwater EVs and the magnitude of the potential impact enables the assessment of the significance of potential groundwater impacts.

This approach has allowed for the evaluation of significance classifications, with and without mitigation. These mitigation measures have been used as a basis for developing an outline for a Groundwater Monitoring and Management Program (GMMP) for the Project, as discussed in Section 13.8.3.

Chapter 4: Assessment Methodology includes further discussion with respect to the significance-based impact assessment framework that has been adopted.

13.4.3 Data sources

The groundwater impact assessment has been developed in reference to information obtained from publicly available, published datasets and reports, and from site-specific geotechnical and hydrogeological investigations. The information sources listed in Table 13.3 have been referenced to establish an understanding of the existing hydrogeological regime within the impact assessment area and in the assessment of potential impacts on groundwater resources. Further details of the information obtained from these sources is provided in Appendix R: Groundwater Technical Report.

TABLE 13.3 DATA SOURCES REFERENCED FOR THE GROUNDWATER IMPACT ASSESSMENT

Data	Source
Hydrology/climate	▶ Historical Climate Database—BoM **(bom.gov.au/climate/data)** ▶ Appendix P: Surface Water Technical Report ▶ Queensland Globe datasets **(qldglobe.information.qld.gov.au)**
Soil types	▶ Inland Rail: Phase 2 - NSW/QLD Border to Gowrie; Geotechnical Interpretive Report (FFJV, 2019) ▶ Inland Rail: Phase 2 - North Star to NSW/QLD Border; Geotechnical Interpretive Report (FFJV, 2020) ▶ Queensland Globe datasets **(qldglobe.information.qld.gov.au)**
Geology/ hydrostratigraphy	▶ Geotechnical Factual Report, Inland Rail Project - Border to Gowrie Section (Golder Associates, 2019a) ▶ Condamine River Valley Area Geotechnical Investigation – Factual Report, Inland Rail Project - Border to Gowrie, Phase 2 (Golder Associates, 2019b) ▶ Inland Rail - Border to Gowrie; 100% Feasibility Design Scope of Works – Hydrogeology (Golder Associates, 2019c) ▶ Geotechnical Factual Report, Inland Rail Project - North Star to Border Section (Golder Associates, 2019d) ▶ Inland Rail - Section 270 (North Star to Border), 100% Feasibility Design Scope of Works - Hydrogeology (Golder Associates, 2019e) ▶ Inland Rail: Phase 2 - NSW/QLD Border to Gowrie; Geotechnical Interpretive Report (FFJV, 2019) ▶ Inland Rail: Phase 2 - North Star to NSW/QLD Border; Geotechnical Interpretive Report (FFJV, 2020) ▶ Goondiwindi 1:250,000 Geological Sheet—1972 (Mond, et al., 1972) ▶ DNRME groundwater database ▶ Queensland Globe geological map datasets **(qldglobe.information.qld.gov.au)**
Groundwater levels and quality	▶ DNRME groundwater database ▶ Queensland Globe datasets **(qldglobe.information.qld.gov.au)** ▶ Inland Rail - Border to Gowrie; 100% Feasibility Design Scope of Works – Hydrogeology (Golder Associates, 2019c) ▶ Inland Rail - Section 270 (North Star to Border), 100% Feasibility Design Scope of Works - Hydrogeology (Golder Associates, 2019e)
GDEs	▶ Groundwater Dependent Ecosystem Atlas - Bureau of Meteorology: **(bom.gov.au/water/groundwater/gde/map.shtml)** ▶ Queensland Globe datasets **(qldglobe.information.qld.gov.au)**
Groundwater use and management	▶ DNRME groundwater database ▶ Water Plan (Border Rivers and Moonie) 2019 ▶ Water Plan (Condamine and Balonne) 2019 ▶ Water Plan (Great Artesian Basin and Other Regional Aquifers [GABORA]) 2017

13.5 Hydrogeological investigations

Between May 2018 and February 2019, geotechnical and hydrogeological investigations were undertaken within the Project footprint with the objective of obtaining geotechnical and hydrogeological data to inform development of the reference design and the draft EIS.

Field investigations included:

- Standpipe piezometer installation—30 groundwater monitoring bores
- Hydraulic aquifer testing (falling head test or rising head test) in standpipe piezometers
- Groundwater level monitoring
- Groundwater quality sampling of Project monitoring bores
- Laboratory analysis of groundwater samples.

A summary of the field works is presented below. Full technical details of the scope and methodologies for the hydrogeological investigation are provided in Appendix R: Groundwater Technical Report. Installation and construction details for the groundwater monitoring bores are also presented in bore logs provided in Appendix G: Geotechnical Investigation Data.

13.5.1 Groundwater monitoring bore installation

Drilling and installation of 30 groundwater monitoring bores was conducted in accordance with the *Minimum Construction Requirements for Water Bores in Australia* (National Uniform Drillers Licensing Committee, 2012). Project monitoring bores were primarily located where features of the reference design, at its stage of development at the time of the investigations, had greatest potential to interface with groundwater.

In each instance, the standpipe piezometer was designed by a qualified hydrogeologist, with installation conducted by the drilling contractor under the supervision of a qualified field engineer and licensed water bore driller.

Each completed groundwater monitoring bore was developed by purging via either manual bailing or with a 12-volt Twister groundwater pump, as appropriate. Purging was completed prior to sampling for groundwater quality analyses. Multiple groundwater bore volumes were removed from each standpipe piezometer to stimulate flow of ambient groundwater toward the standpipe to ensure suitable development of each well.

Field parameters for groundwater quality were monitored during development to quantify when drilling influences had been removed from the piezometer and groundwater representative of the aquifer was being purged. The standpipe piezometer was considered developed when purge water was free of sediment and field parameters had stabilised over subsequent readings.

A summary of the borehole locations and monitoring results are included in Table 13.4. Locations of the Project and monitoring bores are included in Figure 13.17.

TABLE 13.4 PROJECT HYDROGEOLOGICAL INVESTIGATION MONITORING LOCATIONS AND RESULTS

Chainage (approximate)	Well ID	Screened interval (mbgl)	Screened lithology	Aquifer[1]	Surface elevation[2]	Median SWL (mAHD)	RL range from level logger during the field investigation works (mAHD)	Average hydraulic conductivity[3], K (m/day)
Ch 30.7 km (NS2B)	BH2213	13.5 to 19.5	Sandy gravel and sand	Border Rivers Alluvium	227.0	215.1	215.1 to 215.2	0.19
Ch 32.8 km (NS2B)	BH2217	9.2 to 15.2	Clayey gravel and sandy gravel	Border Rivers Alluvium	227.6	215.3	215.3 to 215.4	0.42
Ch 34.8 km (NS2B)	BH2218	8.8 to 14.8	Clayey Gravel and gravelly sand	Border Rivers Alluvium	225.6	214.2	213.7 to 214.8	0.16
Ch 35.1 km	BH2201	20.2 to 29.2	Extremely weathered sandstone	Pilliga Sandstone/Springbok Sandstone (Kumbarilla Beds)	256.5	248.5	248.3 to 248.7	0.3
Ch 49.6 km	BH2302	9 to 15	Sandstone	WCM	300.9	Dry bore		
Ch 52.8 km	BH2203	16 to 25	Sandstone	WCM	278.7	258.9	254.5 to 264.7	$3x10^{-4}$
Ch 53.0 km	BH2304	2.6 to 8.6	Siltstone	WCM	289.8	Dry bore		
Ch 53.4 km	BH2305	9 to 15	Siltstone	WCM	287.2	Dry bore		
Ch 54.9 km	BH2206	16.5 to 25.5	Weathered mudstone/sandstone	WCM	272.4	263.5	263.4 to 263.5	$5x10^{-2}$
Ch 59.1 km	BH2308	9 to 15	Weathered clayey sandstone	WCM	301.6	291.4	287.6 to 295.2	$9x10^{-4}$
Ch 63.7 km	BH2309	9 to 15	Extremely weathered sandstone/mudstone	WCM	277.1	265.7	262.8 to 268.6	$3x10^{-3}$
Ch 65.8 km	BH2210	21 to 30	Siltstone	WCM	283.4	268	258.5 to 277.5	$1x10^{-4}$
Ch 71.1 km	BH2311	9 to 15	Extremely weathered sandstone/mudstone	Eurombah Formation (WCM)	296.7	Dry bore		
Ch 87.3 km	BH2214	14 to 20	Extremely weathered sandstone	WCM	321.6	305.1	304.2 to 306	$2x10^{-3}$
Ch 88.2 km	BH2215	21 to 30	Extremely weathered sandstone	WCM	322.5	308	306 to 310	3.3

Chainage (approximate)	Well ID	Screened interval (mbgl)	Screened lithology	Aquifer[1]	Surface elevation[2]	Median SWL (mAHD)	RL range from level logger during the field investigation works (mAHD)	Average hydraulic conductivity[3], K (m/day)
Ch 93.8 km	BH2216	12.5 to 18.5	Extremely weathered mudstone	WCM	320.8	307	304.3 to 309.8	$8x10^{-4}$
Ch 95.6 km	BH2617	2 to 5	Sand	Alluvium (Canning Creek)	323.3	318.9	318.3 to 319.6	0.2
Ch 112.4 km	BH2341	9 to 15	Mudstone/sandstone	WCM	446.3	435.9	434.9 to 436.9	$9x10^{-3}$
Ch 114.3 km	BH2323	9 to 15	Extremely weathered sandstone/mudstone	Eurombah Formation (WCM)	458.6	446.2	444.5 to 450.7	0.7
Ch 116.2 km	BH2355	17 to 20	Basalt	Main Range Volcanics (MRV)	477.5		Dry bore	
Ch 122.1 km	BH2326	9 to 15	Extremely weathered mudstone	WCM	477	468.9	465 to 472.7	$5x10^{-4}$
Ch 127.2 km	BH2229	24 to 30	Sandstone	WCM	406.6	379.5	377.2 to 381.7	$8x10^{-3}$
Ch 165.1 km	BH2337	9 to 15	Basalt	MRV	487.1		Dry bore	
Ch 166.1 km	BH2338	9 to 15	Basalt/clay	MRV	504.8		Dry bore	
Ch 184.8 km	BH2343	12 to 15	Basalt	MRV	532.8	519.9	519.6 to 520.2	4.9
Ch 187.5 km	BH2344	9 to 15	Sandy gravel/basalt	Alluvium/MRV	524.8	515.6	512.6 to 518.5	0.06
Ch 188.9 km	BH2345	21 to 30	Basalt	MRV	536.1	518.6	516.7 to 520.5	$7x10^{-3}$
Ch 193.5 km	BH2347	17 to 20	Gravelly silt	MRV	463	453.8	453.8 to 454.3	0.3
Ch 195.5 km	BH2248	19 to 25	Sandy clay/clayey sand	WCM	432.9	425.8	425.8 to 425.9	0.2
Ch 201.8 km	BH2352	12 to 15	Basalt	MRV	487.3		Dry bore	

Table notes:
RL—reduced level
SWL—standing water level
mAHD—metres above Australian Height Datum
mbgl—metres below ground level
1 Refer to Section 13.6.4 for introduction and description for each
2 Surface elevation derived from the digital elevation model spatial data or from bore completion logs
3 Mean hydraulic conductivity value derived from falling and rising head tests completed during reference design phase investigations

13.5.2 Groundwater level monitoring

A dedicated automatic pressure transducer was installed in each standpipe piezometer for continuous groundwater level monitoring for durations between four and eight weeks. The pressure transducers (In-Situ Rugged Trolls) were installed at depths ranging between 9 m to 30 m. The transducers record total pressure on the sensor (water column above the sensor and atmospheric/barometric pressure), which is then converted to a groundwater level. Measurements are recorded by the pressure transducers at one-hour intervals and are calibrated by manual static water level measurements.

The groundwater level data obtained from the hydrogeological investigations are presented in Table 13.4 and discussed for each of the relevant aquifer units in Section 13.6.4.

The pressure transducers will remain installed in the network of Project monitoring bores to provide a continued source of groundwater level data in proximity to the Project footprint. This data will be used in the development and finalisation of a Groundwater Management and Monitoring Program (GMMP) for the Project (refer Section 13.8.3), as well as for the monitoring of impacts to groundwater during construction (refer Section 13.8.3.1).

13.5.3 Permeability testing

In-situ hydraulic testing was conducted in standpipe piezometers of completed monitoring bores using the slug test method. Slug tests involve inducing a change in groundwater level within the bore casing by inserting (falling head) and then removing (rising head) a solid slug, or by sudden displacement of the water column in the casing using a gas slug, and then measuring the water level response over time. In each instance, water level recovery was monitored until it returned to 90 per cent of the pre-test water level. The recorded data allows for an estimation of hydraulic conductivity of the screened soil or rock material.

The hydraulic conductivity estimates derived from hydrogeological investigation data are presented in Table 13.4 and discussed for each of the relevant aquifer units in Section 13.6.4.

13.5.4 Groundwater sampling

One round of groundwater sampling was conducted after the completion of all 30 monitoring bores for collection of baseline water quality, durability, and salinity parameters.

Groundwater sampling involved:

- Manual measurement of groundwater levels of each monitoring bore
- Purging of monitoring bores prior to sampling. As part of the purging, a minimum of three bore volumes were removed from each bore and field physicochemical measurements (i.e. pH, electrical conductivity (EC), redox, dissolved oxygen and temperature) were collected during purging to ensure parameters had stabilised.
- Sampling of groundwater for laboratory analysis. Duplicate and triplicate samples were collected to meet adopted quality assurance and quality control (QA/QC) requirements. Field physicochemical measurements were collected at the time of sampling.
- All samples were collected in appropriate sampling containers for the required analytical parameters, chilled and dispatched under chain of custody documentation to a National Association of Testing Authorities (NATA) accredited laboratory for analysis.

13.5.5 Laboratory analysis of groundwater samples

The analysed chemical parameters for each sample were as follows:

- Major anions and cations (i.e. calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}), fluoride (F^{-}), sulfate (SO_4^{2-}), carbonate and bicarbonate alkalinity and hardness)
- pH
- Conductivity
- Total dissolved solids (TDS)
- Total and dissolved metals (i.e. arsenic, boron, barium, beryllium, cadmium, chromium, cobalt, copper, manganese, iron, nickel, lead, selenium, vanadium, zinc, and mercury)
- Nutrients (nitrate, nitrite, ammonia, reactive phosphorous (P), total nitrogen (TN), total Kjeldahl nitrogen and total P (TP))
- Sodium adsorption ratio.

Details of the reported groundwater quality from the reference design phase of works are included in Appendix R: Groundwater Technical Report and summarised in Section 13.6.4.5.

13.6 Existing environment

The subsections below provide discussion on the existing groundwater resources that are located within the impact assessment area, and their quality. In each instance, further detail is included in Appendix R: Groundwater Technical Report, or other chapters of the draft EIS, as referenced.

13.6.1 Land use

Land use within the impact assessment area is predominately grazing land (refer Figure 13.2). The next most common land uses are also predominately of an agricultural nature, including cropping and irrigated cropping. Other land uses that exceed 1 per cent of the Project footprint include land classified as 'other minimal use' (consisting of areas of land that are largely unused, for example, residual native cover or land reserved for stock routes), production forestry and transport and communication (which includes transportation infrastructure and commercial services).

An overview of land uses relevant to groundwater resources is presented in Figure 13.2. Full details of land usage within the impact assessment area are provided in Chapter 7: Land Use and Tenure.

13.6.2 Watercourses

Under the *Water Act 2000* (Qld) a watercourse is defined as a river, creek or other stream, which includes a stream in the form of an anabranch or a tributary, where water flows either permanently or intermittently regardless of flow frequency.

The Project crosses the full width of 15 major waterways (stream order ≥ 3) and 66 minor waterways (stream order < 3). The major waterways that are crossed by the Project are as follows:

- Grasstree Creek—at Ch 13.5 km
- Pariagara Creek—at Ch 67.2 km
- Cattle Creek—at 88.2 km
- Back Creek—at Ch 97.4 km
- Bringalily Creek—at Ch 97.4 km
- Nicol Creek—at Ch 104.3 km
- Back Creek drainage feature—at Ch 126.7 km and Ch 127.9 km
- Condamine River (Main Branch)—at Ch 142.9 km
- Condamine River (North Branch)—at Ch 148.7 km
- Umbiram Creek drainage feature—at Ch 185.9 km
- One Mile Creek drainage feature—at Ch 191.8 km
- Westbrook Creek—at Ch 188.7 km and Ch 197.2 km
- Dry Creek—at 197.8 km

The Project does not include a full width crossing of the Macintyre River; therefore, it is not included in this summary.

In addition to the natural watercourses summarised above, there are several artificial/constructed waterbodies located within the impact assessment area that are intersected by the Project alignment. These 12 artificial/constructed waterbodies are predominantly rural farm dams used for agricultural purposes and typically occur along unnamed drainage features. The artificial waterbodies are located at various chainages from approximately Ch 75.4 km to Ch 161.4 km.

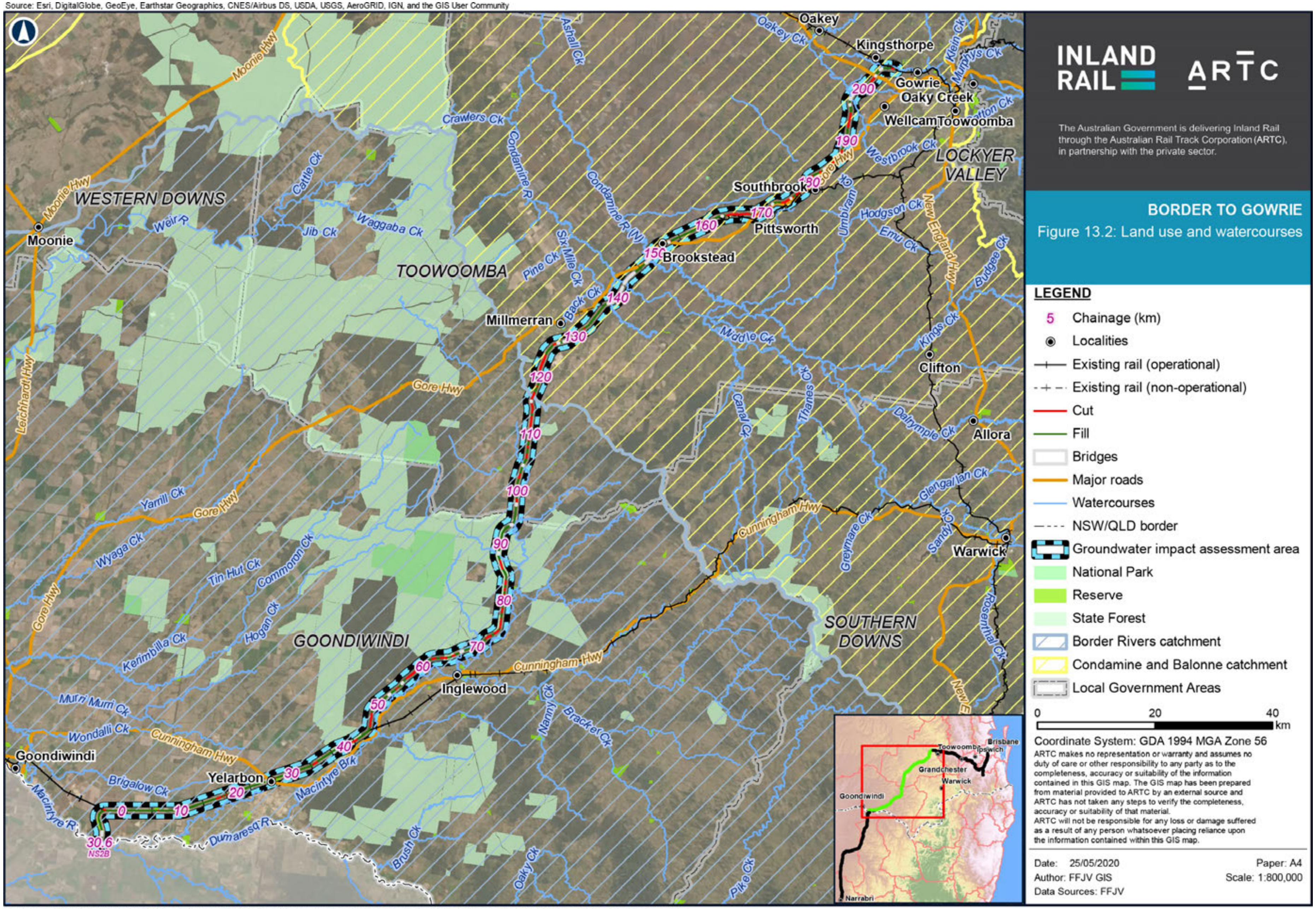
Detailed discussion of watercourses and other drainage features which the Project intersects (natural and artificial) are presented in Chapter 12: Surface Water and Hydrology. An overview of watercourses relevant to groundwater resources is presented in Figure 13.2.

13.6.3 Regional geology

The Project is underlain at depth by the depositional Permo-Triassic-aged Bowen Basin. Overlying the Bowen Basin are the Jurassic to Cretaceous-aged Surat and Clarence–Moreton Basins, which are separated by the north–south trending Kumbarilla Ridge. This ridge forms a subsurface bedrock high which the Project alignment encounters at Ch 117.0 km.

A summarised regional stratigraphic column of the Project is included in Table 13.5. Surface geology mapped across the impact assessment area is depicted in Figure 13.3.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



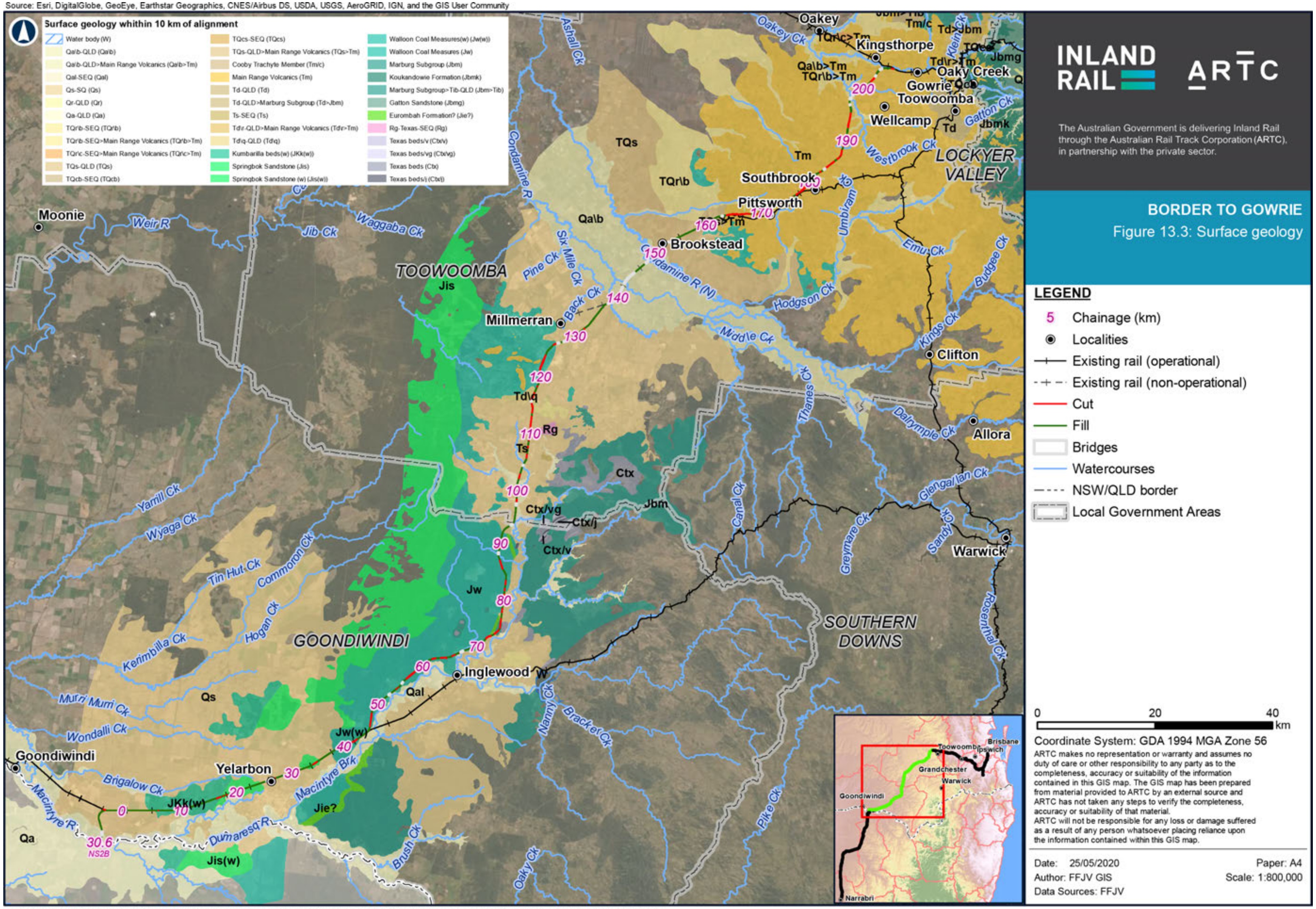
BORDER TO GOWRIE
Figure 13.2: Land use and watercourses

Map by: LUC/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_ARTC_Fig13.2_LandUse_Watercourses_v5.mxd Date: 25/05/2020 13:00

TABLE 13.5 SUMMARISED STRATIGRAPHIC COLUMN FOR THE PROJECT

Age	Surat Basin		Clarence–Moreton Basin	Lithology	Thickness	Extent and comments
Quaternary to Tertiary	Alluvium and Colluvium (includes the Border Rivers and Condamine alluvial units)			Clays, silts, sands and gravels Clays in upper portions of both the Border Rivers and Condamine Alluvium is common. This is likely to reduce recharge via rainfall (Hillier, 2010)	Border Rivers Alluvium: up to 100 m Condamine Alluvium: up to 150 m	Aquifer (water table) associated with modern river sediments, paleochannels and old alluvial fans
Tertiary	Main Range Volcanics			Basalts, tuff and agglomerate.	Typically, 30 to 150 m, highly variable (DNRME, 2016b)	Aquifer (fractured) Outcrop and sub-crop at higher elevations along the eastern portion of the rail alignment between Ch 163.0 km and Ch 206.9 km
Cretaceous	Wallumbilla Formation		Kumbarilla Beds	Mudstone and siltstone	~ 100 m	Aquitard
	Kumbarilla Beds	Bungil Formation		Mudstone, siltstone, and carbonaceous sandstone	< 200 m	Aquitard
		Mooga Formation		Clayey sandstone, siltstone and mudstones	< 100 m	Aquifer
		Orallo Formation		Interbedded siltstone and mudstone	~ 150 m to 250 m	Aquitard
Jurassic		Pilliga Sandstone/Springbok Sandstone		Porous, fine-to-coarse massive sandstone and conglomerate	~100 m to 300 m	Major aquifer for GAB and the Gwydir subregion
	Walloon Coal Measures			Claystone, shales, sandstones and major coal seams	~ 200 m to 400 m	Leaky aquitard
	Hutton Sandstone		Marburg Subgroup	Porous quartz rich sandstone	120 m to 180 m	Major aquifer unit
	Evergreen Formation			Mainly siltstone and mudstone	Average thickness is ~150 m	Confining bed
Jurassic to Triassic	Precipice Sandstone		Helidon Sandstone	Medium to coarse sandstone	Up to 110 m	Aquifer
Triassic to Permian	Bowen Basin (Rewan Group)		Basement	Sandstone, siltstone, claystone, tuff and coal	Up to 1,200 m	Bowen Basin underlies the Surat Basin

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: LUC/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_ARTC_Fig13.3_Surface_Geology_v5.mxd Date: 25/05/2020 13:06

13.6.4 Groundwater regime

There are three main aquifer systems present within the impact assessment area that are relevant to the Project:

- Cainozoic to recent alluvial/colluvial sediments (Quaternary/Tertiary) of shallow alluvial systems along river valleys (Border Rivers and Condamine River alluvial units)
- Tertiary MRV, fractured basalt aquifers in the eastern portion of the Project
- Jurassic-age WCM.

These aquifer systems are part of the larger GAB and have the potential to be sensitive to impacts from Project activities. While the Hutton Sandstone is a regionally significant aquifer, it is not considered to be susceptible to impacts by the Project due to the depth at which it occurs (refer Table 13.5). Therefore, the Hutton Sandstone aquifer is not considered further in this assessment.

The subsections below summarise the physical and chemical aspects of the three aquifers that are susceptible to impacts in the context of their respective hydrogeological regime. Further details of these groundwater units are included in Appendix R: Groundwater Technical Report.

13.6.4.1 Alluvium/colluvium (Quaternary/Tertiary)

The impact assessment area is underlain by two alluvium/colluvium units distinguished by their respective catchments, namely the:

- Border Rivers Alluvium (Queensland)—within the Border Rivers catchment between approximately Ch 30.60 km (NS2B) to Ch 117.0 km
- Condamine Alluvium (Central Condamine and tributary alluvium)—within the Condamine–Balonne catchment between approximately Ch 117.0 km to Ch 206.9 km.

Due to the nature of the alluvial and colluvial sediments, these units are not distinguishable and hence discussed as one (alluvial/alluvium) unit. The characteristics of these two units are discussed below. Groundwater quality within these two units is summarised in Section 13.6.4.5 and groundwater users that are reliant on these units are discussed in Section 13.6.5.

Occurrence

In the Border Rivers catchment, groundwater is associated with alluvial sediments found along the Dumaresq and Macintyre rivers, Macintyre Brook, and Canning Creek. Much of the region is characterised by an upper and lower alluvial system containing groundwater. East of the Macintyre Brook and Dumaresq River, alluvial sediments are largely confined to narrow valleys of Macintyre Brook and Canning Creek (Golder, 2019c). Collectively, these alluvial sediments are referred to the Border Rivers Alluvium.

The Quaternary Condamine Alluvium is associated with the floodplain of the Condamine River and associated tributaries. It is incised primarily into the WCM of the Surat Basin and forms the primary bedrock to the alluvium (DNRME, 2016b). The MRV underlies the alluvium further to the east.

The Border Rivers Alluvium and Condamine Alluvium consist of colluvial sands and soils derived from slope wash deposition. Near the edge of valleys, the colluvium may be interfingered with alluvium and the two become difficult to distinguish. This colluvium is likely to comprise significant portions of the geological unit mapped as abandoned river terraces (Qs) on Figure 13.3. These units are distributed throughout the impact assessment area.

Recharge and discharge mechanisms

Recharge to alluvial aquifers is anticipated to occur from both rainfall and by seepage from ephemeral watercourses. Sub-cropping rock below permeable alluvium may also act as a source of recharge due to upward discharge of groundwater (Golder, 2019c).

Recharge to the Condamine Alluvium is complex and there are differing views on the relative significance of different recharge pathways. The most common and prevalent view is that the alluvium is mainly recharged from river and stream flow leakage (39 mm/year to 115 mm/year) (DNRME, 2016b). Diffuse rainfall recharge is expected to be limited by the high clay content of near-surface soils and fine-grained sheetwash deposits. On average, recharge to the Condamine Alluvium is exceeded by outflows, the largest outflow being extraction from groundwater bores. As a result, groundwater levels in the Condamine Alluvium have declined in many areas, by up to 25 m, over the past 60 years (DNRME, 2016b).

The primary discharge mechanisms from these units are extraction, as baseflow to the adjacent surface water features and local leakage into the underlying units. Evapotranspiration, from vegetation growing along the bed and banks of water features, and seepage to the underlying units from the alluvial/colluvial sediments, are also considered to be primary discharge mechanisms from these units.

Hydraulic parameters and yield

Interrogation of the DNRME Groundwater Database reported groundwater yield results from 26 bores within the impact assessment area for alluvial aquifers. The locations of registered bores within the impact assessment area are shown in Figure 13.17. The yields reported for the 26 registered bores ranged from 0.38 litres per second (L/s) to 25.00 L/s, which results in an average yield of 5.67 L/s. This large variation is attributed to the complex nature of the alluvial sediments, as discussed in previous sections.

A total of 108 regional horizontal hydraulic conductivity records were accessed and analysed, the majority of which were from bores located in the Condamine Alluvium aquifer. From these records, horizontal hydraulic conductivity values were reported to range between 0.089 metres per day (m/day) and 1,728 m/day (Golder, 2019c). Of the 108 records, 88 (81 per cent) were above 8.64 m/day and 39 (36 per cent) were above 86.40 m/day. These records are often biased towards the upper end of the hydraulic conductivity range as tested bores are predominantly drilled for irrigation purposes, for which high yielding alluvial gravels and sand aquifers are targeted.

Groundwater levels and flow

Border Rivers Alluvium

Records from the DNRME Groundwater Database indicate that four registered bores in the impact assessment area are screened within the Border Rivers Alluvium. Representative groundwater elevations for the Border Rivers Alluvium are displayed on Figure 13.4 in mAHD and on Figure 13.5 in mbgl. The data shows a general decreasing trend between 1985 and 2009 in nested bores RN41640003A (deep) and RN41640003B (shallow), located near Ch 23.0 km. The water level reported for the deep bore, when compared to the shallow bore, indicates an upward gradient under semi-confined aquifer conditions.

Bore RN41640038, near Ch 44.0 km, has published data records from 2011 to 2018. This data shows a general decrease in water level over time. The water level ranges between 8 m below ground level (mbgl) to 9 mbgl (+/- 1 m) over the course of the seven years.

The water levels reported for bore RN41640009 are fairly consistent, with levels remaining around 13 mbgl from 2005 to 2018.

A single investigation bore, BH2617, was installed in the Canning Creek Alluvium during the 2018 geotechnical and hydrogeological investigations for the Project. This bore was installed near Ch 95.8 km and has a static water level of 4.8 mbgl.

Groundwater flow within the Border Rivers Alluvium is inferred towards the southwest, as depicted in Figure 13.6. Groundwater contours crossing the Dumaresq River and Macintyre River suggest that these rivers are losing in these reaches.

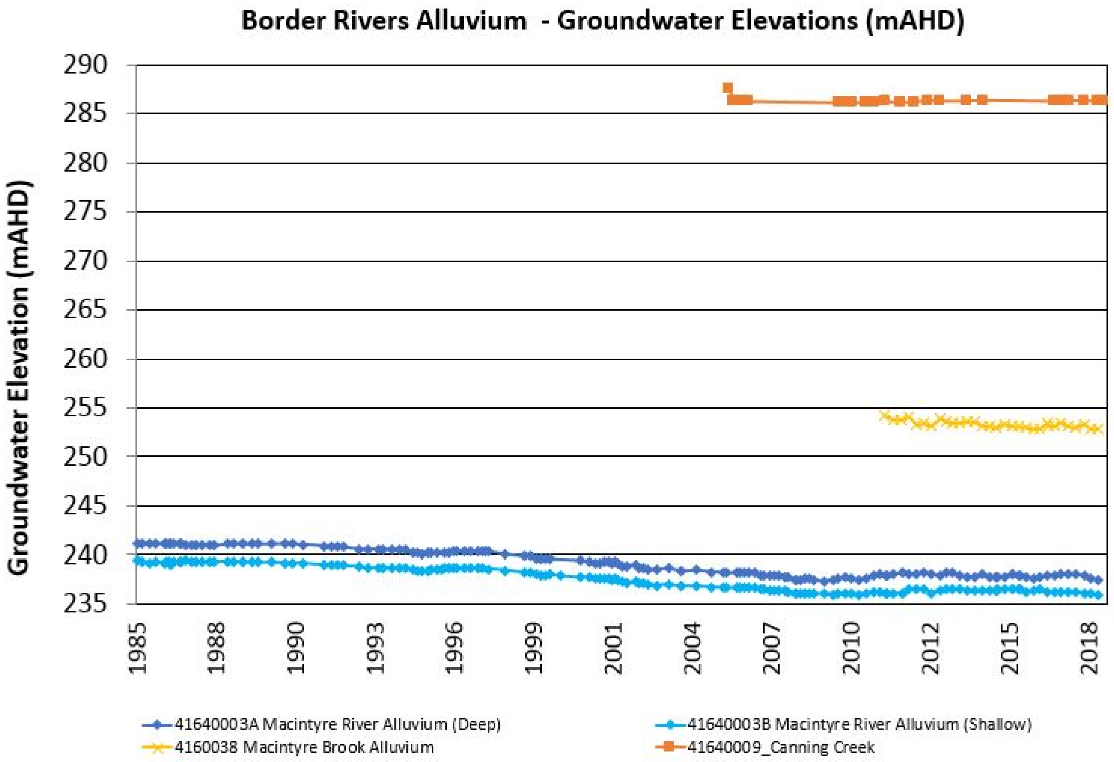


FIGURE 13.4 GROUNDWATER ELEVATION WITHIN THE BORDER RIVERS ALLUVIUM

Figure note: Water level data sourced from the DNRME groundwater database on 31 January 2019

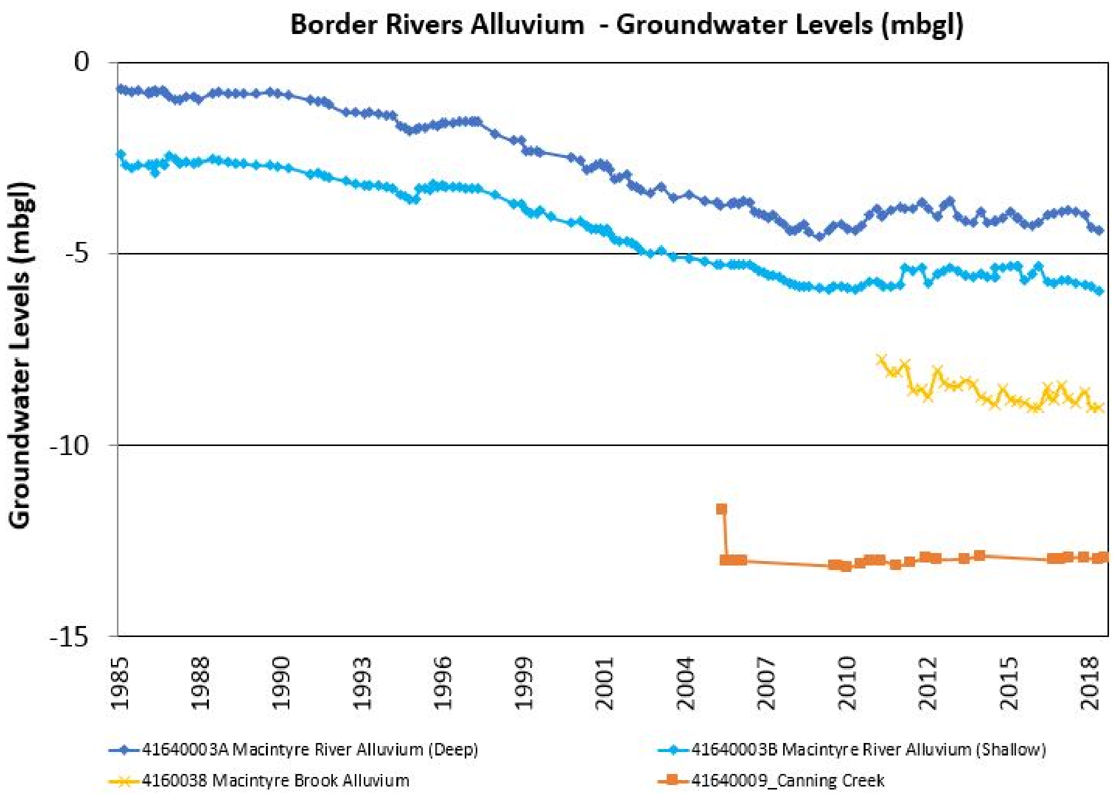


FIGURE 13.5 GROUNDWATER LEVELS WITHIN THE BORDER RIVERS ALLUVIUM

Figure note: Water level data sourced from the DNRME groundwater database on 31 January 2019

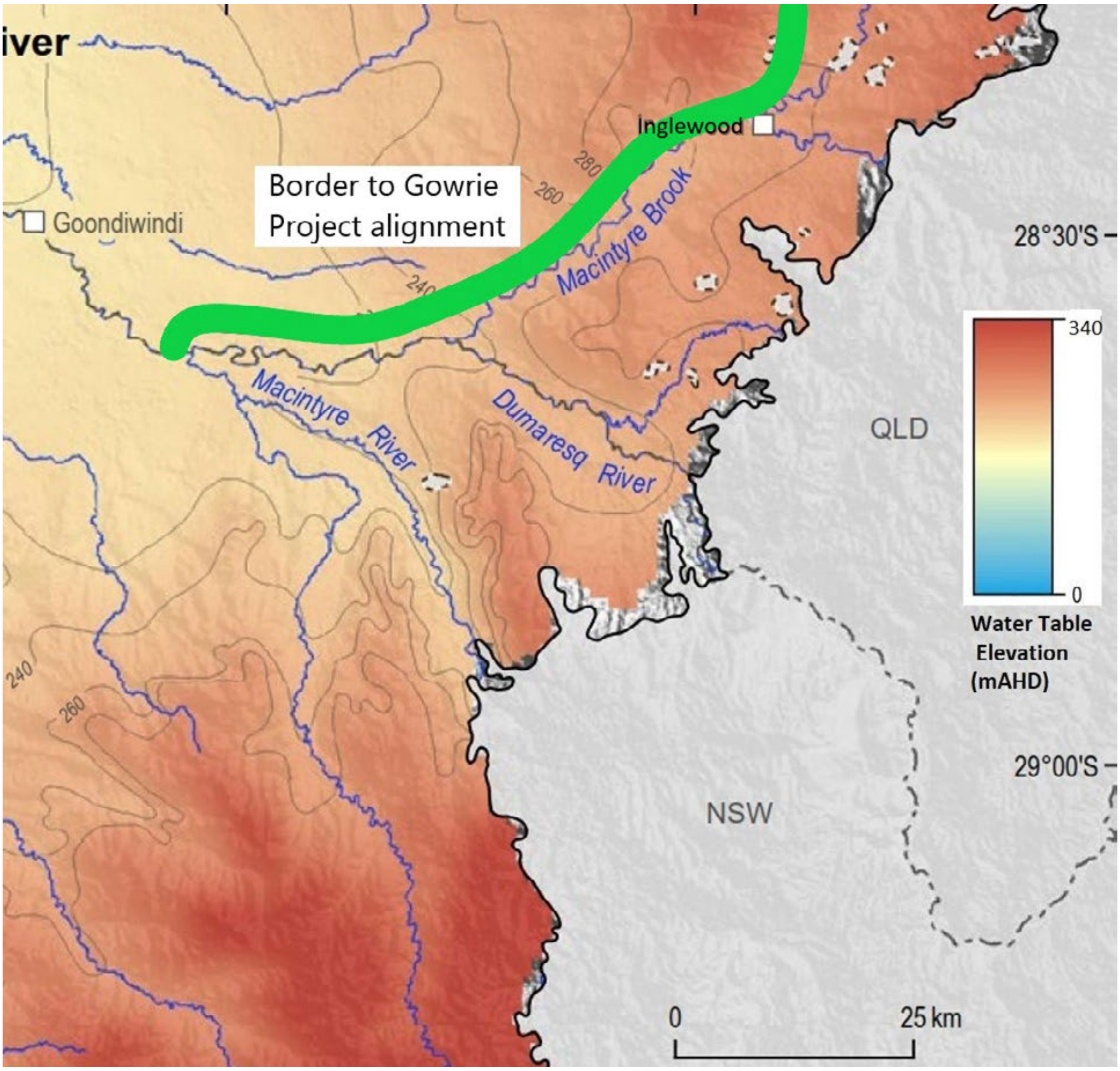


FIGURE 13.6 APPROXIMATE LOCATION OF THE PROJECT IN RELATION TO THE INFERRED GROUNDWATER FLOW DIRECTION OF THE BORDER RIVERS ALLUVIUM

Source: Modified from Ransley et al. (2015)

Condamine Alluvium

Records from the DNRME Groundwater Database indicate that 81 registered bores within the impact assessment area are screened in the Condamine Alluvium aquifer. Screened intervals typically occur above 50 mbgl with the deepest bore screened between 107 mbgl to 119 mbgl. A total of 54 static water levels are recorded from these registered bores. These levels range from 6.9 mbgl to 36.2 mbgl, with a mean static water level of 20 mbgl. Representative groundwater levels for bores with available long-term data within the Condamine Alluvium are displayed in mAHD on Figure 13.7 and in mbgl on Figure 13.8.

A full register of the 81 bores is provided in Appendix R: Groundwater Technical Report.

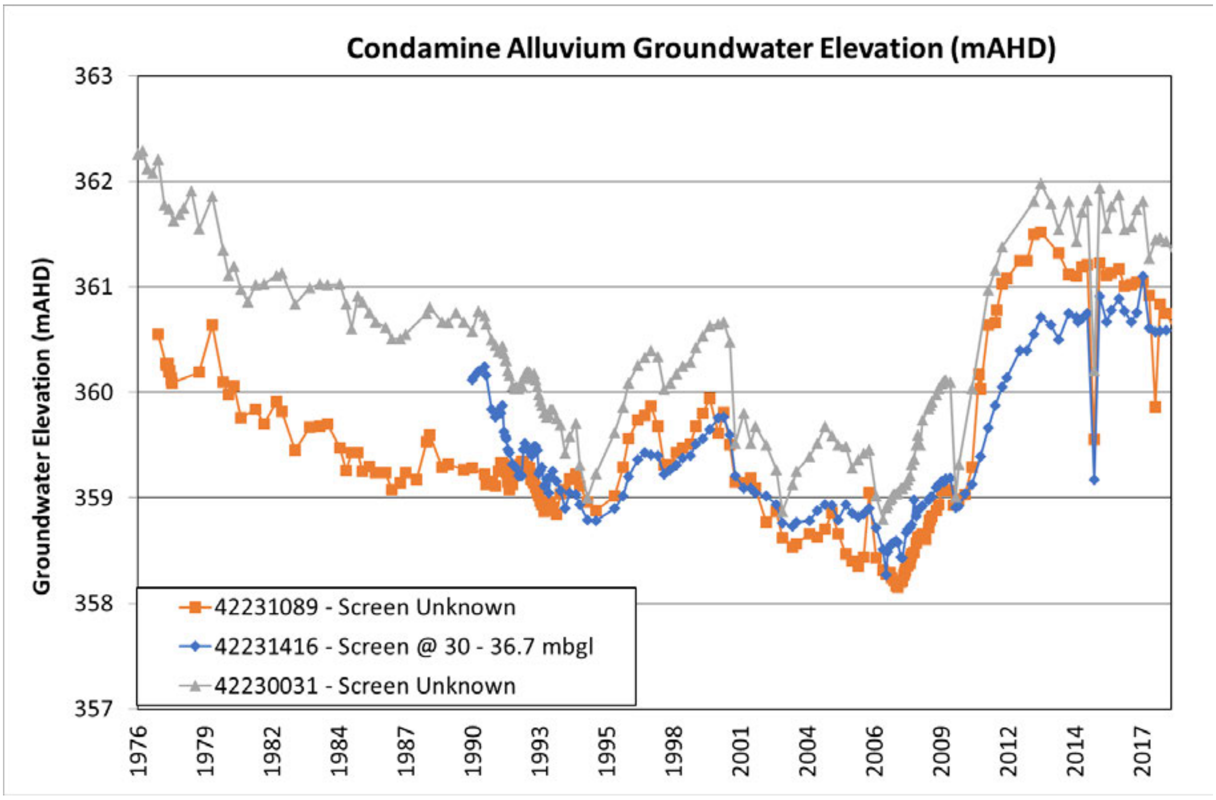


FIGURE 13.7 GROUNDWATER ELEVATION WITHIN THE CONDAMINE ALLUVIUM

Figure note: Water level data sourced from the DNRME groundwater database on 31 January 2019

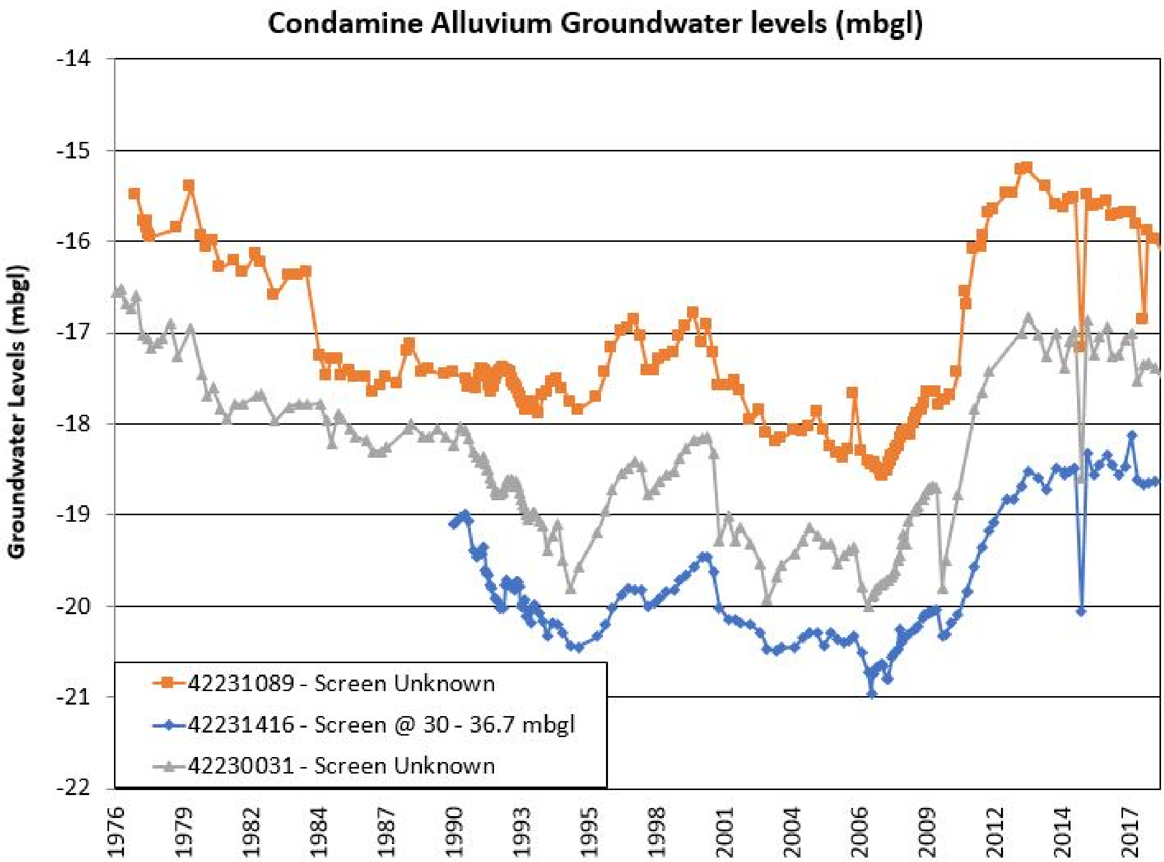


FIGURE 13.8 GROUNDWATER LEVELS WITHIN THE CONDAMINE ALLUVIUM

Figure note: Water level data sourced from the DNRME groundwater database on 31 January 2019

Four bores were installed into the Condamine Alluvium during the 2018 geotechnical and hydrogeological investigations for the Project. Recorded water levels in these bores have a median range of between 358.8 mAHD (BH2235) and 364.8 mAHD (BH2233) where the corresponding static water levels are 22.3 mbgl and 14.1 mbgl, respectively. This range is consistent with historical water level ranges observed in registered bores within the same unit.

Groundwater flow of the Condamine Alluvium with respect to the Project, is inferred to be north–northwest with a local depression centred in Norwin (18 km east of Cecil Plains) inferred to be resultant from groundwater extraction (pumping) (DNRME, 2016a). This inferred direction of flow is depicted on Figure 13.9.

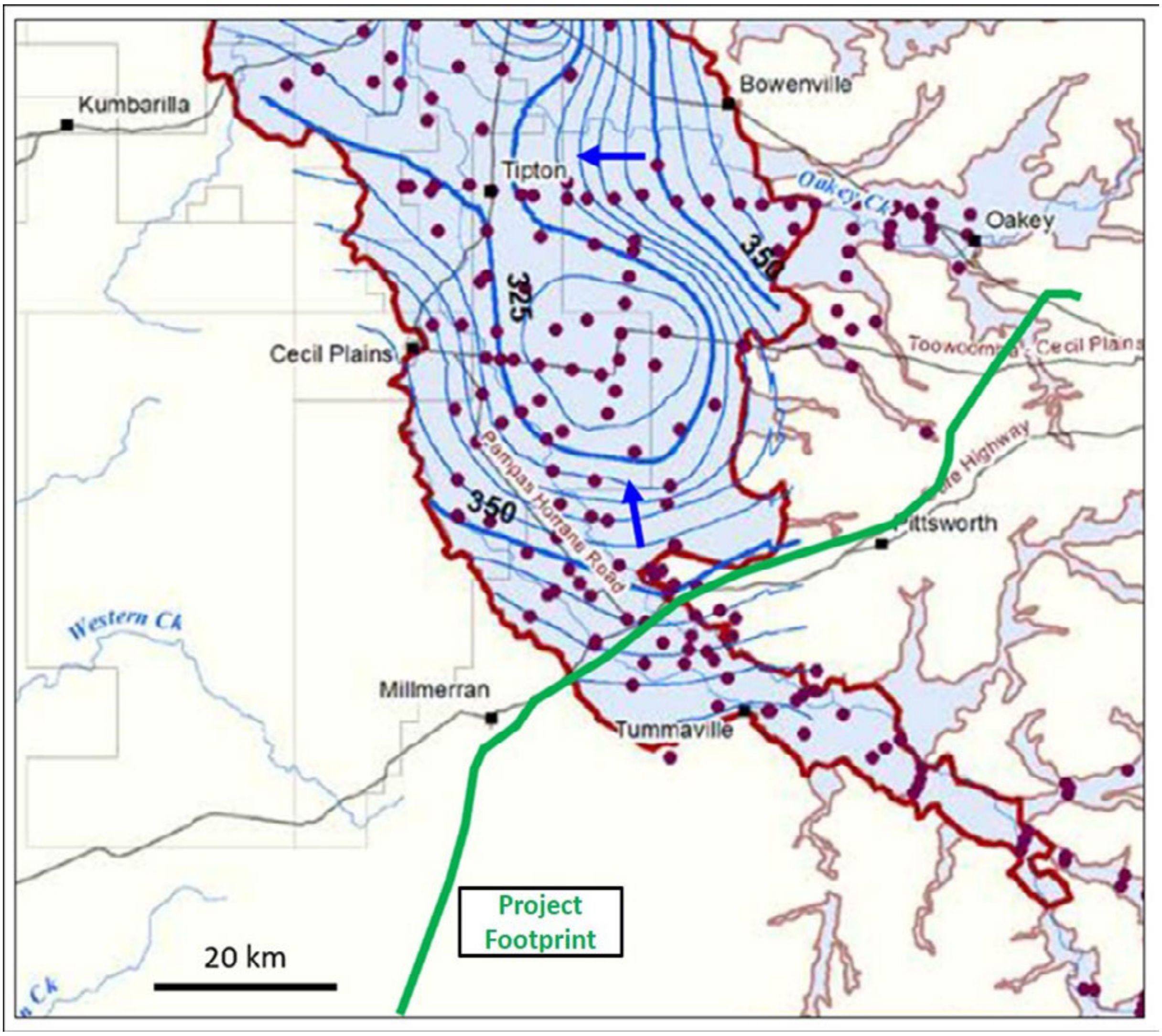


FIGURE 13.9 APPROXIMATE LOCATION OF THE PROJECT IN RELATION TO REGIONAL GROUNDWATER CONTOURS FOR THE CONDAMINE ALLUVIUM INDICATING PREDOMINANT FLOW DIRECTIONS

Source: Modified from DNRME, 2016b

13.6.4.2 Main Range Volcanics (MRV) (Tertiary)

Occurrence

The MRV are located to the east and southeast of the Condamine Alluvium and forms the main geological unit, which outcrops along the Project alignment between Ch 163.0 km, near Pittsworth, to Ch 206.9 km, near Kingsthorpe. The MRV is depicted as Tm in Figure 13.3.

The MRV formation consists mainly of Oligocene–Miocene age alkaline olivine basalts, which erupted from fissures that have since become extensively eroded (DNRME, 2016a). Some portions of the formation are covered by alluvium from tributaries of the Condamine River system (i.e. Westbrook Creek near Ch 196.0 km). The thickness of the MRV is up to 150 m; however, thinner portions of the formation underlie some areas of the Condamine Alluvium.

The MRV are comprised of primary permeability in the form of vesicular zones with secondary porosity in the form of cooling joints and fractures (DNRME, 2016b). The vesicular and weathered zones of these basalts can result in aquifer behaviour that ranges between unconfined, semi-confined or confined (DNRME, 2016b). As a result, groundwater occurrence and hydraulic properties of the MRV are inherently variable due to the nature, location and frequency of the fractures and joints.

The MRV forms a significant productive aquifer used for irrigation, stock, and town water supplies. A total of 149 of the 298 bores registered on the DNRME Groundwater Database and located within the impact assessment area are screened within the MRV (refer Figure 13.17).

Section 13.6.5 provides discussion on groundwater users that are reliant on the MRV and the availability of water from it.

Recharge and discharge mechanisms

Based on available data, recharge to the MRV is considered to primarily be via direct rainfall infiltration, local vertical leakage from the underlying units and adjacent through flow from the Condamine Alluvium where they are co-located, particularly after large rainfall events (DNRME, 2016b).

The primary discharge mechanisms are considered to include bore extraction and local vertical leakage to deeper units.

Hydraulic parameters and yield

A review of regional literature data and results from the Project hydrogeological investigations, identified 69 aquifer tests that provided hydraulic conductivity values ranging from 8.64×10^{-5} to 2,590 m/day. Literature values for transmissivity in the MRV typically range from 200 square metres per day (m^2/day) to 300 m^2/day (DNRME, 2016b). These transmissivity values correspond to horizontal hydraulic conductivity values of 2 m/day to 3 m/day for a typical MRV thickness of 100 m. The literature and Project hydrogeological investigation data indicate the hydraulic conductivity of the MRV is highly variable, reflecting the fractured and anisotropic nature of the aquifer.

The specific yield for the MRV is estimated at 0.1, while a hydraulic conductivity value of 0.061 m/day has been adopted as a typical value for modelling inflow assessments (Golder, 2019c). The average bore yield within the MRV is approximately 4 L/s based on registered bores within the impact assessment area (refer Figure 13.17).

Groundwater levels and flow

There is an abundance of publicly available groundwater level information for bores screened in the MRV within the impact assessment area. Of the 148 registered bores identified, 55 have records of static water levels. These levels range between 1.8 mbgl and 60.1 mbgl, with an average of approximately 18.7 mbgl. Representative groundwater levels from bores with long-term data within the MRV are displayed on Figure 13.10, in mAHD, and on Figure 13.11 in mbgl. The presented data covers the period from 1976 to 2017 and shows different patterns suggesting variable aquifer responses to recharge and/or discharge over time and space.

Groundwater flow within the MRV is inferred to be towards the west and northwest as depicted in Figure 13.12.

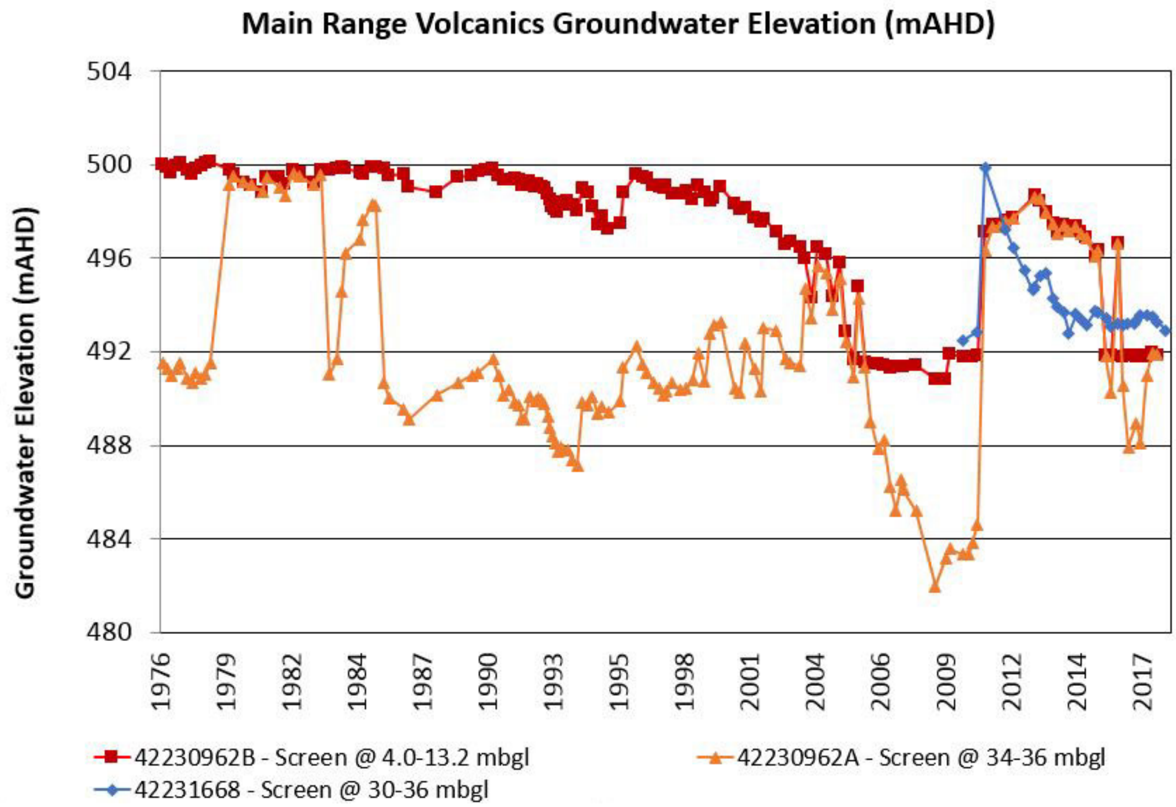


FIGURE 13.10 GROUNDWATER ELEVATION WITHIN THE MAIN RANGE VOLCANICS

Figure notes:

Water level data sourced from the DNRME groundwater database on 31 January 2019

Nested well RN42230962 is located 2.0 km east of Ch 188.0 km. Well RN42231668 is located 4.7 km east of Ch 197.0 km.

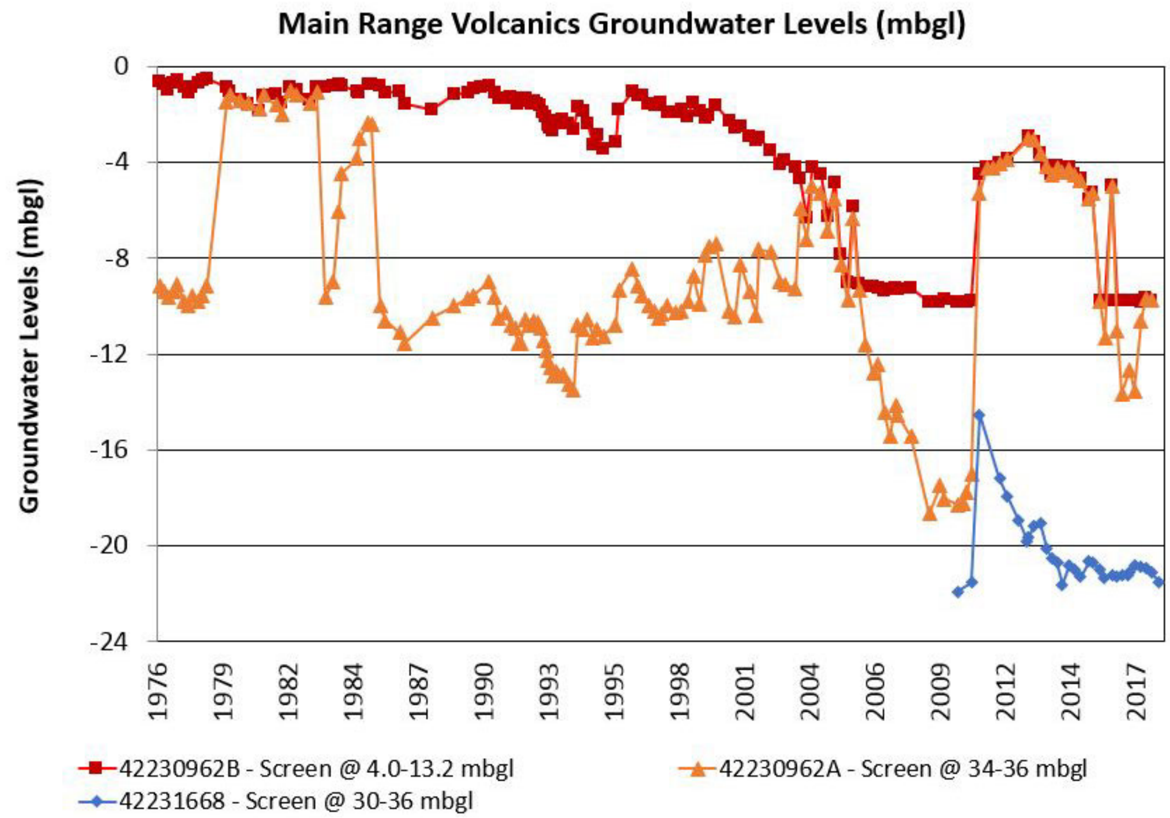


FIGURE 13.11 GROUNDWATER LEVELS WITHIN THE MAIN RANGE VOLCANICS

Figure notes:

Water level data sourced from the DNRME groundwater database on 31 January 2019

Nested well RN42230962 is located 2.0 km east of Ch 188.0 km. Well RN42231668 is located 4.7 km east of Ch 197.0 km.

13.6.4.3 Kumbarilla Beds

Occurrence

The lithology of the Kumbarilla Beds comprises sandstone, siltstone, mudstone, and some conglomerate. The formations within the Kumbarilla Beds lie unconformably over the WCM and are often indistinguishable from each other in this area. The unconformity is likely the result of erosion, as scouring has been observed at the contact between the WCM and lower Springbok Sandstone unit of the Kumbarilla Beds (DNRME, 2016a).

The lower sandstones of the Kumbarilla Beds were deposited by streams flowing generally towards the centre of the basin, frequently in small channels eroded into the uppermost siltstones of the WCM, and occasionally into the coal seams (DNRME, 2016a).

The Project alignment traverses intermittent outcrop and subcrops of the Kumbarilla Beds between approximately Ch 4.0 km and Ch 37.0 km. Several registered groundwater bores in fractured rock located between Ch 30.60 km (NS2B) to Ch 38 km are recognised to be screened across the Kumbarilla Beds.

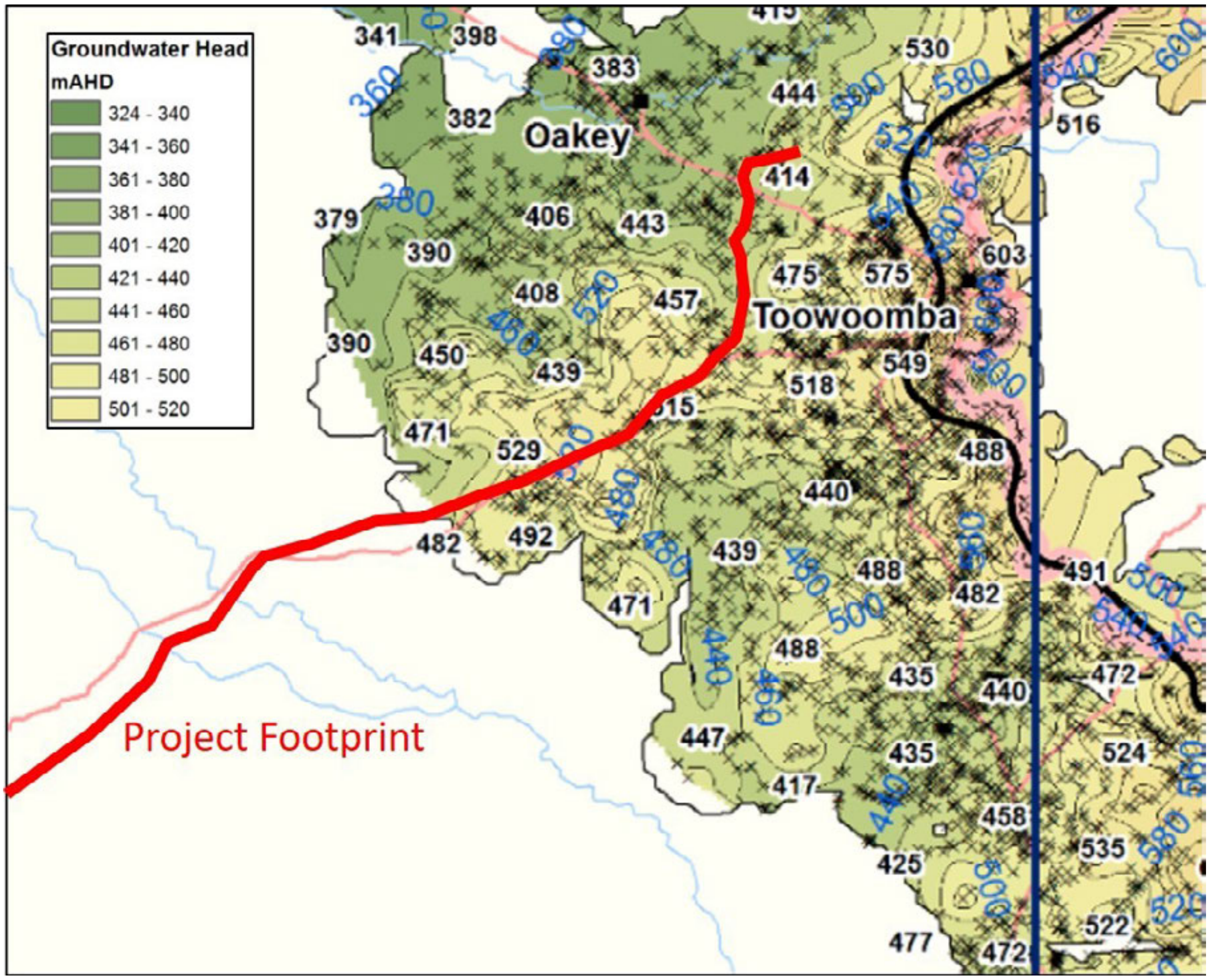


FIGURE 13.12 APPROXIMATE LOCATION OF THE PROJECT IN RELATION TO INFERRED GROUNDWATER FLOW DIRECTION OF THE MAIN RANGE VOLCANICS

Figure note: Red line is the Project footprint

Source: DNRME, 2016b

Recharge and discharge mechanisms

The outcrops of the Kumbarilla Beds are believed to be recharged by direct infiltration of rainfall, and by seepage from ephemeral streams during periods of flow following rainfall. Locally, upward leakage from sub-cropping rock below permeable alluvium may also act as a source of recharge (DNRME, 2016b).

Discharge mechanisms from the Kumbarilla Beds are believed to occur via seepage/through flow into the underlying and/or adjacent aquifers, evapotranspiration (primarily in subcrop/outcrop areas), and groundwater extraction.

Hydraulic parameters and yield

The DNRME Groundwater Database has record of one pump test of a registered bore within the impact assessment area and located in the Kumbarilla Beds. Transmissivity was estimated from this single pump test at 404 m^2/d (RN43148). The reported yields ranged from 0.18 L/s to 5.5 L/s.

One slug test near Ch 35.0 km (BH2201) was conducted within the Springbok Sandstone sub-unit of the Kumbarilla Beds during the Project hydrogeological investigations. Hydraulic conductivity was reported from this slug test as 0.3 m/day based on the results of this falling head test.

The site-specific aquifer test results (based on various interpretations) and regional (literature) hydraulic conductivity data indicate the various units of the Kumbarilla Beds range from 3.7×10^{-9} m/s (0.0003 m/day) to 8.2×10^{-6} m/s (0.7 /day) (Golder, 2019c).

Groundwater levels and flow

Representative groundwater levels for the Kumbarilla Beds are displayed in Figure 13.13 and Figure 13.14 for bore RN41640003 for the period of 1985 to 2017. A long gradual declining trend is apparent to 2009. This trend may relate to drought conditions and/or bore extraction, the impact of which would be compounded during drought. After 2009, groundwater levels increased slightly then remain largely static. This suggests this bore has not recovered since the Millennium drought broke in 2011 and/or has been unable to recover from extraction.

The data for bore RN41640003, as shown in Figure 13.13 and Figure 13.14, demonstrates a relatively small degree of seasonal variance in water levels, which may reflect confinement of the aquifer.

Groundwater flow in the Kumbarilla Beds near the Project is inferred towards the west, which follows the general topographic trends in the region (University of Queensland (UQ), 2014).

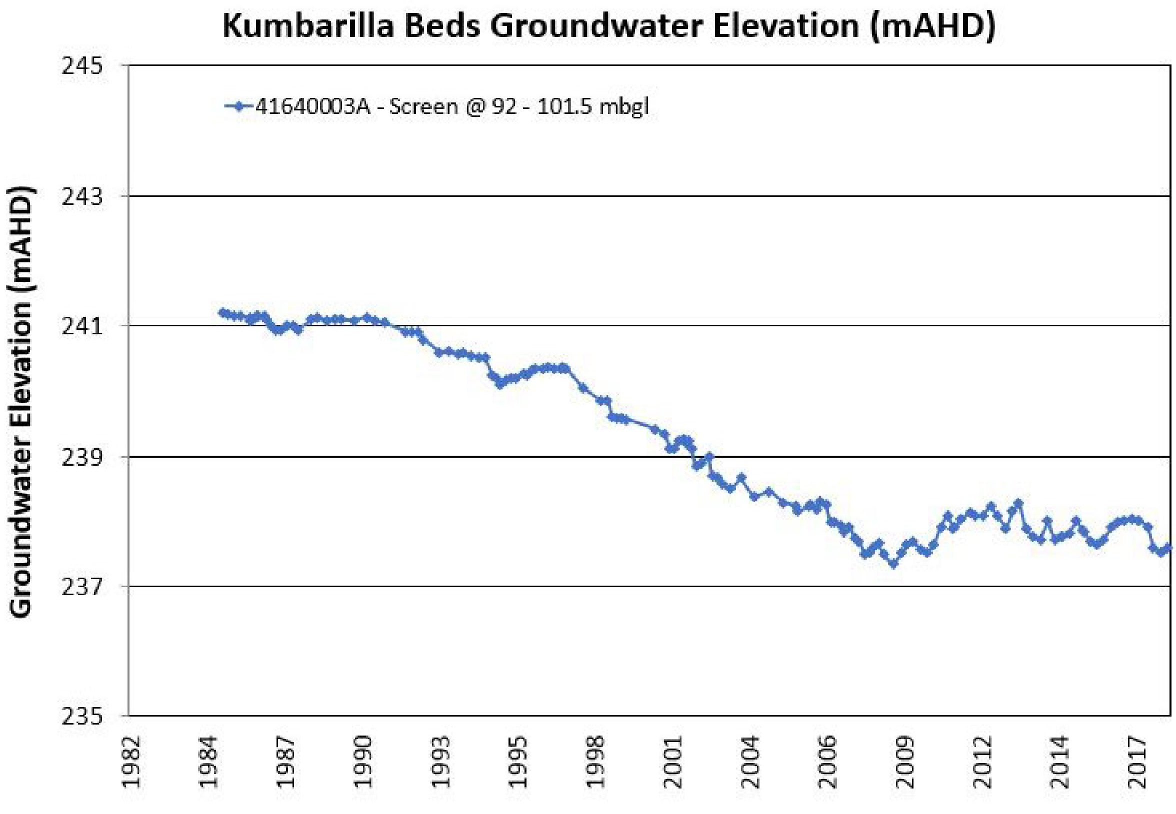


FIGURE 13.13 GROUNDWATER ELEVATION WITHIN THE KUMBARILLA BEDS

Figure note: Water level data sourced from the DNRME Groundwater Database on 31 January 2019

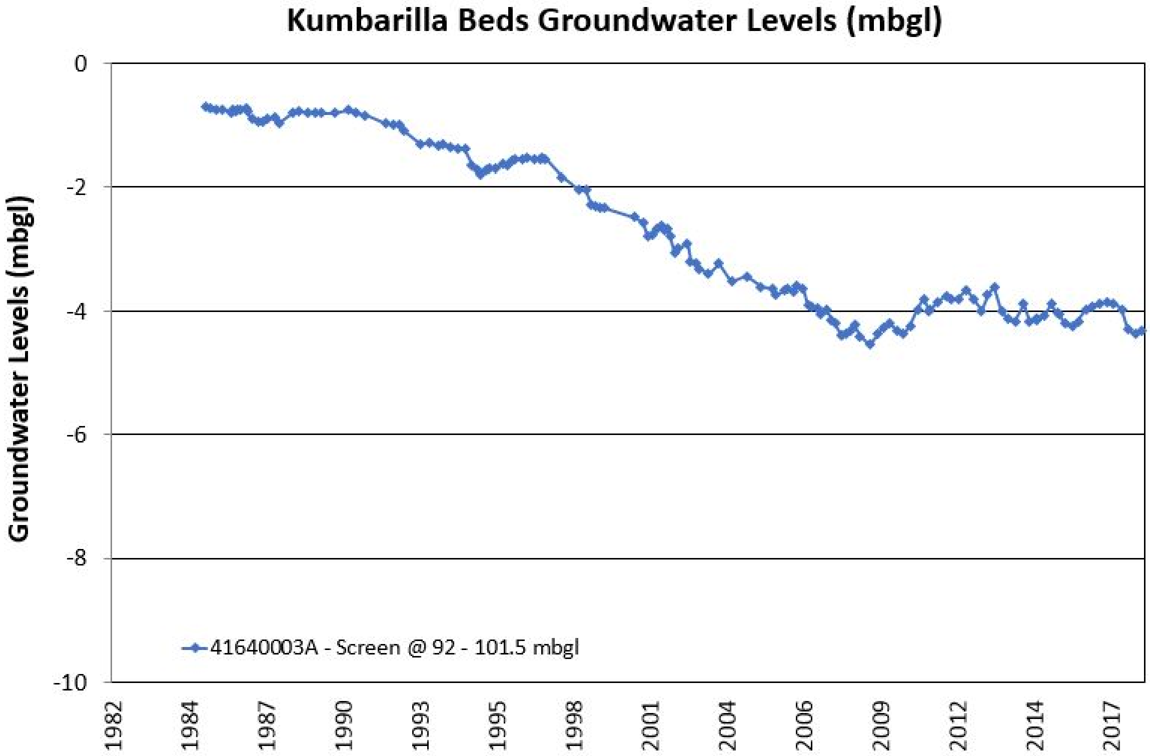


FIGURE 13.14 GROUNDWATER LEVELS WITHIN THE KUMBARILLA BEDS

Figure note: Water level data sourced from the DNRME Groundwater Database on 31 January 2019

13.6.4.4 Walloon Coal Measures (WCM) (Jurassic)

Occurrence

The WCM are an important coal resource of the Surat Basin. The WCM comprise claystones, shales, sandstones and coal seams of fluvial and lacustrine origin with an average total thickness of 300 m (Exon, 1976; DNRME, 2016b). The WCM are contiguous between the Surat and Clarence–Moreton Basins, forming a continuous unit over the Kumbarilla Ridge, and represent a widespread episode of deposition of river, lake, swamp and marsh sediments. The formation has been either partly eroded, or exposed, over much of the eastern part of the Clarence–Moreton Basin (DNRME, 2016b).

The contact between the Condamine Alluvium and the underlying WCM is characterised by a clay zone of undifferentiated origin, which is often dominated by multi-coloured clay (DNRME, 2016b). On a regional basis, the underlying WCM are considered to be an aquitard, although groundwater is extracted extensively for stock and domestic supplies where the WCM occur at shallow depth (DNRME, 2016b).

The WCM intermittently outcrop and subcrop along the Project alignment between Ch 38.0 km and Ch 126.0 km, along the northern banks of Macintyre Brook and Canning Creek and towards Millmerran. The extent of the WCM are depicted as Jw in Figure 13.3.

A review of data from the 30 registered bores within the impact assessment area that are located in the WCM indicate that the WCM are typically screened at depths shallower than 100 mbgl. Eleven bores established during the Project hydrogeological investigation between Ch 53.0 km and Ch 122.0 km intersected the WCM. In these locations, extremely weathered sandstone and mudstone was encountered from 2 mbgl to 20 mbgl (Golder, 2019a).

Recharge and discharge mechanisms

Recharge of the WCM is considered to be primarily through seepage from the overlying and underlying units and via direct rainfall infiltration in areas of subcrop (DNRME, 2016b).

The primary discharge mechanisms from the WCM are considered to include bore extraction, where the WCM locally acts as an aquifer, and vertical seepage into the under and overlying units.

Hydraulic parameters and yield

A total of seven bores were installed and screened in the WCM during the Project hydrogeological investigation. Aquifer tests, in the form of slug and variable head tests, were completed for each of these bores. Hydraulic conductivity values from these tests ranged from 0.0001 m/day to 0.05 m/day. Typical literature values for the hydraulic conductivity in the WCM range from 0.00016 m/day to 0.045 m/day (DNRME, 2016b), which is consistent with the results obtained from testing during the Project hydrogeological investigation.

Groundwater levels and flow

The DNRME groundwater database includes 22 water level records from registered bores located in the WCM. These recorded levels range between zero (artesian) and 102 mbgl, with a mean level of 35 mbgl. Time-series data for three representative bores with long-term data is presented in Figure 13.15, in mAHD, and Figure 13.16, in mbgl, over the period from 1977 to 2017.

Bore RN42231135 shows significant variation and a strong downtrend in levels, particularly after the drought broke in early 2011 but during an increase in coal seam gas (CSG) development projects in the region.

The other two bores (RN42231358 and RN42231340) show less dramatic changes in water level over time, where, conversely, bore RN42231340 shows an increasing trend between 1988 and 2017. Water level variation in the WCM reveals the complex hydrogeological setting of this geological formation coupled with the pressures of resource development and landowner extraction.

Groundwater flow in the WCM in the Condamine to Gowrie area (i.e. Ch 115.0 km to Ch 206.9 km) is generally towards the northwest; however, between Millmerran and Yelarbon, the flow direction is inferred towards the west–southwest (DNRME, 2016a). Available groundwater level data suggests that there is potential for groundwater flow from the basalts to the WCM (UQ, 2014). This flow is likely exacerbated by depressurisation of the coal seams, which can induce flow from the adjacent units.

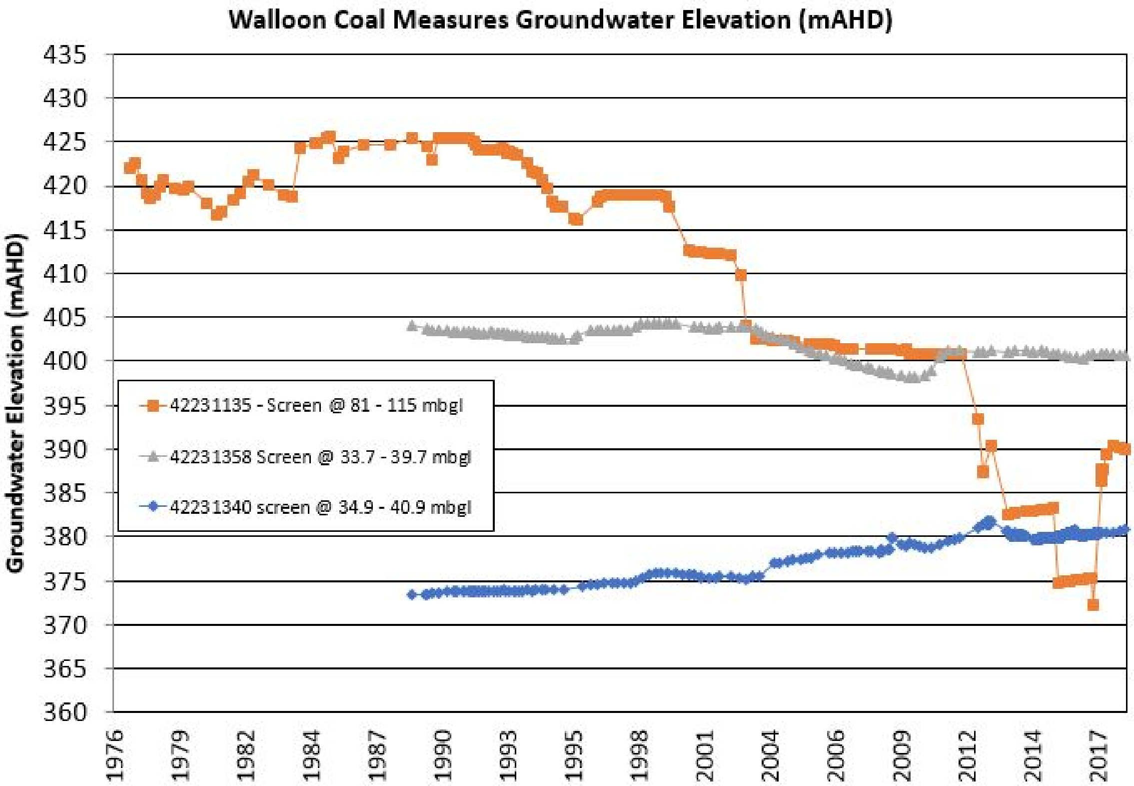


FIGURE 13.15 REPRESENTATIVE GROUNDWATER ELEVATION WITHIN THE WALLOON COAL MEASURES

Figure note: Water level data sourced from the DNRME Groundwater Database on 31 January 2019

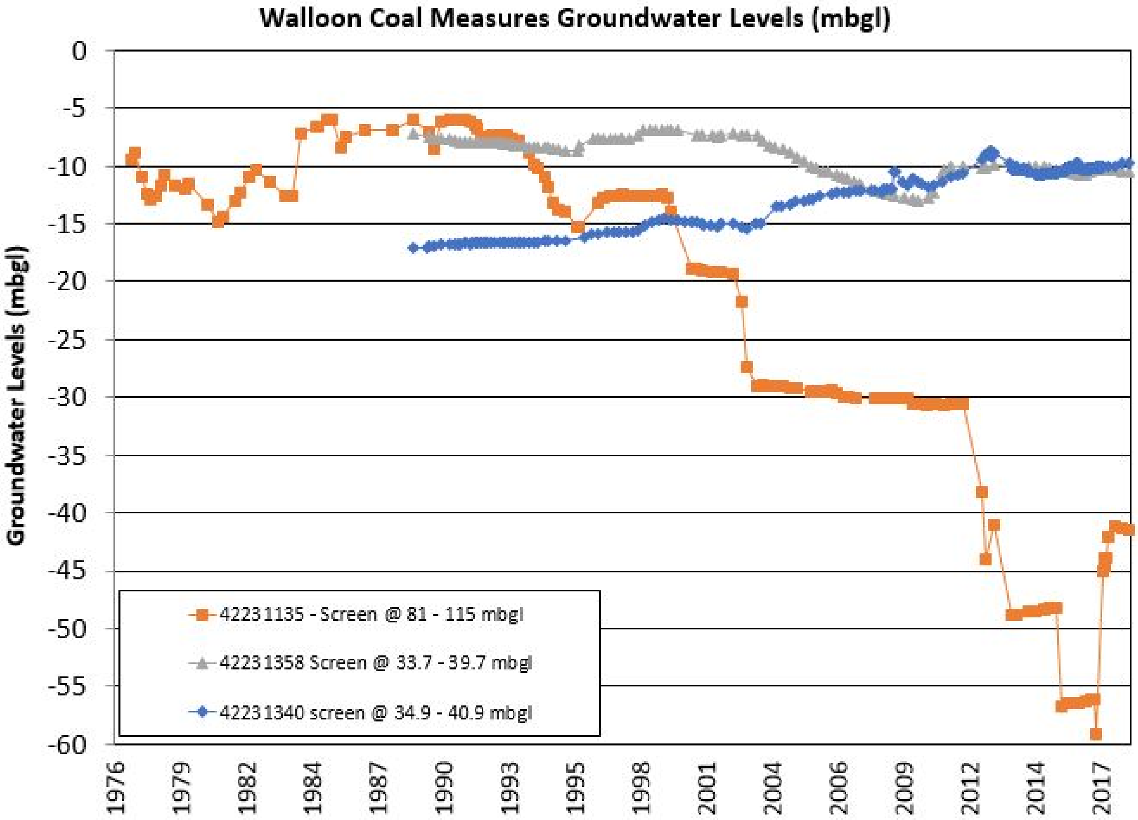
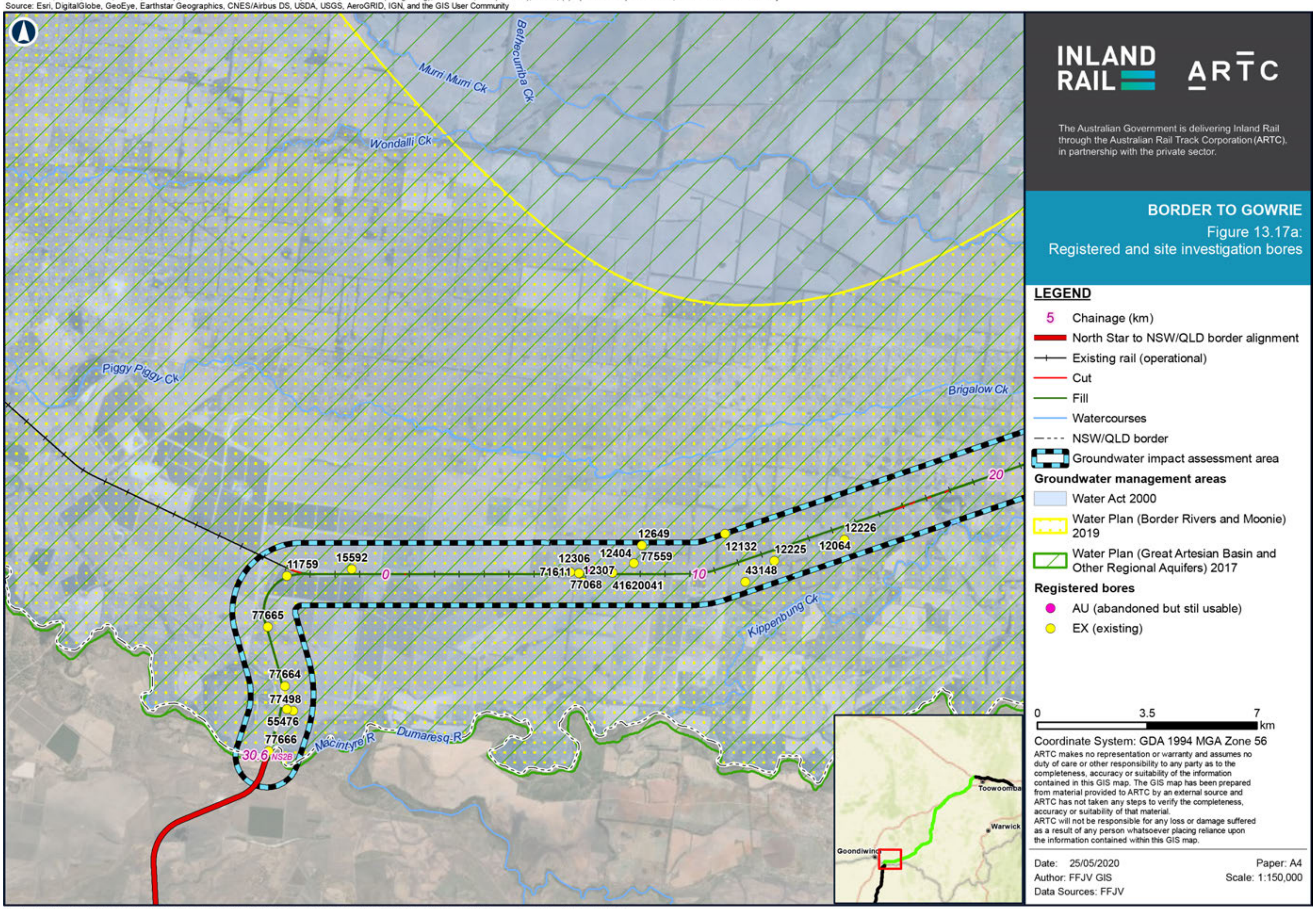


FIGURE 13.16 REPRESENTATIVE GROUNDWATER LEVELS WITHIN THE WALLOON COAL MEASURES

Figure note: Water level data sourced from the DNRME Groundwater Database on 31 January 2019

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



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
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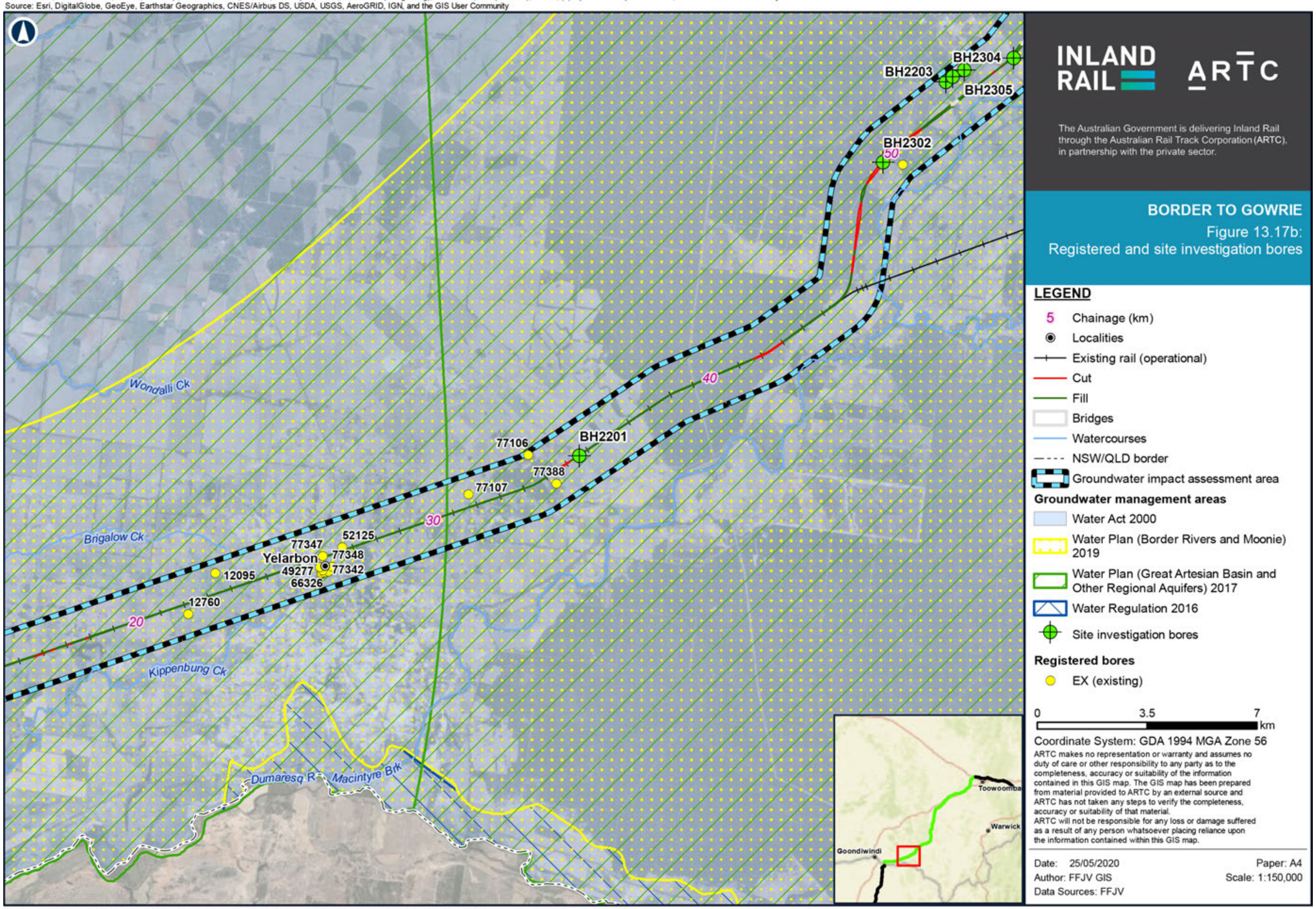

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Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
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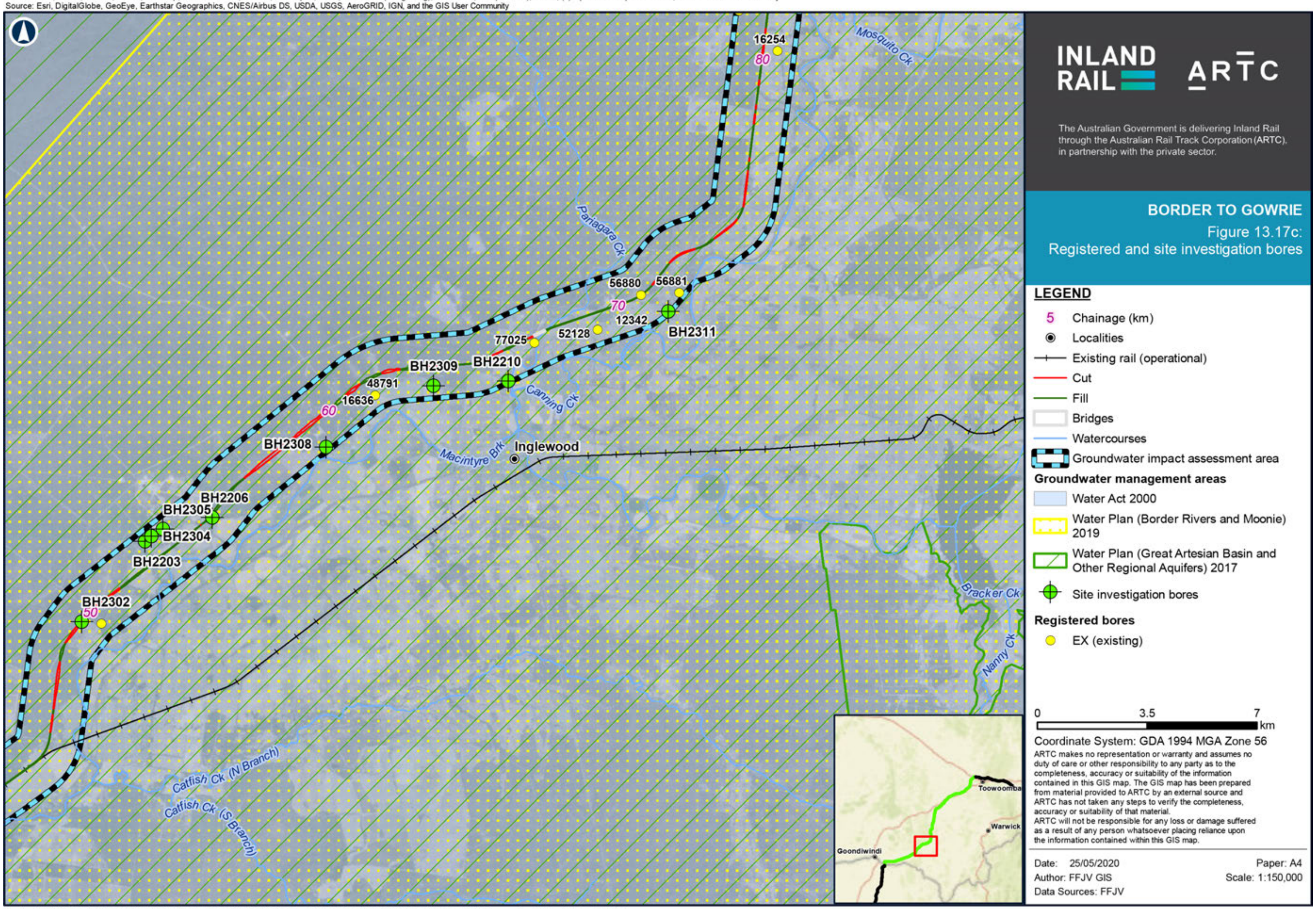

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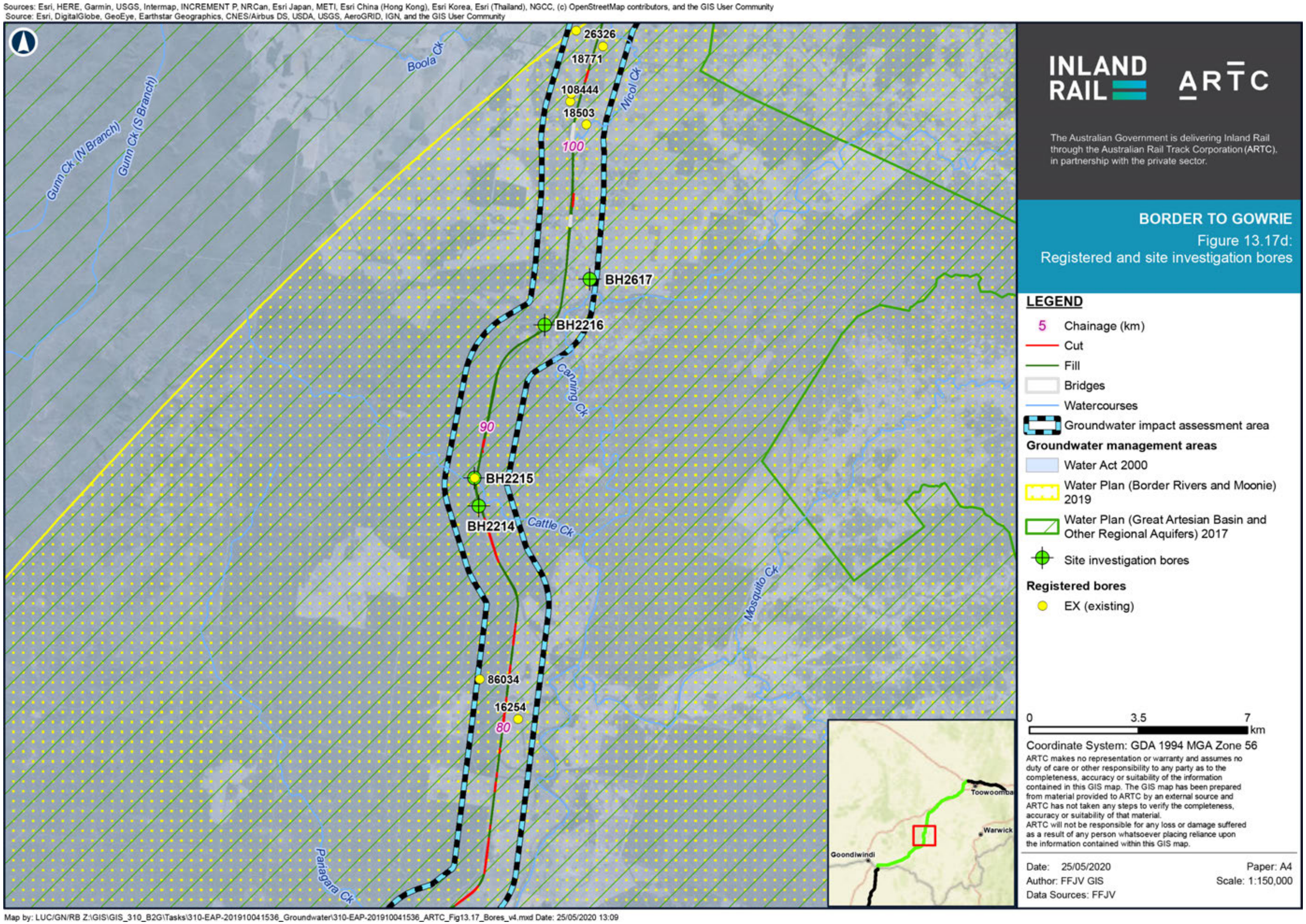
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
26326
18771
108444
18503
100
BH2617
BH2216
90
BH2215
BH2214
86034
16254
80
Boola Ck
Nicol Ck
Gunn Ck (N Branch)
Gunn Ck (S Branch)
Canning Ck
Cattle Ck
Mosquito Ck
Panagara Ck
INLAND RAIL
ARTC
The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.
BORDER TO GOWRIE
Figure 13.17d:
Registered and site investigation bores
LEGEND
5 Chainage (km)
Cut
Fill
Bridges
Watercourses
Groundwater impact assessment area
Groundwater management areas
Water Act 2000
Water Plan (Border Rivers and Moonie) 2019
Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017
Site investigation bores
Registered bores
EX (existing)
0
3.5
7
km
Coordinate System: GDA 1994 MGA Zone 56
ARTC makes no representation or warranty and assumes no duty of care or other responsibility to any party as to the completeness, accuracy or suitability of the information contained in this GIS map. The GIS map has been prepared from material provided to ARTC by an external source and ARTC has not taken any steps to verify the completeness, accuracy or suitability of that material.
ARTC will not be responsible for any loss or damage suffered as a result of any person whatsoever placing reliance upon the information contained within this GIS map.
Toowoomba
Warwick
Goondiwindi
Date: 25/05/2020
Author: FFJV GIS
Data Sources: FFJV
Paper: A4
Scale: 1:150,000
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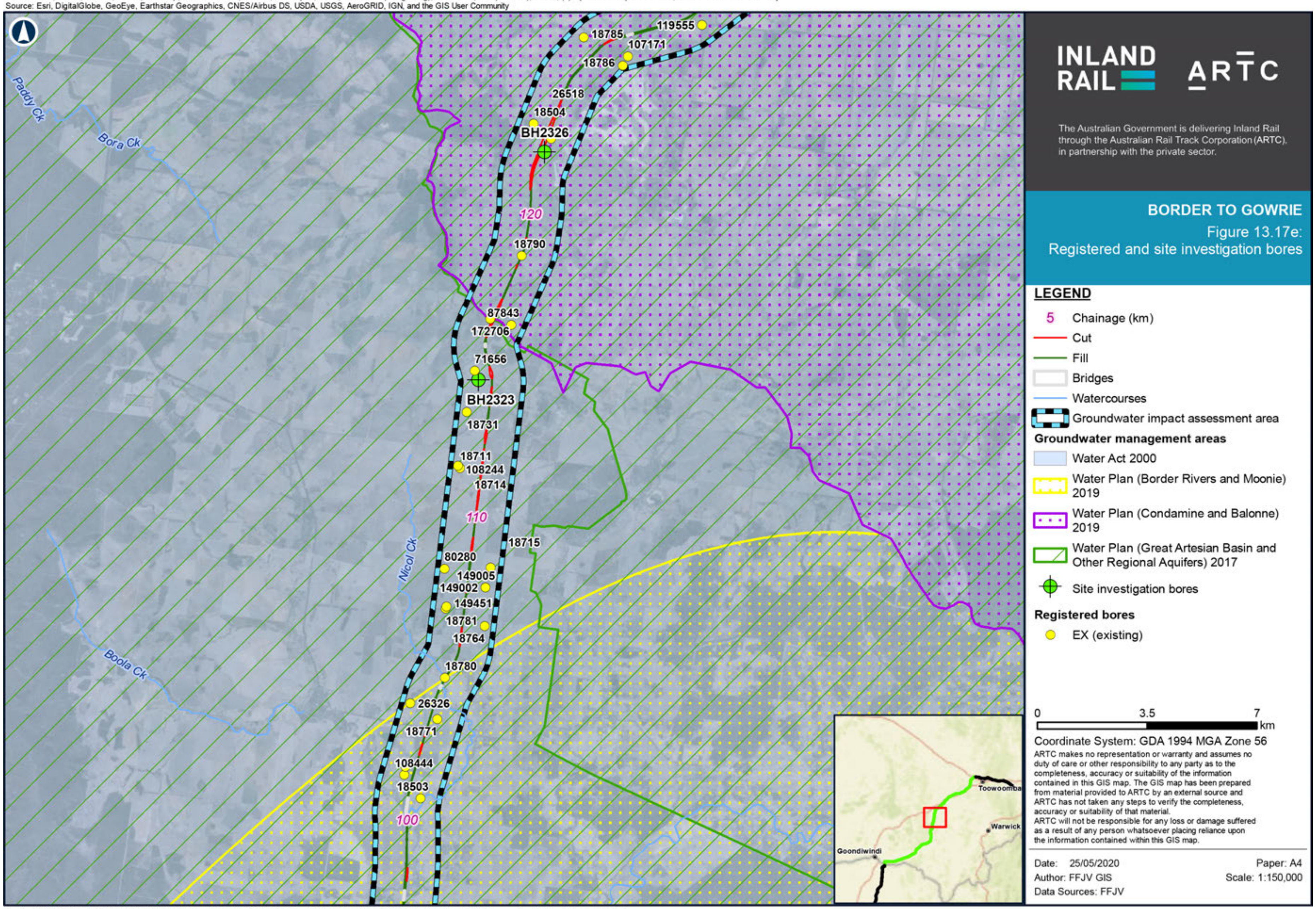
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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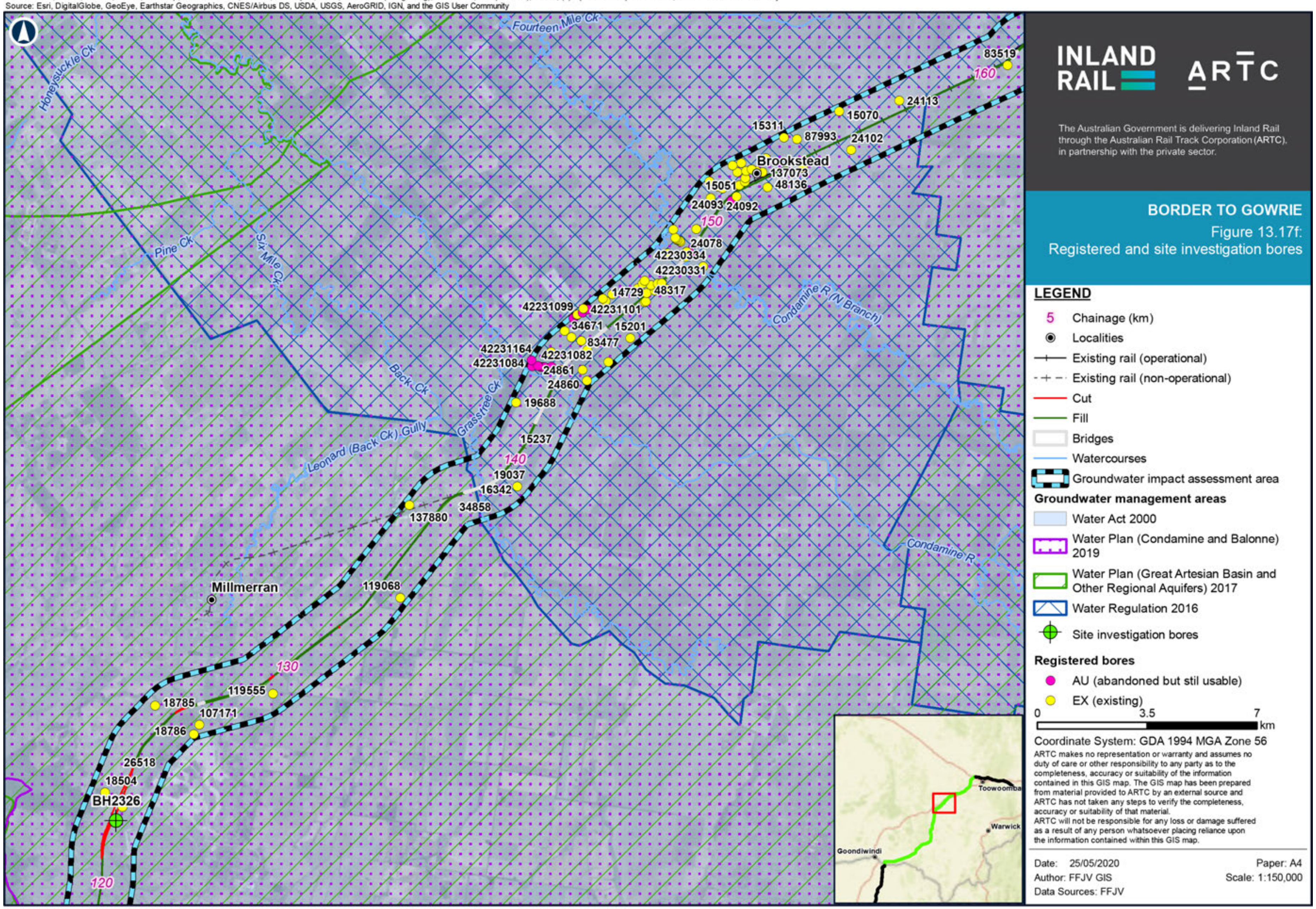
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN,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



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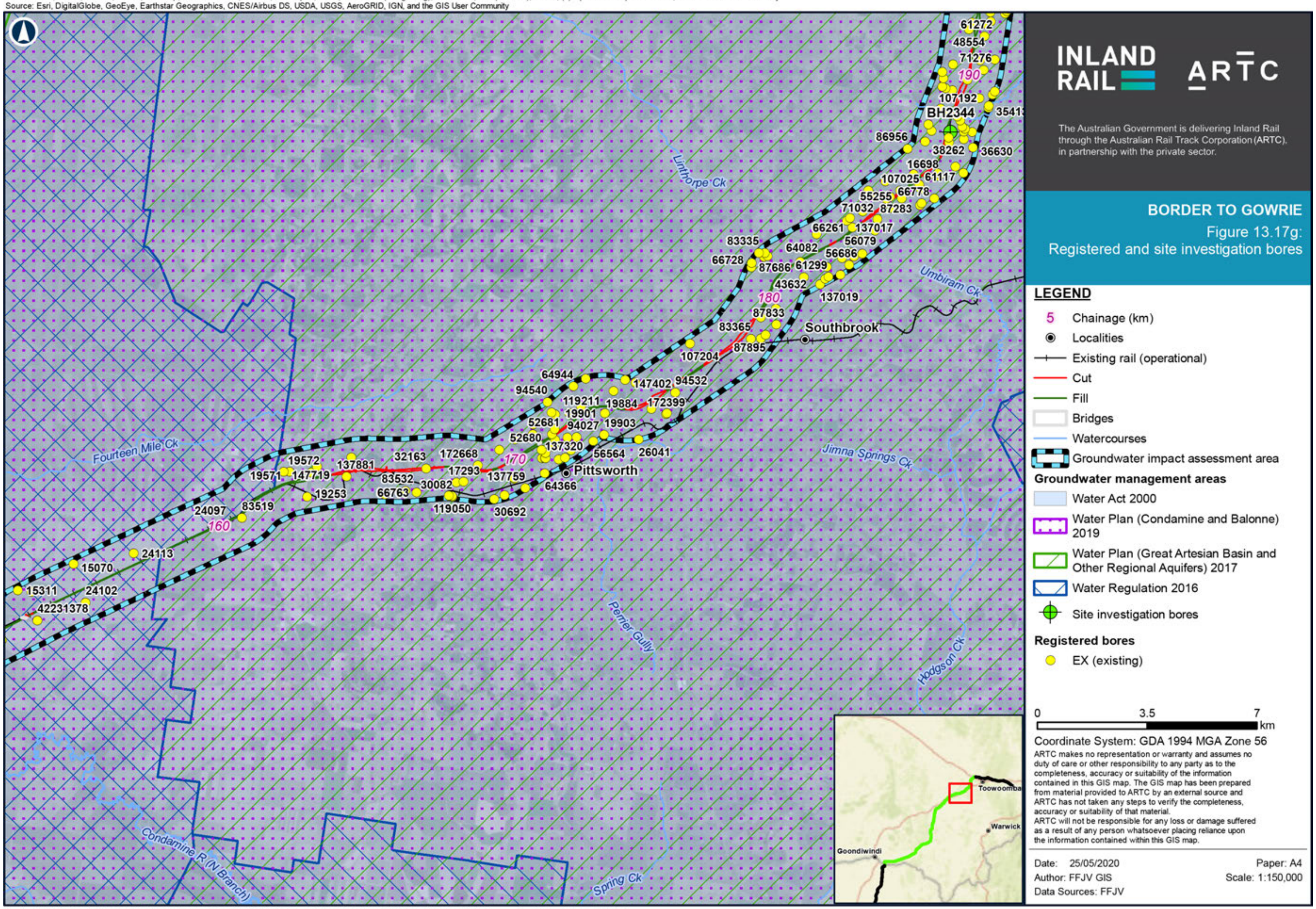
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN,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



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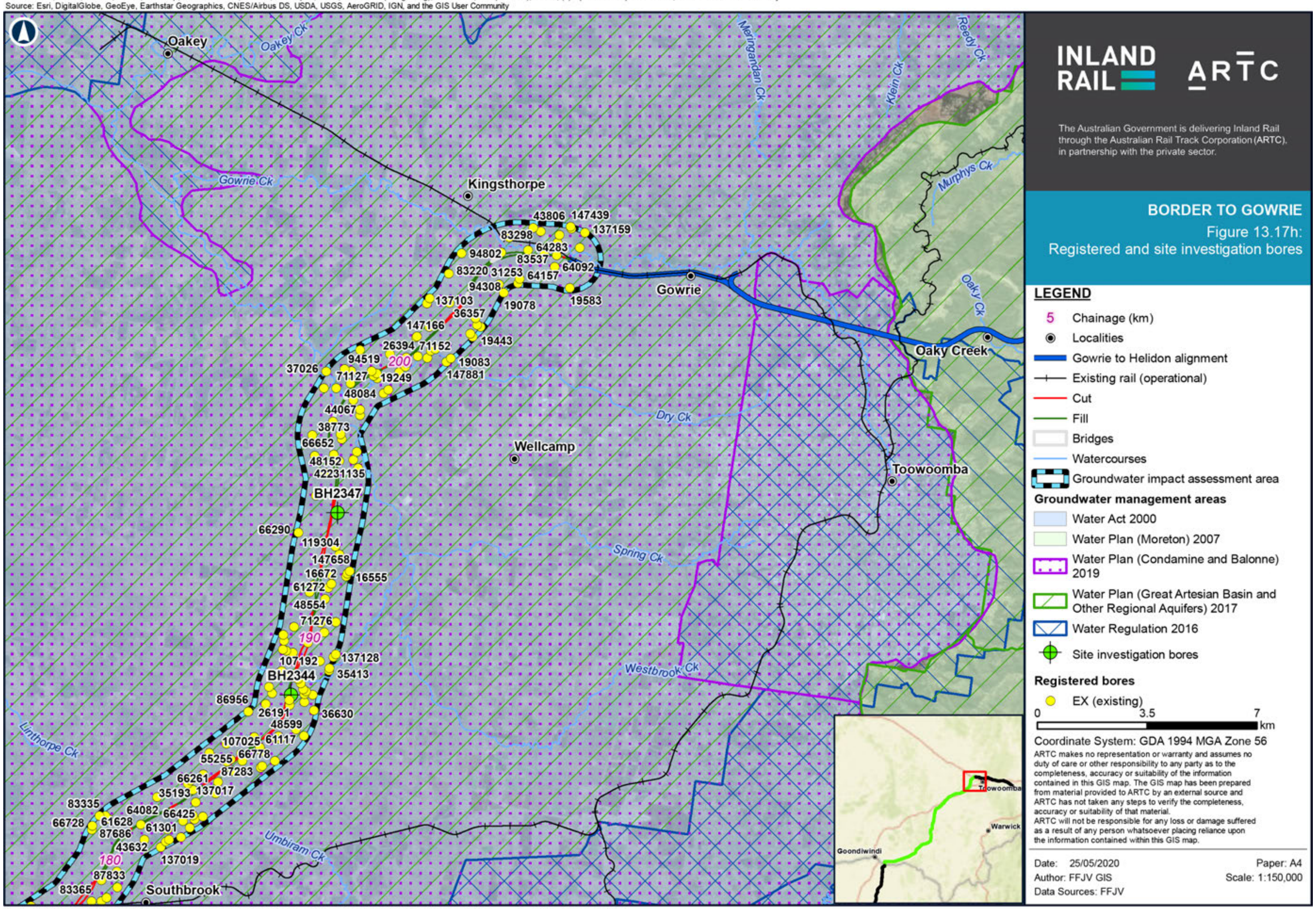
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN,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



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13.6.4.5 Groundwater quality

In 2016, DNRME undertook a hydrochemical assessment for the Condamine Alluvium, MRV, WCM, and the Hutton/Marburg Sandstone (DNRME, 2016a). The results from that report have been referenced for this assessment; specifically, those that focus on the interrelationship between the Condamine Alluvium, the MRV and the WCM. These three formations are important for understanding groundwater connectivity within the impact assessment area. Quality data obtained from the DNRME assessment was compared to the *Australian Drinking Water Guidelines* (NHMRC and NRMMC, 2011) and the ANZECC and ARMCANZ Guideline 2018 to identify the existing water quality of each aquifer.

Water samples can be analysed for, and characterised by, their hydrochemical composition. Such analysis enables a hydrochemical type to be assigned to a water source or, in this case, an aquifer. A hydrochemical type is a sequence of a water sample's three major ions, listed in order of increasing concentration. A summary of major ion concentrations for the Condamine Alluvium, the MRV and the WCM is shown in Table 13.6. This data shows that water from the Condamine Alluvium and the MRV has a sodium–bicarbonate–chloride ($Na–HCO_3–Cl$) dominant hydrochemical type, while water from the WCM is sodium–chloride–bicarbonate ($Na–Cl–HCO_3$) dominant.

The data also shows that the WCM has much higher concentrations of Na^+, HCO_3^-, Cl^-, sodium adsorption ratio (SAR) and total dissolved solids (TDS) than the Condamine Alluvium and the MRV. In particular, SAR and the percentage of Ca^{2+} and Mg^{2+}, as contributed from the weathering of rock minerals, differs greatly between the Condamine Alluvium and the WCM (DNRME, 2016a).

TABLE 13.6 HYDROCHEMICAL COMPOSITION OF WATER IN THREE MAIN AQUIFERS

Aquifer	Hydrochemical type	Major ions	Mean (mg/L)	Median (mg/L)	Range (mg/L)	No. of observations
Condamine Alluvium	($Na–HCO_3–Cl$)	Na^+	347	195	27–900	1,133
		HCO_3^-	408	390	6–973	
		Cl^-	585	235	8–900	
		SAR	7 (no unit)	5	1–56	
		TDS	1,371	827	200–16,700	
Main Range Volcanics	($Na–HCO_3–Cl$)	Na^+	128	100	15–1,340	980
		HCO_3^-	357	345	6–1,150	
		Cl^-	272	180	10–3,300	
		SAR	4 (no unit)	2	1–35	
		TDS	778	651	75–5,4760	
Walloon Coal Measures	($Na–Cl–HCO_3$)	Na^+	1,062	730	63–6,331	367
		HCO_3^-	614	508	12–1,650	
		Cl^-	1,537	940	35–11,058	
		SAR	51 (no unit)	22	1–219	
		TDS	3,209	2,283	326–18,999	

Source: DNRME, 2016a

The Piper diagram is one of the most commonly used techniques to interpret water chemistry data, such as that presented in Table 13.6. Piper diagrams plot relative abundances of major cations and anions on adjacent tri-linear fields, with these points then being extrapolated to a central diamond field. Here, the chemical character of water, in relation to its environment, can be observed and changes in the quality interpreted. The cation and anion plotting points are derived by computing the percentage equivalents per million for the main diagnostic cations of Ca^{2+}, Mg^{2+} and Na^+/K^+, and anions Cl^-, $SO4^{2-}$, and CO_3^{2-}/HCO_3^-.

Waters from different environments typically plot in diagnostic areas or 'hydrochemical facies'. The upper half of the diamond normally contains water of static environments, while the middle area normally indicates an area of dissolution and mixing. The lower triangle of this diamond shape indicates an area of dynamic and co-ordinated environments. Sodium chloride brines (old water) normally plot in the right corner of the diamond shape while recently recharged water plots on the left corner of the diamond plot. The top corner normally indicates water contaminated with gypsum (sulphate impact).

Water quality, including Piper diagrams and determination of corresponding hydrochemical characteristics, is presented in the following subsections for each of the relevant aquifer units.

Border Rivers Alluvium

Water chemistry data from water samples obtained from the Border Rivers Alluvium (DNRME, 2016b) have been plotted onto a Piper diagram to determine the hydrochemical character of the aquifer (refer Figure 13.18). The data points plot in two well-defined groups. The orange group is dominated by Cl–Ca–HCO_3 ions whereas the blue group is dominated by Na–K–HCO_3 ions.

These two groups clearly originate from different zones within the aquifer and acquire their character from the hosting alluvial sediments. The blue group suggests possible mixing of waters from two different regimes.

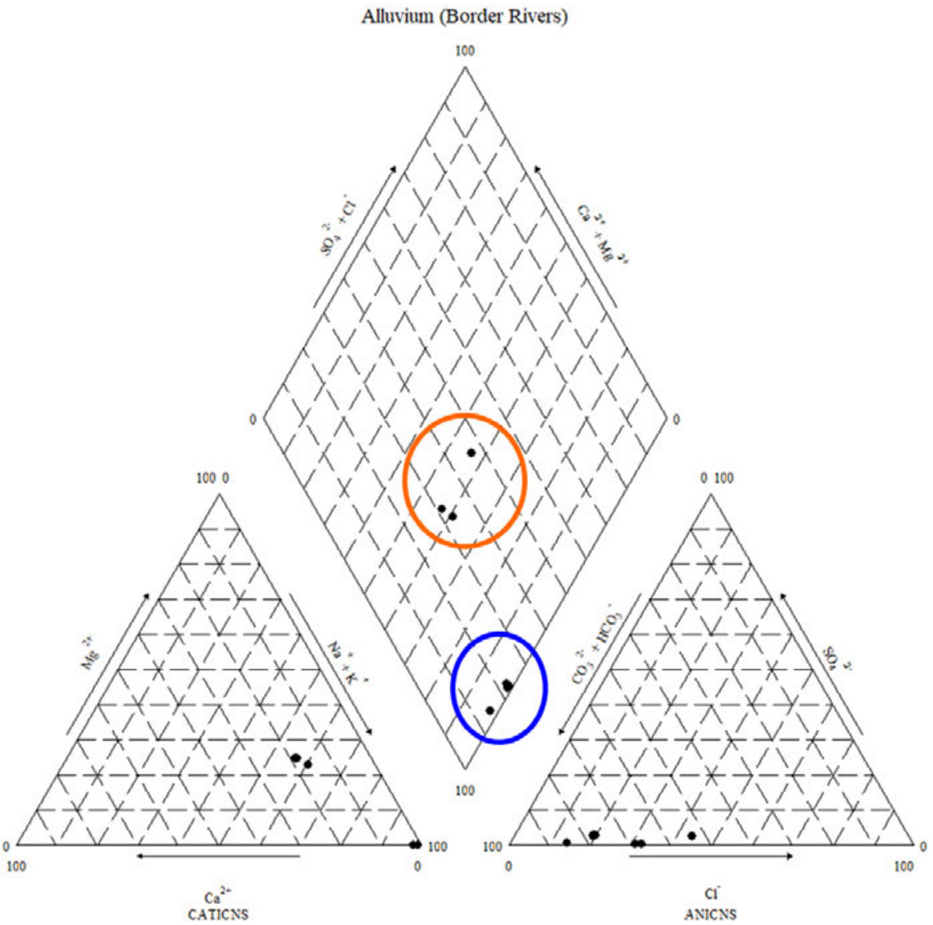


FIGURE 13.18 PIPER DIAGRAM OF RESULTS FOR GROUNDWATER COLLECTED FROM THE BORDER RIVERS ALLUVIUM

When comparing the water quality to the NHMRC Drinking Water standards, only the median value of TDS exceeds the parameter standard of 600 mg/L; however, when taking maximum values into account, there are exceedances such as TDS (1,448 mg/L), pH (8.6), chloride (565 mg/L), sodium (542 mg/L), iron (0.62 mg/L) and nitrate (36 mg/L).

Salinity is highly variable in this aquifer with electrical conductivity (EC) ranging between 563 µS/cm and 2,600 µS/cm, which is considered fresh to brackish groundwater. This suggests that certain parts of the aquifer can yield moderately saline water and that such areas are probably further from recharge zones, which typically reflects longer residence time in the aquifer.

Condamine Alluvium

Water chemistry data from water samples obtained from the Condamine Alluvium (DNRME, 2016b) have been compared to the *Australian Drinking Water Guidelines* (NHMRC and NRMMC, 2011). An assessment of median parameter values indicates that none of the criteria established in the Australian Drinking Water Guidelines are exceeded by water samples from the Condamine Alluvium; however, when maximum values are considered, there are exceedances such as TDS (990 mg/L), pH (8.9), chloride (750 mg/L), and sodium (A297 mg/L).

Salinity is highly variable in this aquifer, with TDS ranging between 227 and 990 mg/L, which is considered to be fresh (< 1,000 mg/L). This suggests that the aquifer is regularly recharged and that there is no extended residence time to facilitate water–sediment interaction (i.e. this is a typical dynamic primary aquifer system).

Water chemistry data from water samples obtained from the Condamine Alluvium have been plotted onto a Piper diagram to determine the hydrochemical character of the aquifer (refer Figure 13.19). The data points plot in a well-defined area where the dominant ions are Na–HCO_3–Cl, which is consistent with the Na–HCO_3–Cl hydrochemical classification previously documented by DNRME (DNRME, 2016a).

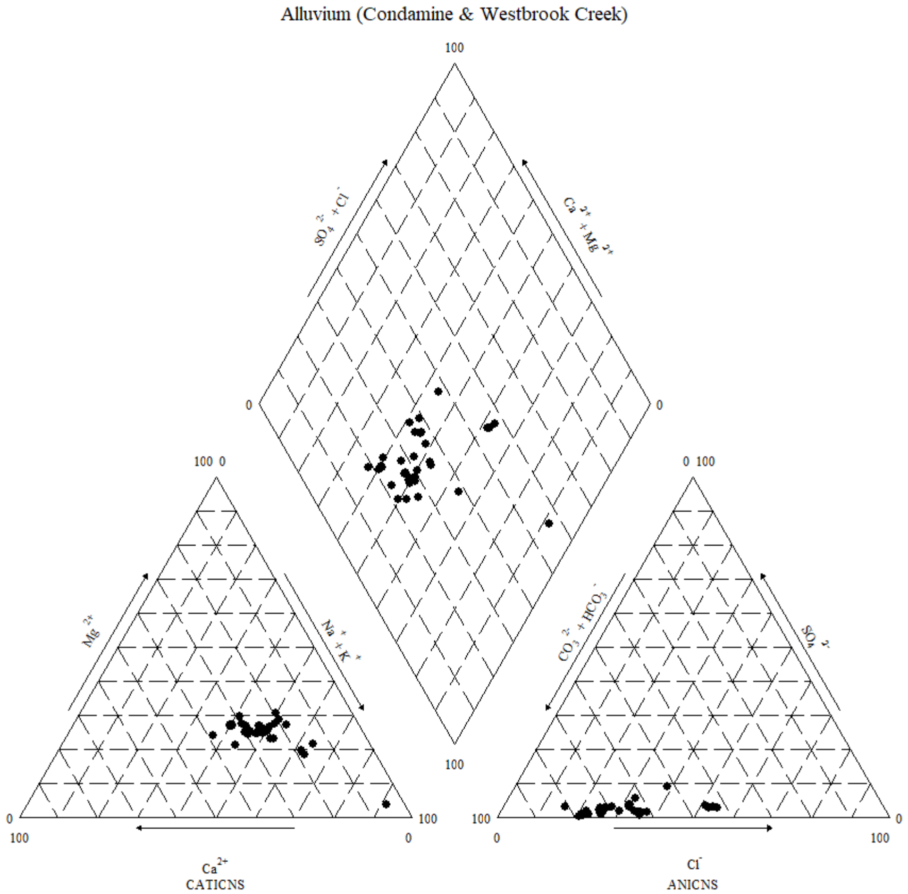


FIGURE 13.19 PIPER DIAGRAM OF RESULTS FOR GROUNDWATER COLLECTED FROM THE ALLUVIUM FROM CONDAMINE RIVER

Main Range Volcanics

The MRV consist of basalt that underlies the Condamine Alluvium tributaries in the eastern portion of the impact assessment area and overlies the WCM.

Data from the MRV is plotted in Figure 13.20 and presents available data from the DNRME groundwater database (black circles) and data from the site investigations for the Project (BH2344 and BH2347) (Golder, 2019c). The DNRME have previously reported groundwater from the MRV as being Na–HCO_3–Cl dominant and ranging from fresh to brackish in salinity (DNRME, 2016b); however, when plotted onto a Piper diagram, water chemistry data shows that water within this aquifer does not have a specific hydrochemical signature, with individual samples plotting across the diagram (rather than plotting in a cluster). The dominant cation in the majority of samples is shown to be magnesium and the dominant anion is shown to be bicarbonate. The scattered nature of the samples indicates that there are multiple processes occurring in this aquifer. These processes are likely to involve recent recharge, mixing environments and cation exchange of magnesium and calcium for sodium (refer Figure 13.20).

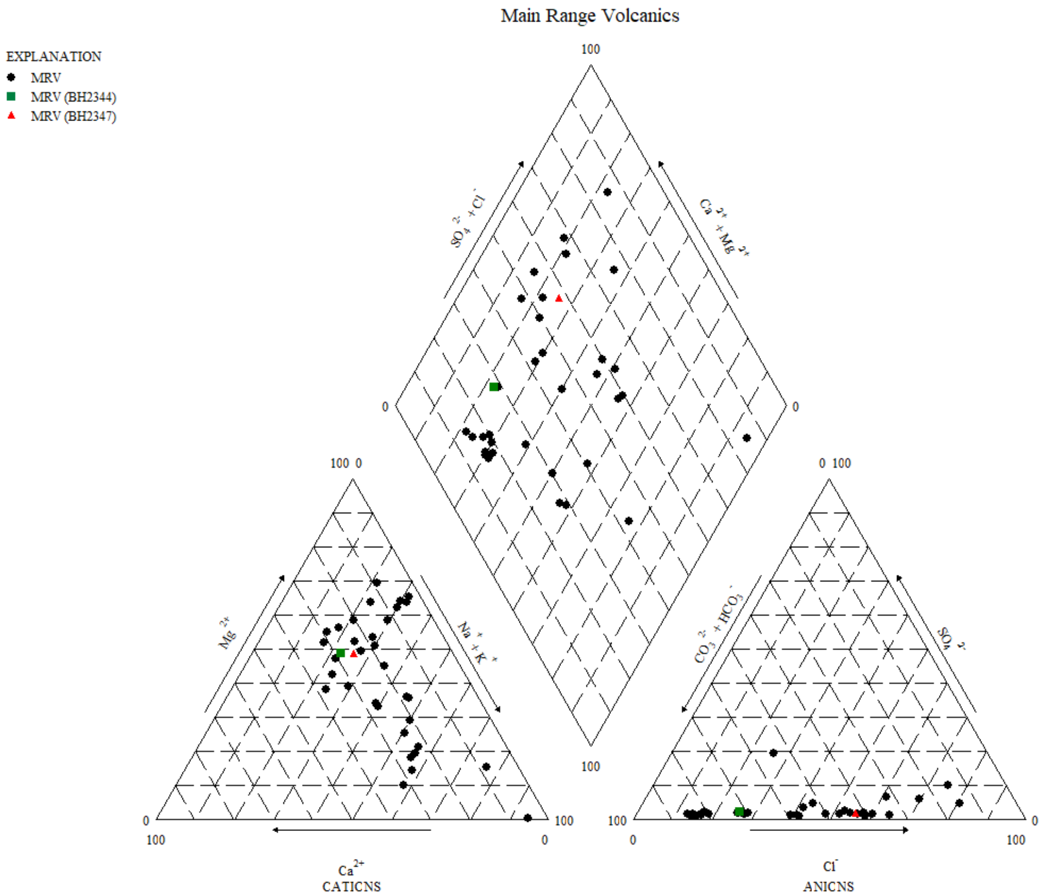


FIGURE 13.20 PIPER DIAGRAM OF RESULTS FOR GROUNDWATER SAMPLES COLLECTED FROM THE MAIN RANGE VOLCANICS AQUIFER (DNRME GROUNDWATER DATABASE)

Walloon Coal Measures

The quality of the groundwater within the WCM is highly variable due to the structure of the unit and the hydraulic connectivity (leakage) with the overlying units, which are known to be of fresher quality. Water chemistry data from water samples obtained from the WCM indicate TDS values ranging from 374 mg/L up to 5,741 mg/L, which is considered fresh to saline. The high variability in the dissolved salt load is also evident in the scattered nature of samples when plotted into a Piper diagram, as depicted in Figure 13.21.

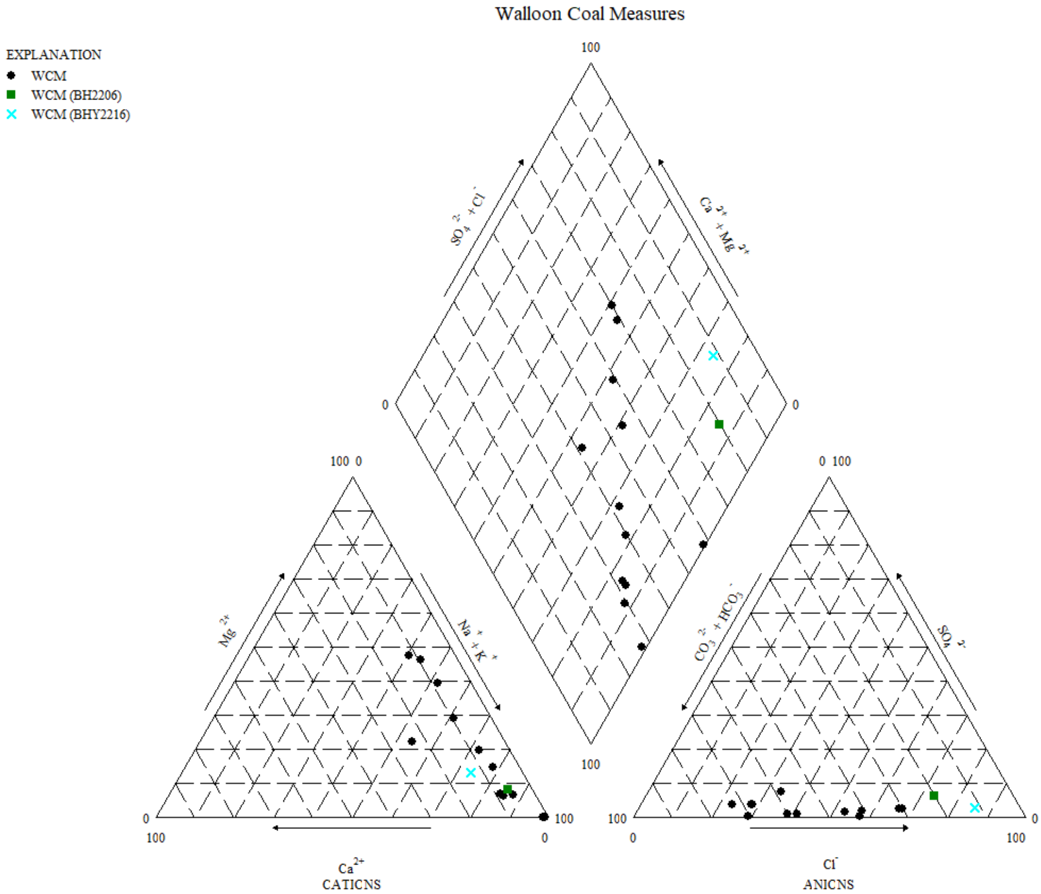


FIGURE 13.21 PIPER DIAGRAM OF RESULTS FOR GROUNDWATER SAMPLES COLLECTED FROM THE WALLOON COAL MEASURES AQUIFER

Regional salinity

Salinity is a major land degradation issue that can impact on land productivity, in-stream salt loads and concentrations. Two salinity risk assessments have previously been undertaken within the impact assessment area. The Murray Darling region salinity risk assessment intersects the impact assessment area between the Macintyre River and east of Millmerran State Forest (Biggs et al., 2010b). The Condamine Catchment salinity risk assessment intersects the impact assessment area from east of Millmerran State Forest to Gowrie (Searle et al., 2007).

The Murray Darling region salinity risk assessment identified 58 known salinity expression areas affected by secondary salinity, including the Yelarbon Desert in the Border Rivers catchment. The Yelarbon area (from approximately Ch 20 km to Ch 30 km) is known for its extremely alkaline, sodic sodosol soils strongly attributed to upwelling of sodium bicarbonate rich groundwater (Biggs et al., 2010a). This upwelling is primarily attributed to an offset fault from the Peel Fault, which allows saline groundwater to infiltrate the soil zone (Knight et al., 1989). The Peel Fault is discussed in further detail in Appendix R: Groundwater Technical Report.

Within the Border Rivers catchment, the salinity risk assessment identified the use of saline groundwater, leaking dams and dissolution of salts as the most common salinity types, on assessment of the existing landscape. Despite the need for greater research regarding secondary salinity formation and the impact of salinity on infrastructure assets, the risk assessment concluded salinity in the region will have a low risk to rail infrastructure (Biggs et al., 2010b).

The Condamine Catchment salinity risk assessment identified more than 170 salinity expression sites, with most influenced by climatic conditions. The assessment identified return to typical long-term weather patterns will likely increase the size and number of dryland salinity expressions in the region and increase salt load exported from the catchment. The impact assessment area intersected sub-catchments considered to contain a very-low-to-high overall salinity risk. The Millmerran area was considered to have a very-low to low risk of secondary salinity, while the Pittsworth and Gowrie area was considered to have moderate risk. An area of high salinity risk intersects the impact assessment area near Southbrook and presents a 'current' threat, through salinity, to infrastructure assets in the area (Searle et al., 2007).

Further details on the salinity risk within the Project footprint is discussed in Chapter 8: Land Resources.

13.6.5 Groundwater users

A search of registered groundwater bores within the impact assessment area was completed in March 2019 using the DNRME Groundwater Database and Queensland Globe. The search identified a total of 439 registered bores within the impact assessment area of which 156 were excluded from further evaluation due to an absence of data on aquifer lithology, bore construction details or water levels. The remaining 283 registered bores within the impact assessment area are depicted in Figure 13.17. The database was used to develop an appreciation for existing groundwater usage within the impact assessment area.

A review of reported groundwater uses from relevant aquifers surrounding the Project footprint has been completed to assist with the evaluation of EVs. This review is based on the Queensland water entitlements database (DNRME, 2018b) which details the licence type and source aquifer for all water entitlements in Queensland. An annual water volume is typically assigned to each licence (refer Table 13.7) and is summarised for each of the three water sharing plans identified for the Project (refer Section 13.3).

Analysis of water entitlements within the impact assessment area indicates that irrigation is the primary groundwater entitlement licence type for the key aquifers near the Project footprint. For the shallow aquifers (being the Border Rivers Alluvium, the Condamine Alluvium, and the MRV) irrigation comprises 70 to 85 per cent of the annual assigned groundwater take. This is followed by stock, industrial and urban takes from these shallow aquifers. In the Border Rivers Alluvium, the majority of the assigned entitlements are for supplementing surface water supplies during drought periods, which often results in only a small proportion of the groundwater allocation being used (DNRME, 2016b).

Under the Water Plan (GABORA) 2017, Great Artesian Basin (GAB) sedimentary rock aquifers from the Surat and Clarence Moreton Basins have almost 2,500 entitlements assigned to stock and domestic purposes compared to irrigation use, which has 286 entitlements. This discrepancy is likely reflective of the less suitable groundwater chemistry for irrigation (i.e. high sodium adsorption ratios) from formations such as the Kumbarilla Beds and WCM (refer Table 13.7).

Intensive stock and town water supply entitlements comprise most of the remaining entitlements for groundwater takes from sedimentary rock aquifers in the area.

TABLE 13.7 SUMMARY OF GROUNDWATER ENTITLEMENTS FOR THE IMPACT ASSESSMENT AREA

Queensland Water Plan	Water source	Licensed purpose	Number of entitlements	Water made available (ML/yr)	Per cent of assigned water volume
Queensland Border Rivers–Moonie Water Resource Plan 2019	Border Rivers Alluvium	Irrigation	76	13,749	72.6
		Industrial and commercial	7	44	0.2
		Irrigation and stock	6	3,917	20.7
		Town water and urban supply	4	547	2.9
		Domestic supply and stock	3	30	0.2
		Any	3	664	3.5
Total per cent of assigned water volume					**100.1**
Total per cent available for new entitlements under Queensland Border Rivers–Moonie Water Resource Plan 2019					**0.0**
Water Plan (Condamine and Balonne) 2019	Condamine River Alluvium and tributaries	Irrigation and minor stock	742	96,387	83.2
		Stock intensive	37	749	0.6
		Any	35	11,634	10.0
		Commercial and industrial	17	1,430	1.2
		Town water and urban supply	13	4,204	3.6
		Aquaculture	7	683	0.6
		Environmental	5	716	0.6
		Productive base	3	106	0.1
	Total per cent of assigned water volume				**99.9**
	Main Range Volcanics	Irrigation and minor stock	1,019	48,712	80.9
		Commercial and industrial	82	3,076	5.1
		Stock intensive	60	959	1.6
		Any	41	1,761	2.9
		Town water and urban supply	11	5,483	9.1
		Agriculture and aquaculture	10	254	0.4
	Total per cent of assigned water volume				**100.0**
Total per cent of assigned water volume					**100.0**
Total per cent available for new entitlements under Water Plan (Condamine and Balonne) 2019					**0.0**
Water Plan (GABORA) 2017	Balonne–Condamine and Border Rivers Basin Regions	Stock and domestic	2,447	Not assigned	N/A
		Irrigation and minor stock	286	10,945	20.1
		Stock intensive	174	11,319	20.8
		Town water and urban supply	70	17,967	33.0
		Commercial and industrial	55	8,497	15.6
		Any	53	4,918	9.0
		Aquaculture	6	696	1.3
		Dairying	4	62	0.1
Total per cent of assigned water volume					**99.9**
Total per cent available for new entitlements under Water Plan (GABORA) 2017					**0.01**

13.6.6 Groundwater dependant ecosystems

Groundwater plays an important role in sustaining aquatic and terrestrial ecosystems, such as springs, wetlands, rivers and vegetation. Understanding these groundwater-dependent ecosystems (GDEs) is essential for groundwater management and planning.

The BoM has developed a Groundwater Dependent Ecosystems Atlas (GDE Atlas) as a national dataset of Australian GDEs and potential GDEs (BoM, 2019c). The GDE Atlas contains information about three types of ecosystems:

- **Aquatic** ecosystems that rely on the surface expression of groundwater—this includes surface water ecosystems that may have a groundwater component, such as rivers, wetlands and springs. Marine and estuarine ecosystems can also be groundwater dependent but these are not mapped in the Atlas.
- **Terrestrial** ecosystems that rely on the subsurface presence of groundwater—this includes all vegetation ecosystems.
- **Subterranean** ecosystems—this includes cave and aquifer ecosystems.

The sections below summarise known GDEs that occur within the impact assessment area. Additional details are provided in Appendix R: Groundwater Technical Report.

Additional details on GDEs identified within the impact assessment area, in relation to ecological function and surface water quality are discussed in Chapter 10: Flora and Fauna and Chapter 12: Surface Water and Hydrology, respectively.

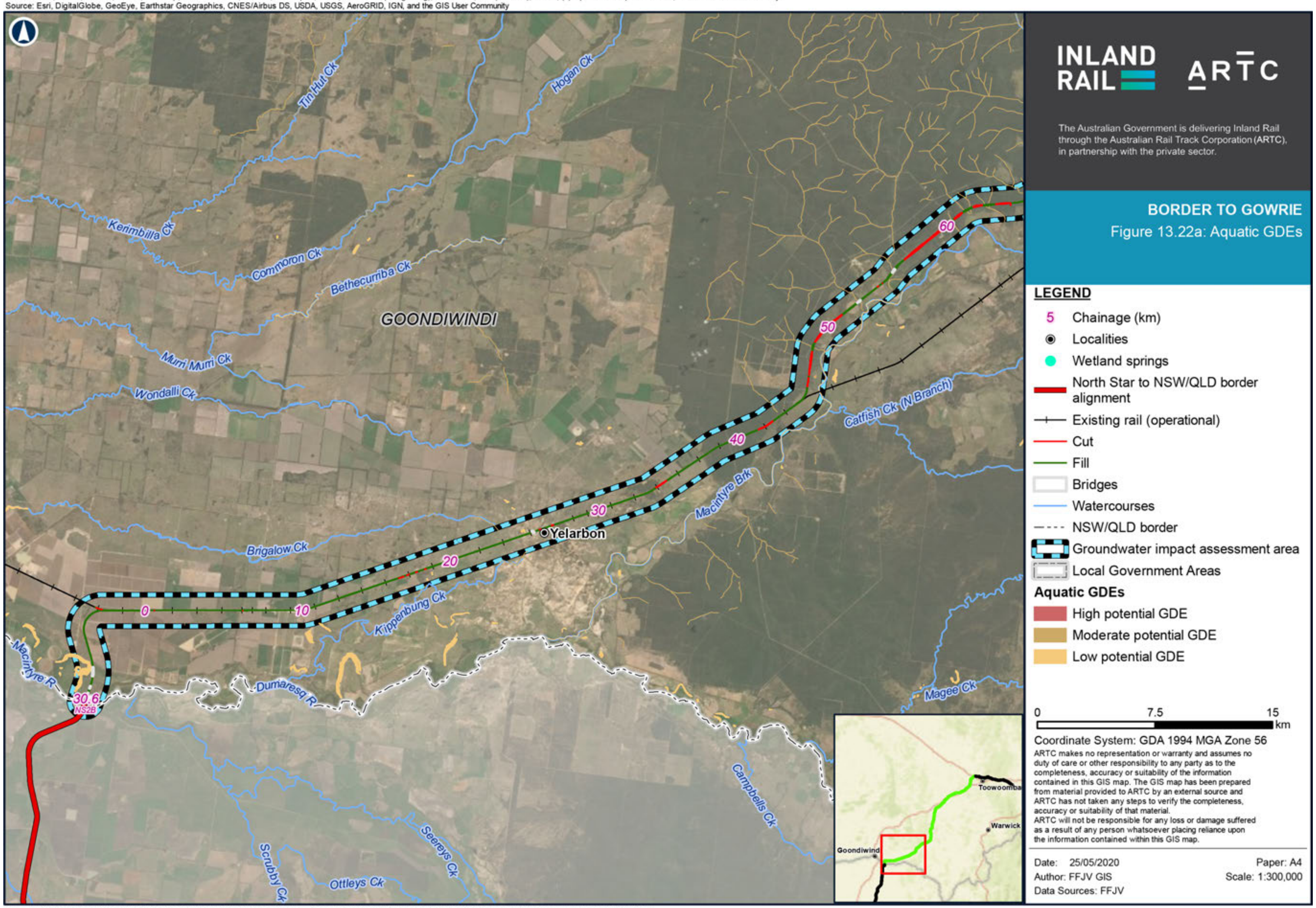
13.6.6.1 Aquatic groundwater dependent ecosystems

The GDE Atlas indicates that there are no high potential aquatic GDEs located within 5 km of the Project footprint. Areas where potential aquatic GDEs are identified within 5 km of the Project are as follows:

- Between Ch 40.0 km and Ch 95.0 km, the Project crosses numerous unnamed tributaries associated with Macintyre Brook and Canning Creek. These drainage features have a moderate aquatic GDE potential.
- Unnamed creeks with moderate potential for aquatic GDEs occur to the southwest of Millmerran within and surrounding the Project footprint between Ch 115.0 km to Ch 125.0 km
- The Condamine River, which the Project alignment crosses near Ch 142.9 km, is considered to have a low potential for aquatic GDEs
- Low-to-moderate potential for aquatic GDEs is associated with narrow, unnamed creeks underlain by the MRV subcrop between Ch 160.0 km to Ch 206.9 km.

The location of potential aquatic GDEs in relation to the Project footprint are shown on Figure 13.22.

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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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
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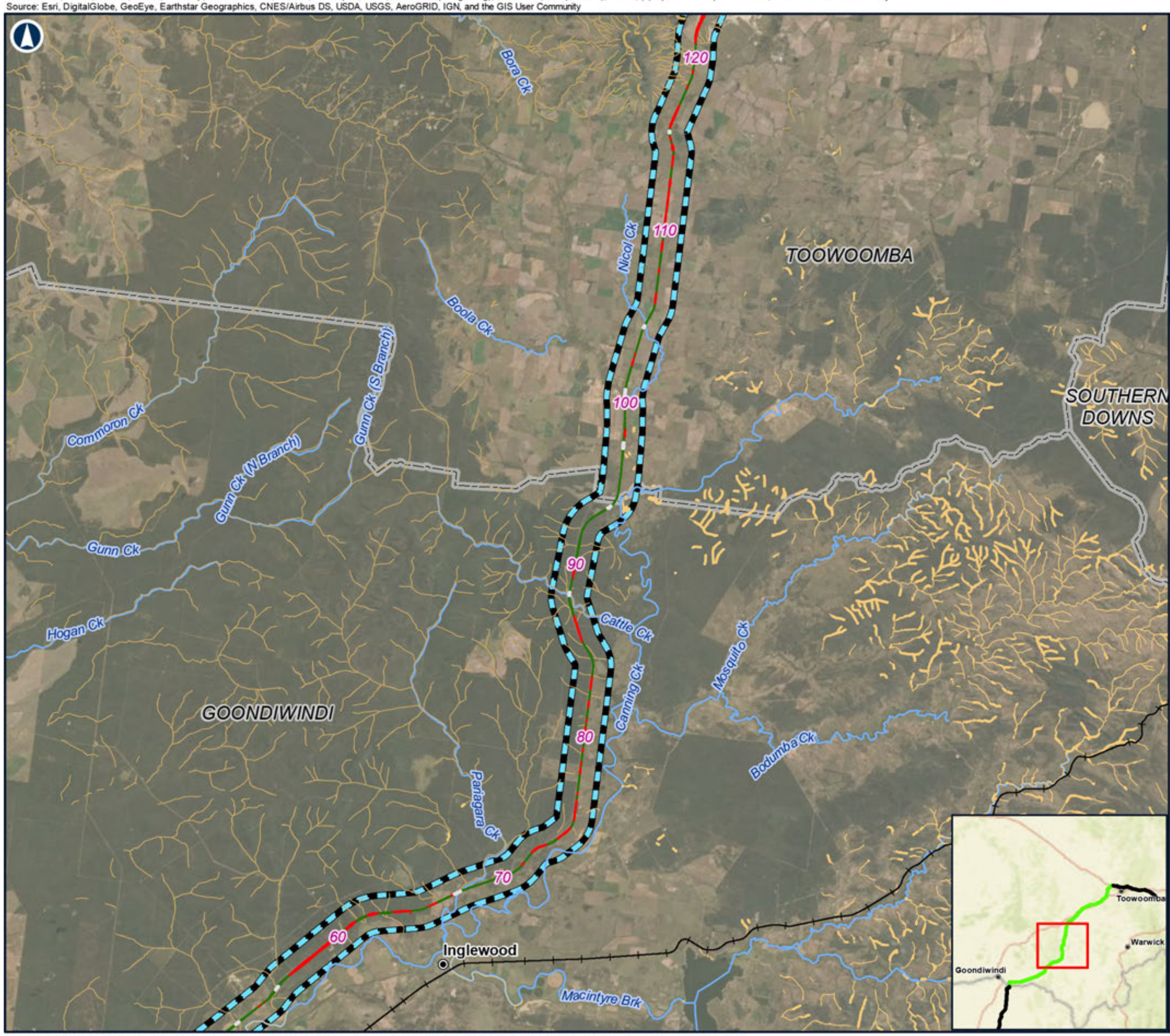

INLAND RAIL

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

BORDER TO GOWRIE

Figure 13.22b: Aquatic GDEs

LEGEND

- 5 Chainage (km)
- Localities
- Wetland springs
- Existing rail (operational)
- Cut
- Fill
- Bridges
- Watercourses
- Groundwater impact assessment area
- Local Government Areas

Aquatic GDEs

- High potential GDE
- Moderate potential GDE
- Low potential GDE

0 7.5 15 km

Coordinate System: GDA 1994 MGA Zone 56

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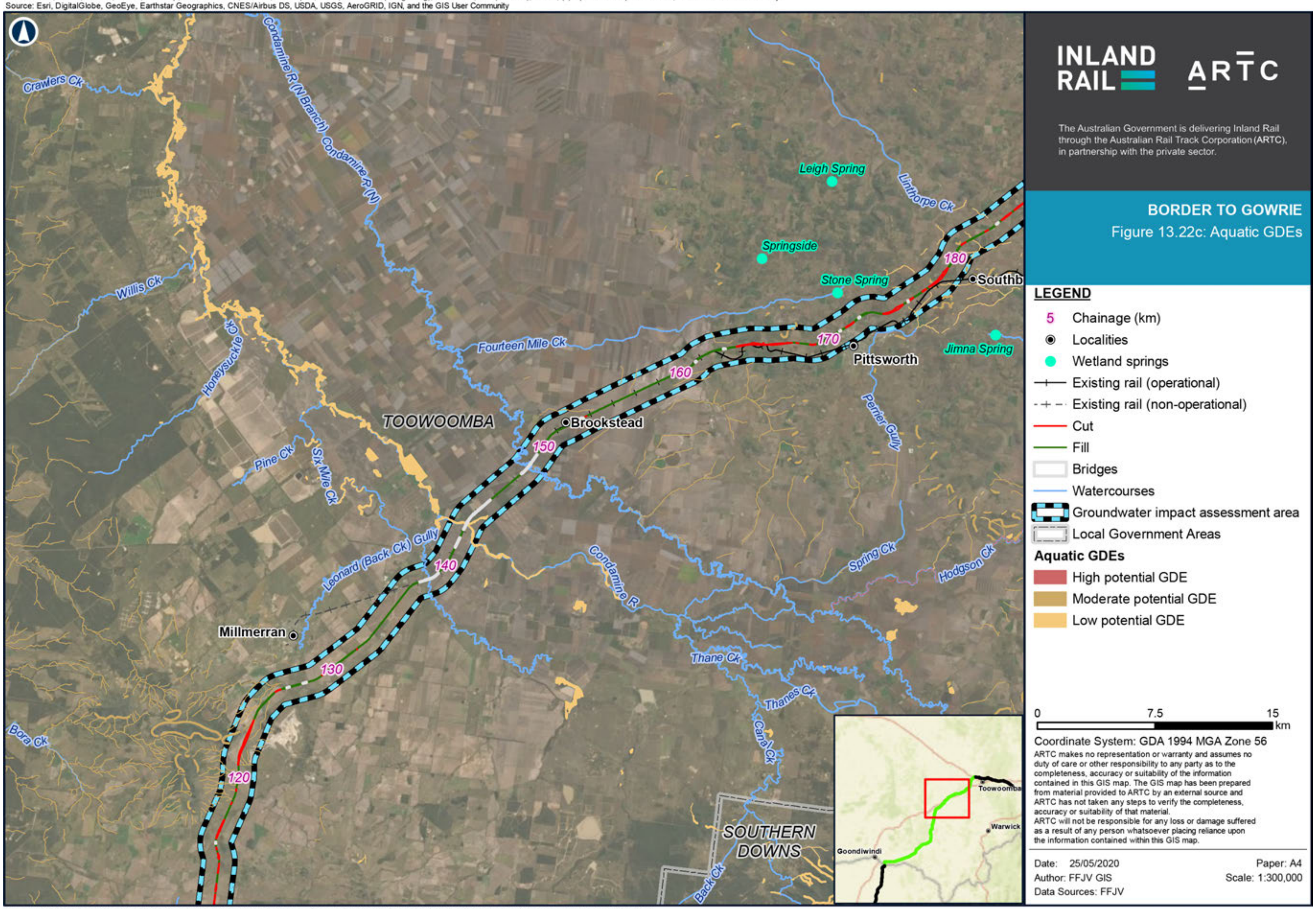
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN,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



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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
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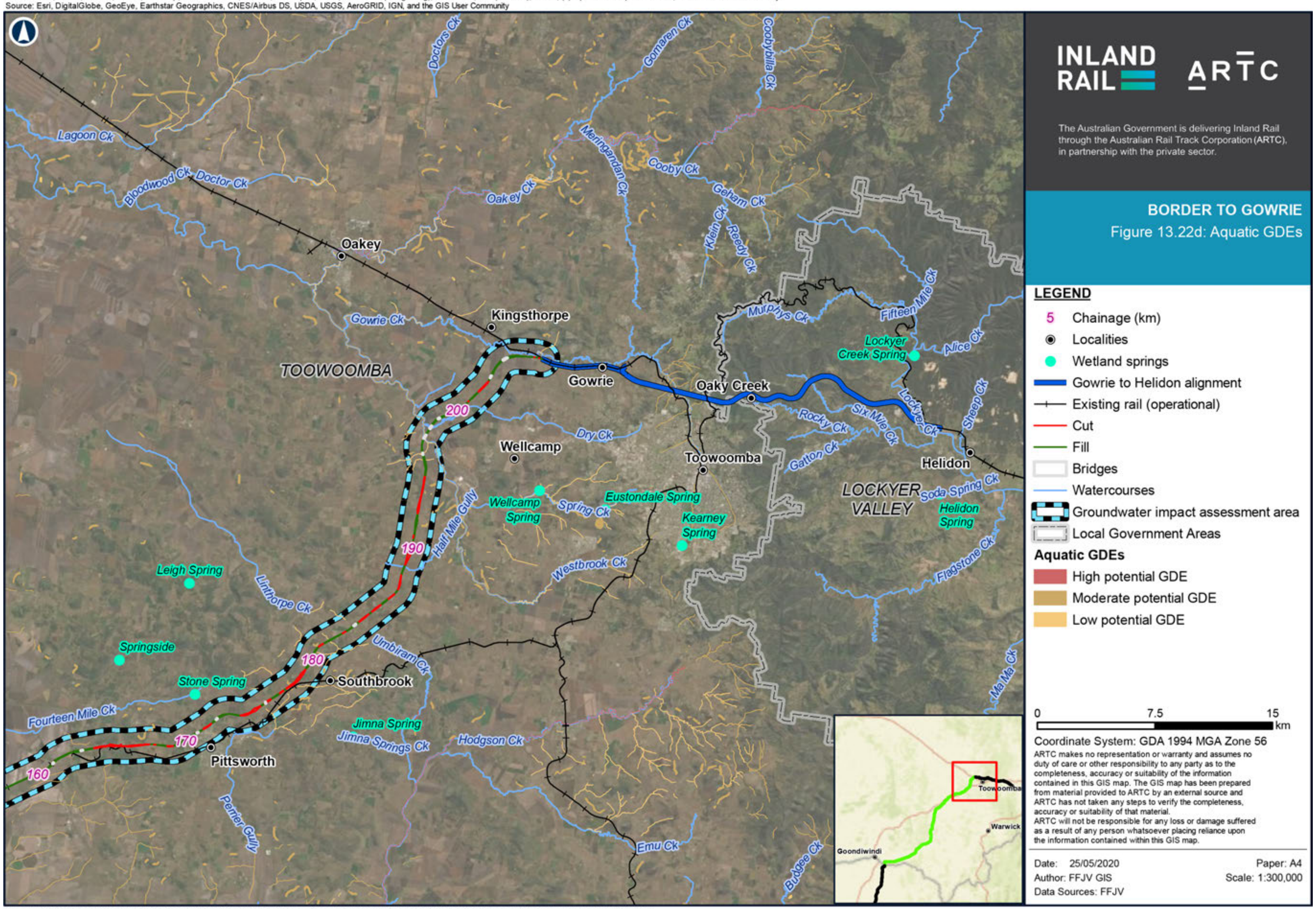

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13.6.6.2 Terrestrial groundwater dependent ecosystems

Areas where terrestrial GDEs are identified by the GDE Atlas as occurring within 5 km of the Project footprint are as follows:

- One high potential terrestrial GDE is crossed by the Project alignment between Ch 25.0 km and Ch 28.0 km, near Yelarbon. This GDE is associated with the alkaline landscape of the Yelarbon Desert sandy plains (DSITI, 2017). Here, permeable sediments of the Border Rivers Alluvium store and readily transmit groundwater from the underlying GAB to provide a permanent connection to this GDE. This GDE is recognised under Water Plan (GABORA) 2017 as a GDE Area.
- Broad areas of moderate potential for terrestrial GDEs occur between Ch 55.0 km and Ch 95.0 km. These areas are characterised to have intermittent connection to brackish aquifers associated with shallow alluvium (DSITI, 2017).
- Irregular areas of moderate potential for terrestrial GDEs are crossed by and surround the Project footprint between Ch 165.0 km to Ch 200.0 km. These GDEs are associated with fractured-rock aquifers of the MRV, which may provide an intermittent connection to these ecosystems.

The location of terrestrial GDEs in relation to the Project footprint are shown on Figure 13.23a–d.

13.6.6.3 Springs

A spring is a hydrogeological feature that occurs due to natural groundwater discharge and may be classed as having a permanent or non-permanent (ephemeral) saturation regime. GDEs may in turn be associated with the expression of surface water in a spring. Springs can have substantial environmental, cultural and economic values.

A total of 10 springs are identified within a 20 km distance from the Project footprint. All of these springs are sourced from the MRV. Nine of these springs are classified as non-permanently saturated, as detailed in Table 13.8.

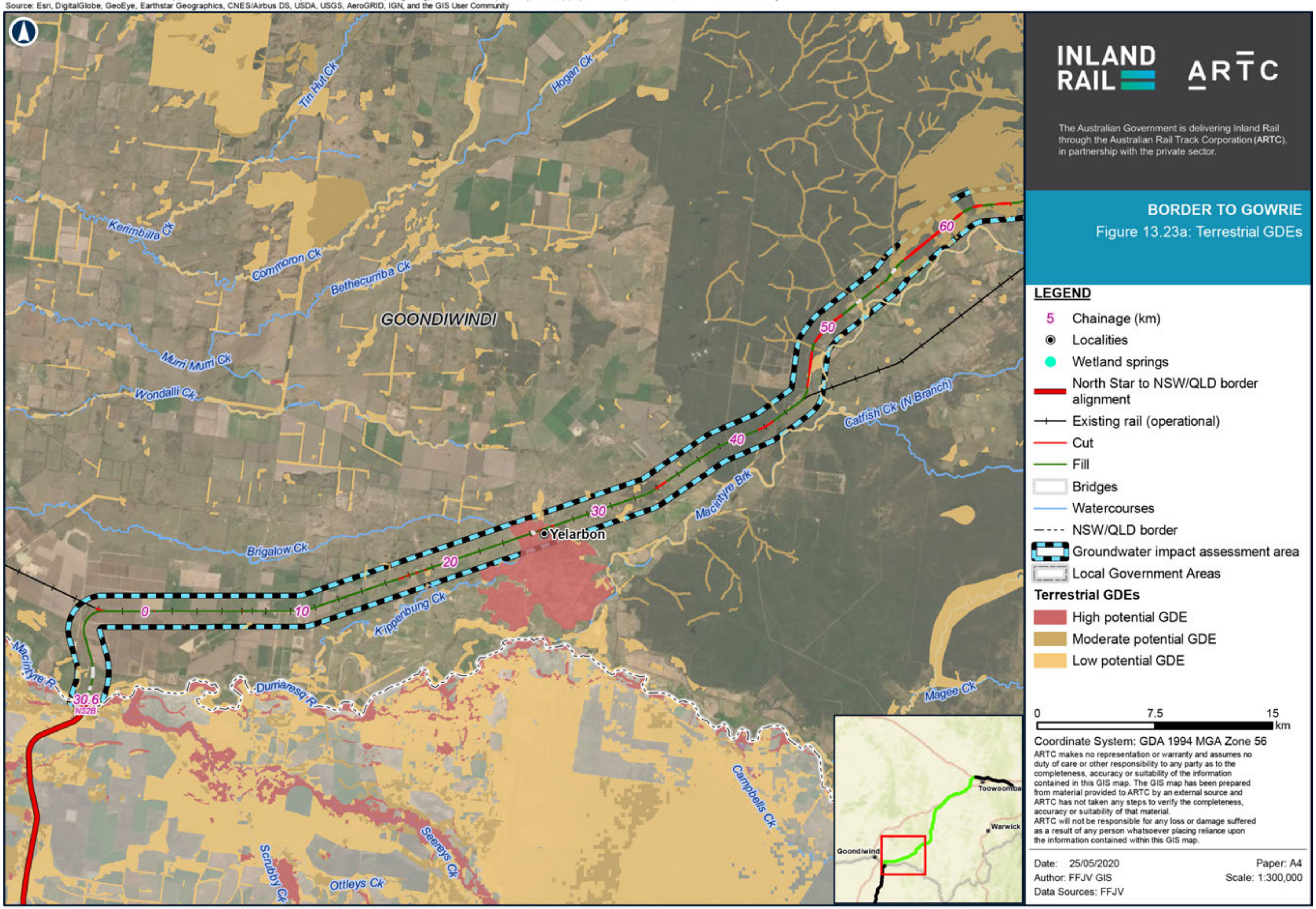
The closest registered spring to the Project alignment, Stone Spring, is 2 km to the northwest of Ch 173.0 km, near Pittsworth. There are no mapped GAB springs identified within a 20 km distance from the Project alignment. Locations of the mapped springs in proximity to the Project are depicted on Figure 13.22.

TABLE 13.8 SUMMARY OF SPRINGS WITHIN 20 KM OF THE PROJECT ALIGNMENT

Spring name/Site #	Distance from Project alignment (km)	Direction from Project alignment	Spring type	Source aquifer
Stone Spring/1145	2	NW of Ch 173.0 km	Active and non-permanent	MRV
Jimna Springs/1147	5.3	SE of Ch 178.0 km		MRV
Springside/1146	5.7	N of Ch 168.0 km		MRV
Wellcamp Spring/1150	7.4	E of Ch 195.0 km		MRV
Leigh Spring/1144	8.8	NW of Ch 173.0 km		MRV
Merigandan Creek/1155	9.4	NE of Ch 206.0 km		MRV
Eustondale Spring/1154	11.6	E of Ch 195.0 km		MRV
Lilligren Spring/1156	12.1	NE of Ch 206.0 km		MRV
Westbrook Creek/1153	14.4	E of Ch 195.0 km		MRV
Kearneys Spring/1139	17.5	E of Ch 195.0 km	Active—Permanent	MRV

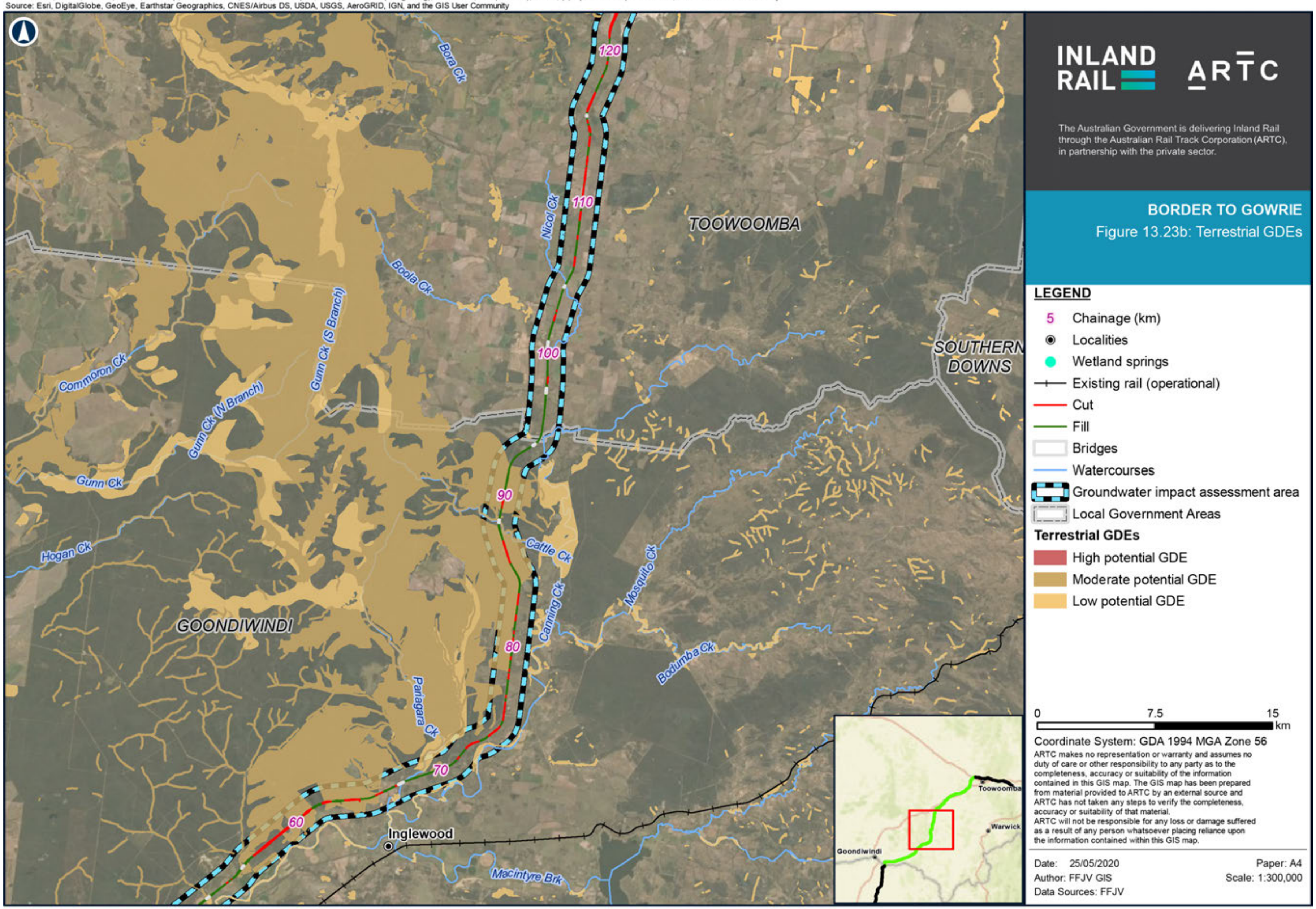
Table notes: Data sourced from QLD Springs Dataset (Queensland Herbarium and DSTIA, 2016)).

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



Map by: LUC/GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_ARTC_Fig13.23_Terrestrial_GDEs_v6.mxd Date: 25/05/2020 14:35

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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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
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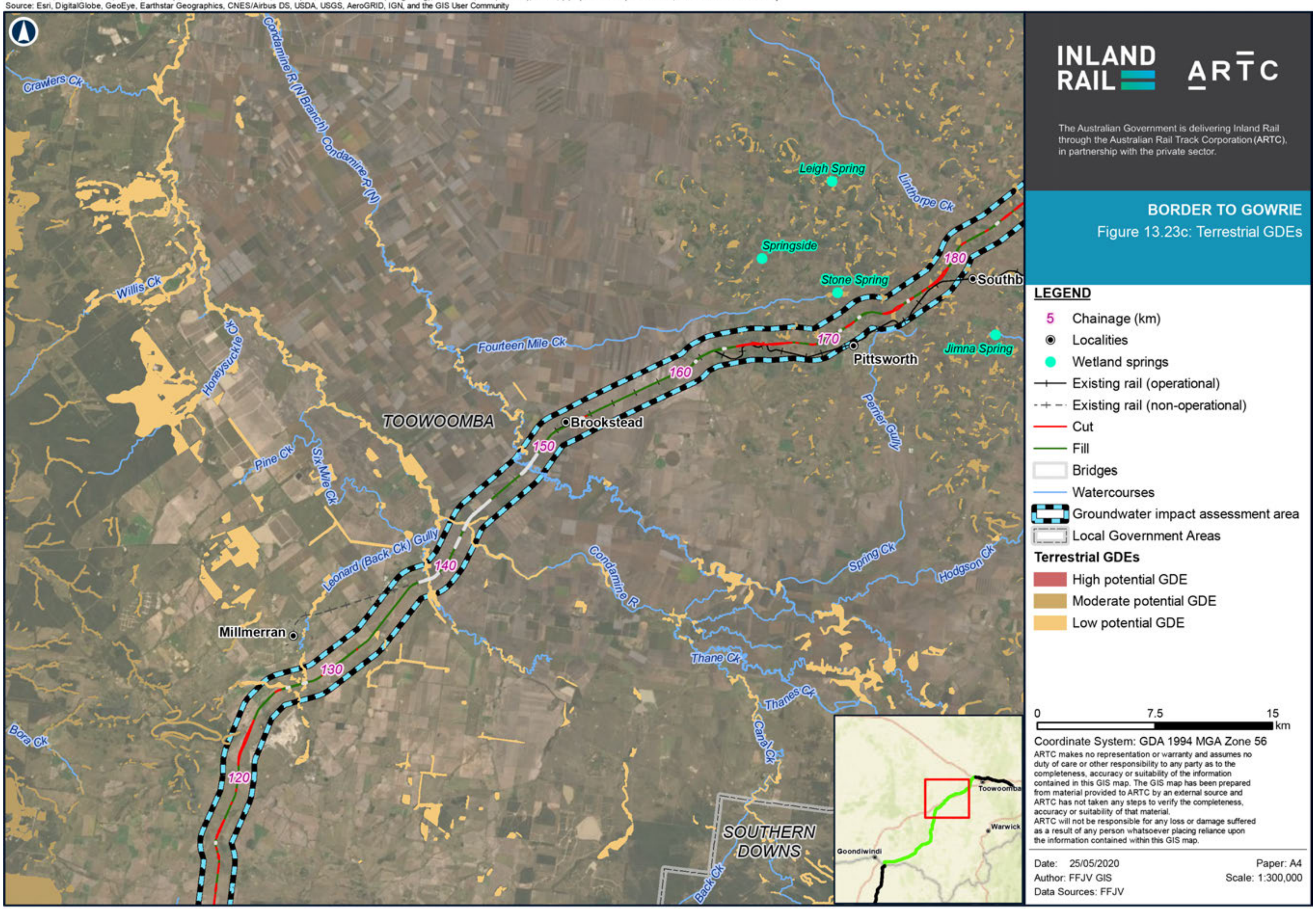

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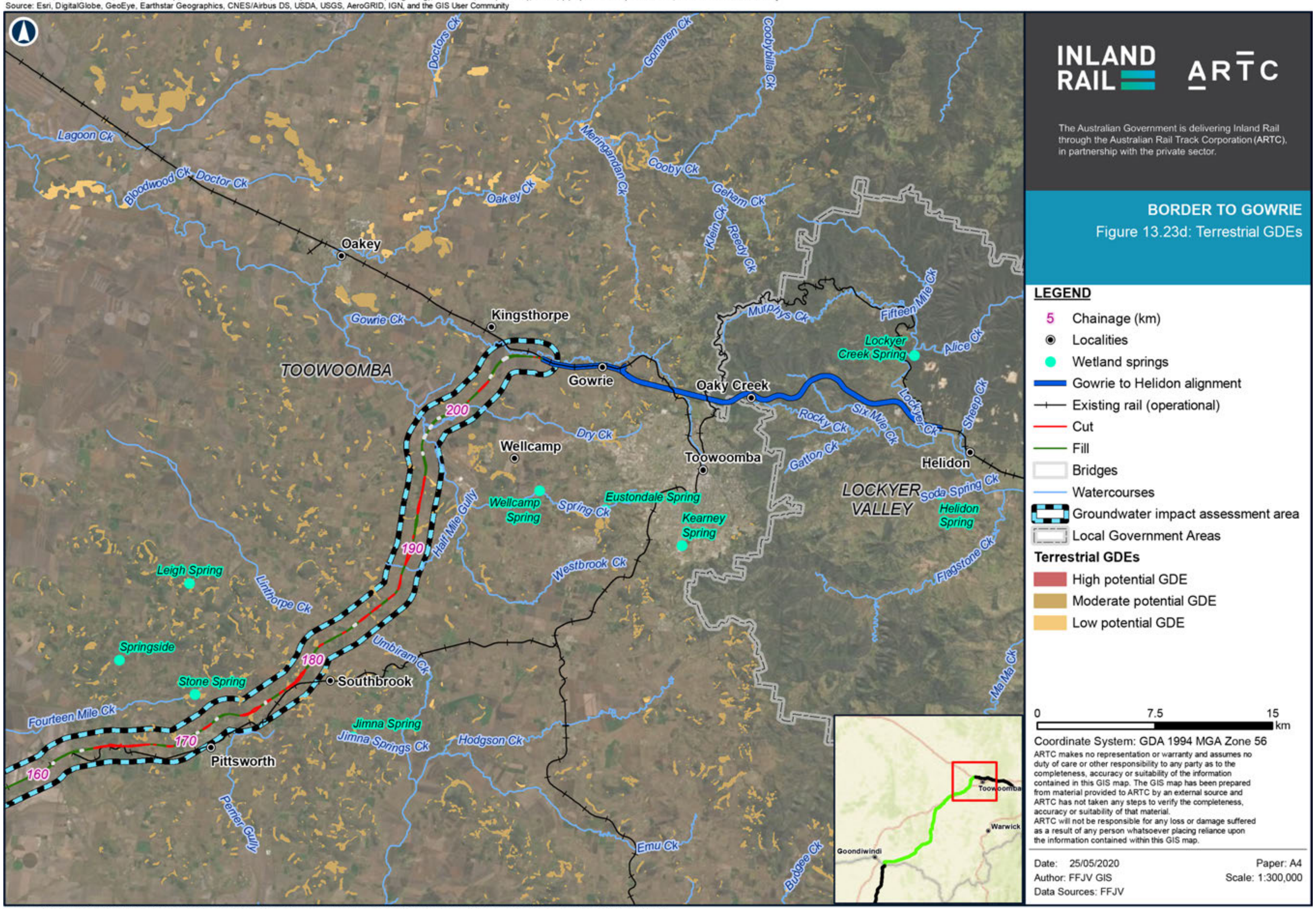
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN,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



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13.6.7 Environmental values

The Queensland Government has developed HWMPs for each river catchment and are the key planning tool for improving water quality in Queensland. 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 impact assessment area that are sufficiently important to be protected or enhanced.

This section describes groundwater-related EVs within the impact assessment area as defined under the following HWMPs:

- Ch 30.6 km (NS2B) to Ch 117.0 km: within the boundaries of the Border Rivers catchment. The relevant EVs for the impact assessment area are described in the *Healthy Waters Management Plan: Queensland Border Rivers and Moonie River Basins* (DES, 2019a).
- Ch 117.0 km to Ch 206.9 km: within the boundaries of the Condamine–Balonne River catchment. The relevant EVs for the impact assessment area are described in the *Healthy Waters Management Plan: Condamine River Basin* (DES, 2019b).

Table 13.9 summarises the relevant EVs and associated WQOs for the Project and corresponding criteria to evaluate whether the WQO is being attained. Table 13.10 lists the WQOs in full.

A detailed discussion of the HWMPs and the determination of WQOs and EVs is included in Appendix R: Groundwater Technical Report.

TABLE 13.9 SUMMARY OF ENVIRONMENTAL VALUES AND WATER QUALITY OBJECTIVES

Environmental value	WQOs/Guidelines to assess WQO	Evaluation of relevance to the Project
Groundwater—aquatic and terrestrial ecosystems	<u>Border Rivers catchment:</u> WQOs defined in Tables 35 and 37 in the HWMP for aquifers in the Border Rivers catchment (DES, 2019a). <u>Condamine–Balonne River catchment:</u> WQOs defined in Tables 31 and 32 in the HWMP for aquifers in Condamine–Balonne River catchment (DES, 2019b).	Regional aquatic GDE data from the GDE Atlas was evaluated in Section 13.6.6. This indicated there were no high potential aquatic GDEs traversed by, or in proximity to, the Project footprint. Regional terrestrial GDE data from the GDE Atlas was evaluated in Section 13.6.6.2. This indicated there is one high potential terrestrial GDE traversed by the Project alignment between Ch 25.0 km to Ch 28.0 km, near Yelarbon. The nearest spring is Stone Spring, located 2 km to the northwest of Ch 173.0 km. There are numerous areas with low-to-moderate potential to support aquatic and terrestrial GDEs; therefore, there is the potential for such GDEs to be impacted by dewatering or changes in groundwater quality during the construction phase of the Project. Mitigation measures to minimise such impacts are discussed further in Section 13.7.5. Based on the above, this EV is considered relevant to the Project.
Groundwater—irrigation	ANZECC/ARMCANZ Guideline 2018 The threshold salinity tolerances for plants grown in loamy to clayey soils (considered the primary soil conditions traversed by the rail alignment) are 600 µS/cm to 7,200 µS/cm as stated in Section 4.2.4 of the ANZECC/ARMCANZ Guideline 2018.	Groundwater use for irrigation is a significant EV for the region, particularly from shallow aquifers such as the Border Rivers Alluvium, Condamine Alluvium and MRV. The suitability of water from registered bores within the impact assessment area and from bores installed during the Project hydrogeological investigation is reinforced in Section 13.6.5. For example, the alluvium and MRV in the Border Rivers and Condamine catchments generally report median salinity values of less than 2,000 µS/cm in the area. Based on the above, this EV is considered relevant to the Project.

Environmental value	WQOs/Guidelines to assess WQO	Evaluation of relevance to the Project
Groundwater—farm supply/use	ANZECC/ARMCANZ Guideline 2018	Water quality results indicate that groundwater abstracted from most aquifers traversed by the Project alignment could be used for general farm purposes, although quality is noted to be highly variable. Based on the above, this EV is considered relevant to the Project.
Groundwater—stock water	ANZECC/ARMCANZ Guideline 2018 (i.e. median faecal coliforms of < 100 organisms per 100 ml) The water quality tolerances of livestock vary between livestock types (e.g. beef cattle have no adverse effects up to a TDS of 4,000 mg/L, whereas dairy cattle can only tolerate up to 2,500 mg/L TDS).	The review of entitlements, allocations and licensed uses confirmed that stock watering is a major use of groundwater in the area. This EV is the second most common use of groundwater (after irrigation) from the alluvium and MRV. Stock watering is the primary use for groundwater abstracted from the GAB aquifers (i.e. Kumbarilla Beds, WCM). Available salinity data for registered bores confirms that the alluvium, MRV and GAB aquifers are suitable for stock water (median EC values of < 1500 µS/cm). More variable water quality is evident in the WCM and may preclude some landowner bores from use for stock watering for less tolerant livestock. Based on the above, this EV is considered relevant to the Project.
Aquaculture	ANZECC/ARMCANZ Guideline 2018 HWMP (Border Rivers)—Table 59	While aquaculture is recognised as a potential EV for some aquifers within the impact assessment area, no known aquaculture operations are located in proximity to the Project footprint; therefore, the scale and presence of the water use is considered limited and not a significant EV for this Project.
Groundwater—drinking water	ANZECC/ARMCANZ Guideline 2018 HWMP (Border Rivers)—Table 61	The suitability of water for human consumption is defined in the *Australian Drinking Water Guidelines* (NHMRC & NRMMC, 2011). The TDS threshold for fair-to-good water palatability is < 900 mg/L under these guidelines. Most aquifers within the impact assessment area have median TDS values below this value and are potentially suitable for drinking water use. All relevant aquifers detailed in the Condamine and Border Rivers HWMPs are recognised to have a drinking water EV. Based on the above, this EV is considered relevant to the Project.
Industrial	Applicable WQOs to protect this EV are variable between different industries and are considered on a case-by-case basis	This EV is not considered relevant to the Project given that the majority of land use within the impact assessment area is comprised of stock grazing, dry land cropping and irrigated cropping. As summarised in Section 13.6.1 the remaining land uses of the Project footprint are attributed to non-industrial applications inclusive of production forestry, transportation and communications.
Cultural and spiritual	Protect or restore cultural, spiritual and ceremonial values consistent with approved policies and plans. Aboriginal waterways assessments may provide information to support the cultural, spiritual and ceremonial value.	Regionally, the Border Rivers and Condamine–Balonne River catchments have cultural and spiritual values recognised EVs for all relevant aquifers traversed by the Project, as detailed in the Border Rivers and Condamine–Balonne River catchment HWMPs (refer Appendix R: Groundwater Technical Report). Based on the above, this EV is considered relevant to the Project.
Visual amenity	Not applicable	The nearest spring is Stone Spring, located 2 km to the northwest of Ch 173.0 km; therefore, this item is not considered to be applicable to groundwater within the impact assessment area.
Recreational	Not applicable	This EV is not considered relevant to in-situ groundwater and is typically a consideration for surface water. There is a possibility of seasonal bore water use to fill swimming pools. There are no registered groundwater springs within 2 km of the Project alignment that could be considered for recreational use.

TABLE 13.10 GROUNDWATER WATER QUALITY OBJECTIVES APPLICABLE TO THE AQUIFERS WITHIN THE IMPACT ASSESSMENT AREA

Groundwater unit	Percentile	Sodium (Na)	Calcium (Ca)	Magnesium (Mg)	Bicarbonate (HCO_3)	Chloride (Cl)	Sulphate (SO_4)	Nitrate (NO_3)	EC	pH	Alkalinity	Silicon Dioxide (SiO_2)	Fluoride (F)	Iron (Fe)	Manganese (Mn)	Zinc (Zn)	Copper (Cu)	SAR	Total N	Total P
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Meq/L	mg/L	mg/L
Border Rivers	20th	150	13	10	110	117	15.1	0.3	531	6.5	104	31	0.16	0.000	0.01	0.005	0.013	4.95	0.085	0.000
	50th	329	34	23	253	381	64.5	1.9	1,800	7.3	214	60	0.30	0.010	0.04	0.020	0.015	17.00	0.543	0.049
	80th	4,589	710	569	489	8,723	1,100.0	12.5	23,910	8.0	414	81	0.90	0.056	9.74	0.160	0.070	35.7	2.717	1.235
Macintyre Brook	20th	44	3	1	145	46	1.1	0.0	410	7.5	132	10	0.20	0.005	0.01	ID	ID	1.80	ID	ID
	50th	124	19	11	295	115	7.9	0.8	1,178	7.9	243	40	0.41	0.005	0.01	ID	ID	8.92	ID	ID
	80th	412	32	28	610	270	30.2	6.4	1,700	8.6	559	44	0.89	0.121	0.83	ID	ID	31.59	ID	ID
GAB–South East Kumbarilla	20th	315	2	0	459	72	0.0	0.0	1,173	8.0	506	13	0.55	0.005	0.00	0.000	0.000	38.10	0.000	0.000
	50th	417	3	1	720	120	2.0	0.5	1,600	8.4	660	15	1.50	0.020	0.01	0.005	0.015	56.30	0.109	0.000
	80th	530	4	2	969	260	9.1	1.3	2,050	8.6	865	19	3.20	0.130	0.01	0.017	0.015	71.65	0.283	0.033
Central Condamine	20th	85	19	12	239	70	5.0	0.2	603	7.4	200	27	0.10	0.005	0.01	0.005	0.015	3.20	0.043	0.000
	50th	213	34	16	382	170	22.0	0.5	1,160	7.9	321	33	0.16	0.010	0.01	0.005	0.015	7.30	0.109	0.033
	80th	535	61	25	465	739	84.7	2.0	2,800	8.3	390	40	0.30	0.050	0.05	0.010	0.015	12.80	0.435	0.154
Condamine North Branch	20th	83	27	17	280	54	4.0	0.0	660	7.5	240	28	0.10	0.005	0.01	0.005	0.015	2.50	0.000	0.000
	50th	105	37	26	380	80	9.6	0.5	805	7.9	320	36	0.10	0.010	0.01	0.005	0.015	3.30	0.109	0.033
	80th	158	52	34	451	136	26.0	1.0	1,050	8.3	376	40	0.20	0.030	0.01	0.010	0.015	4.90	0.217	0.098
Toowoomba Region Basalts	20th	66	16	7	180	88	3.4	0.5	660	7.5	150	20	0.10	0.000	0.00	0.005	0.01	1.30	0.087	0.000
	50th	97	52	59	350	184	10.0	5.0	1,200	7.9	291	34	0.20	0.020	0.01	0.005	0.015	2.20	1.054	0.000
	80th	147	100	116	530	356	22.0	33.0	1,750	8.2	443	47	0.30	0.050	0.02	0.025	0.015	6.20	7.391	0.000

Groundwater unit	Percentile	Sodium (Na)	Calcium (Ca)	Magnesium (Mg)	Bicarbonate (HCO_3)	Chloride (Cl)	Sulphate (SO_4)	Nitrate (NO_3)	EC	pH	Alkalinity	Silicon Dioxide (SiO_2)	Fluoride (F)	Iron (Fe)	Manganese (Mn)	Zinc (Zn)	Copper (Cu)	SAR	Total N	Total P
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Meq/L	mg/L	mg/L
South East Walloons	20th	121	9	4	300	101	3.4	0.0	880	7.7	251	12	0.10	0.000	0.00	0.000	0.000	2.90	0.000	0.000
	50th	225	39	27	455	236	13.0	1.0	1,500	8.0	390	17	0.27	0.010	0.01	0.010	0.010	8.10	0.217	0.000
	80th	425	89	89	662	560	46.2	6.0	2,550	8.4	562	30	0.50	0.060	0.02	0.148	0.025	17.89	1.324	0.033

Table notes:
In some instances, values have been rounded for consistent presentation of decimal places for each parameter
ID = insufficient data
EC = electrical conductance
SAR = sodium adsorption ratio
Total N = total nitrogen
Total P = total phosphorus

Source: Healthy Waters Management Plan: Queensland Border Rivers and Moonie River Basins (DES, 2019a) and Healthy Waters Management Plan: Queensland Condamine River Basins (DES, 2019b)

13.7 Potential impacts

Potential impacts are discussed in two aspects—groundwater resources and groundwater quality—for each stage of the Project in the subsections below. Further detail is presented in Appendix R: Groundwater Technical Report.

13.7.1 Conceptual hydrogeological model

Key aspects of the hydrogeological regime within the impact assessment area are summarised below, and a conceptual understanding of the hydrogeological regimes within the impact assessment area are presented on Figure 13.24 and Figure 13.25. Conceptualisation is divided broadly into two sections of the Project:

- Ch 30.60 km (NS2B)—Ch 117.0 km: characterised by the Surat Basin consolidated strata and overlying Cainozoic unconsolidated sediments of the Border Rivers Alluvium
- Ch 117.0 km—Ch 206.9 km: characterised by the Clarence–Moreton consolidated strata and overlying Cainozoic MRV and unconsolidated sediments of the Condamine Alluvium.

The groundwater conceptualisations are a representation of the groundwater systems that incorporate an interpretation of the geological and hydrogeological conditions. Further, the conceptualisations consolidate the current understanding of the key processes of each groundwater system, including the influence of stresses, to assist in the understanding of potential changes/impacts on the systems as a result of the Project.

Additional detailed discussion of the conceptual hydrogeological model is included in Appendix R: Groundwater Technical Report.

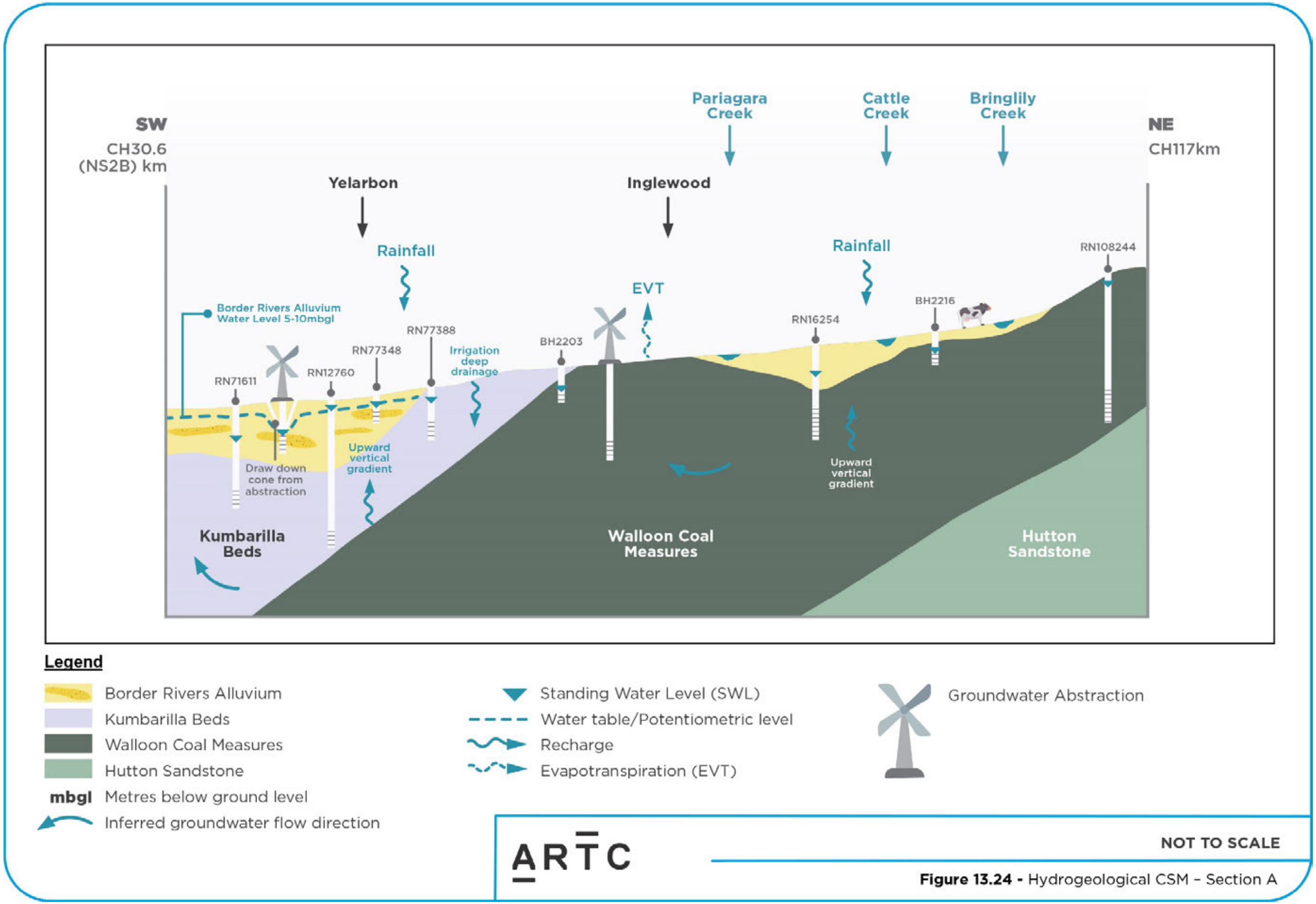

Figure 13.24 - Hydrogeological CSM – Section A

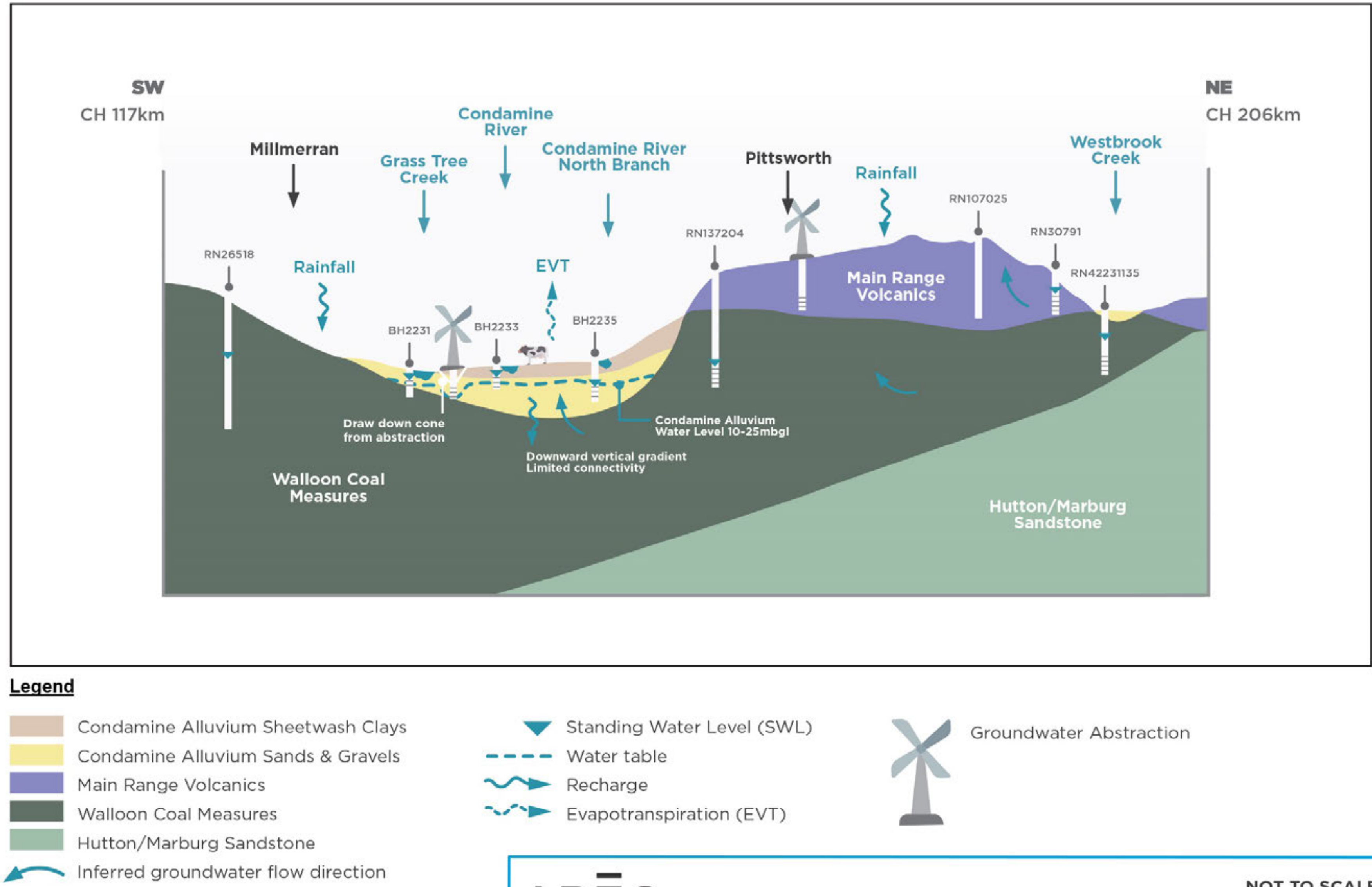

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Figure 13.25 Hydrogeological CSM – Section B

13.7.2 Predictive modelling

Predictive modelling was undertaken to evaluate the extent of potential drawdown and estimate potential seepage rates for deep cuts (> 10 m) required to achieve the vertical rail alignment of the Project. Details of the construction methodology, conceptual models, assumptions, and numerical modelling aspects are summarised below.

Additional details for all aspects of this discussion are provided in Appendix R: Groundwater Technical Report.

13.7.2.1 Approach

Numerical predictive models have been developed to support the hydrogeological design and assessment of impacts for the Project. These local-scale groundwater models were developed as 2-D cross-sectional models oriented perpendicular to the Project alignment. The primary objectives of the predictive modelling were to:

- Assess potential groundwater drawdown due to drainage of cuts
- Estimate groundwater seepage rates for cuts
- Assess groundwater quality parameters to inform reference design for earthworks and cuts.

Five indicative cuts along the Project alignment were identified as best representing the local geological conditions and worst-case potential impacts on groundwater resources (deepest cuts into each stratigraphy). The indicative cuts that were subject to 2-D modelling are listed in Table 13.11. These indicative cuts were subsequently modelled to evaluate potential extent of drawdown, changes to flow regime and to estimate potential seepage rates.

The vertical rail alignment and the earthworks design for the Project will continue to be developed and refined through the detail design process. This may result in modifications to the location and dimensions (depth, width and length) of cuts that are currently included in the reference design and have been subject to predictive numerical modelling. Consequently, revised 2-D modelling of deep cuts will be required through the detail design process to confirm potential drawdown and seepage rates, and ensure that appropriate controls are included in the design.

TABLE 13.11 CUTS SELECTED FOR PREDICTIVE MODELLING

Cut ID	Model section, chainage (km)	Reason for selection	Closest watercourse/water bore	Cut length (m)
310–C08	Ch 57.67	Deepest cut in C1–Jw (XW) model ground	Non-perennial Macintyre Brook to the southeast (1,400 m). Nearest registered bore is BH2308 (1,710 m).	3,450
310–C25	Ch 114.46	Deepest cut in C2–Qs/Jw (XW) model ground	Non-perennial tributary of Nicol Creek to the south (230 m). Nearest registered bore is BH2323 (460 m).	380
310–C31	Ch 164.60	Deepest cut in C3–1–Jw model ground, with the most significant variation in topography	Non-perennial tributary of Condamine River (North Branch) (320 m). Nearest registered bore is BH2337 (535 m).	1,680
310–C37	Ch 174.52	Deepest cut in C3–3–Tm model ground	Perrier Gully Tributary (560 m). Nearest registered bore is RN19886 (360 m).	2,290
310–C44	Ch 188.91	Deepest cut in C3–5–Tm model ground	Non-perennial tributary of Westbrook Creek to the north (355 m). Nearest registered bore is BH2345 (42 m).	1,500

The five models were set up to represent the range of hydrogeological conditions that may be encountered during construction and operation of the Project. A summary of the modelled cut locations and the corresponding design details is presented in Table 13.12.

TABLE 13.12 SUMMARY OF NUMERICAL MODELS/LOCATIONS WHERE CUTS MAY ENCOUNTER GROUNDWATER

Cut ID	Model section, chainage (km)	Median centreline elevation along cut (m AHD)	Cut depth (mbgl)	Median groundwater elevation at cut (m AHD)	Estimated depth of cut below the median groundwater elevation (m)
310–C08	Ch 57.67 km	314.3	17.4	309.7	12.8
310–C25	Ch 114.46 km	451.3	15.4	436.6	0.7
310–C31	Ch 164.60 km	474.0	29.5	454.3	9.8
310–C37	Ch 174.52 km	548.1	29.7	541.9	23.5
310–C44	Ch 188.91 km	509.3	26.4	505.5	22.6

Each model was developed to consist of between three to four geologic/hydrogeologic layers, depending on the in-situ profile, in order to simulate drawdown/seepage between stratigraphic units. The SEEP/W finite element software package was used to construct the predictive models to estimate steady state and upper level (conservative) inflows to deep cuts and the resulting drawdown impacts from excavations. An example cross-sectional output from a 2-D SEEP/W model in presented in Figure 13.26.

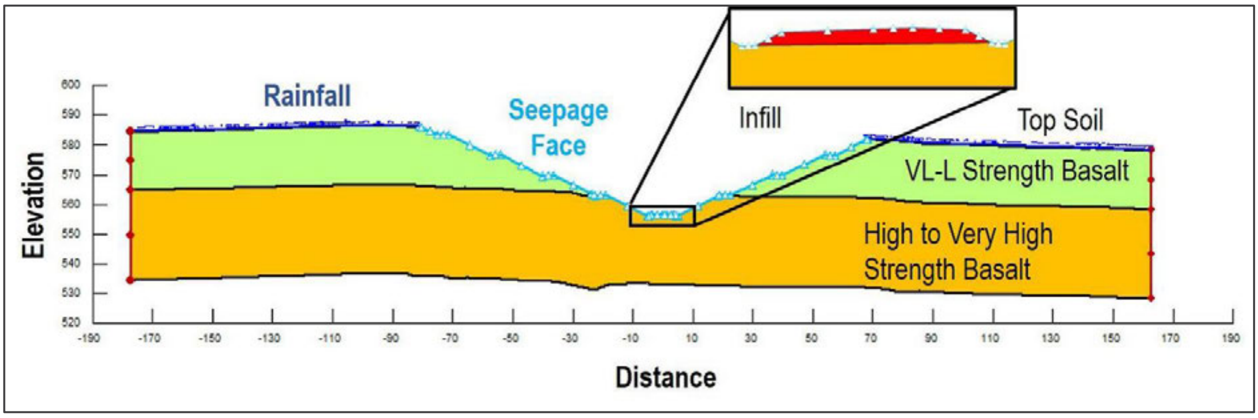


FIGURE 13.26 EXAMPLE OF CROSS-SECTIONAL OUTPUT FROM A 2-D SEEP/W MODEL

There are inherent uncertainties in the adoption of any numerical modelling method, as the process involves development of a simplified representation of a real system. Sensitivity analysis was incorporated into the methodology to account for potential uncertainties in the 2-D modelling, such as heterogenous geological conditions, variable aquifer characteristics (as encountered in the alluvium and MRV) and paucity of location-specific data. Due to these known uncertainties, the numerical models are considered to be Class 1 (Barnett et al., 2012), which is defined as having a high degree of uncertainty; however, the numerical simulations undertaken for this assessment are considered to be suitable for developing coarse relationships between groundwater extraction locations and rates and associated impacts (Barnett et al., 2012).

The predictions generated by numerical models are not unique and multiple combinations of setups and parameters can achieve reasonable sensitivities when calibration data is limited. Sensitivity analysis was performed to compare model outputs with different sets of reasonable parameter estimates to allow for more accurate predictions. Sensitivity analysis also tested the robustness of the model to changes in parameters. The various parameters were adjusted during the sensitivity testing until the simulated groundwater levels best aligned with data obtained from published sources as well as that obtained from Project hydrogeological investigations. The sensitivity analysis provided for greater accuracy in the output model predictions and for some of the uncertainty in numeric modelling to be negated.

The numerical models developed are considered an initial assessment of the Project on groundwater resources. Revised 2-D modelling of deep cuts will be required through the detail design process to confirm potential drawdown and seepage rates and ensure that appropriate controls are included in the design.

13.7.2.2 Seepage estimates

Seepage rate estimates were obtained for the entire length of each cut, through the multiplication of modelled seepage rates by the total length of cut, as specified in Table 13.11. The modelled geology and cut geometry for each section modelled have been extrapolated across the entirety of each cut such that calculated seepage rates are considered to be conservative estimates.

The estimated seepage results are presented in Table 13.13.

TABLE 13.13 PREDICTIVE MODELLING RESULTS—SEEPAGE ESTIMATES

Cut ID	Model section, chainage (km)	Cut length (m)	Cut depth (mbgl)	Expected seepage for entire cut (m^3/year)	Upper range seepage for entire cut (m^3/year)
310–C08	Ch 57.67	3,450	17.4	1,750	11,100
310–C25	Ch 114.46	380	15.4	30	280
310–C31	Ch 164.60	1,680	29.5	260	740
310–C37	Ch 174.52	2,290	29.7	7,100	105,000
310–C44	Ch 188.91	1,500	26.4	1,870	17,500

Predictive simulations indicate:

- Seepage is concentrated at the bottom of the cuts, on both sides of infill material
- Initial inflow of seepage will be higher than the average rate predicted for steady state scenarios, then will plateau
- Seepage values simulated are considered to be low and attributed to the low K values applied, based on an average of site-specific data
- Temporary increases in seepage may be observed in cuts with sandy soil or weathered sandstone following rainfall events
- Seepage of groundwater from bedrock is anticipated to be low except where enhanced by weathering of fractures.

It is anticipated that seepage water, in general, will evaporate due to local climate conditions and relatively small volumes when considered with the length of the cuts. Cut 310–C37 is predicted to encounter seepage volumes of 7,100 m^3/year to 105,000 m^3/year, which equates to rates of 0.23 L/s and 3.3 L/s across the entire surface of a 2.29 km cut, to 29.7 m depth. Such a large estimated range is expected to be refined during detail design when additional site-specific hydrogeological data is combined with the finalised design for model re-calibration and re-run of predictive simulations.

13.7.2.3 Drawdown estimates

Modelling results indicate that drawdown is only expected to occur at three of the five modelled locations. In these locations, there are no registered bores located outside of the Project footprint that are also within the extent of predicted drawdown. At the locations where drawdown is anticipated to occur, the maximum extent of drawdown is predicted to range from 15 m to 80 m from the centre of the Project alignment.

Table 13.14 presents the predicted drawdown results where the range in drawdown extent represents the upper value steady state results.

TABLE 13.14 PREDICTED DRAWDOWN VALUES AT MODELLED CUTS

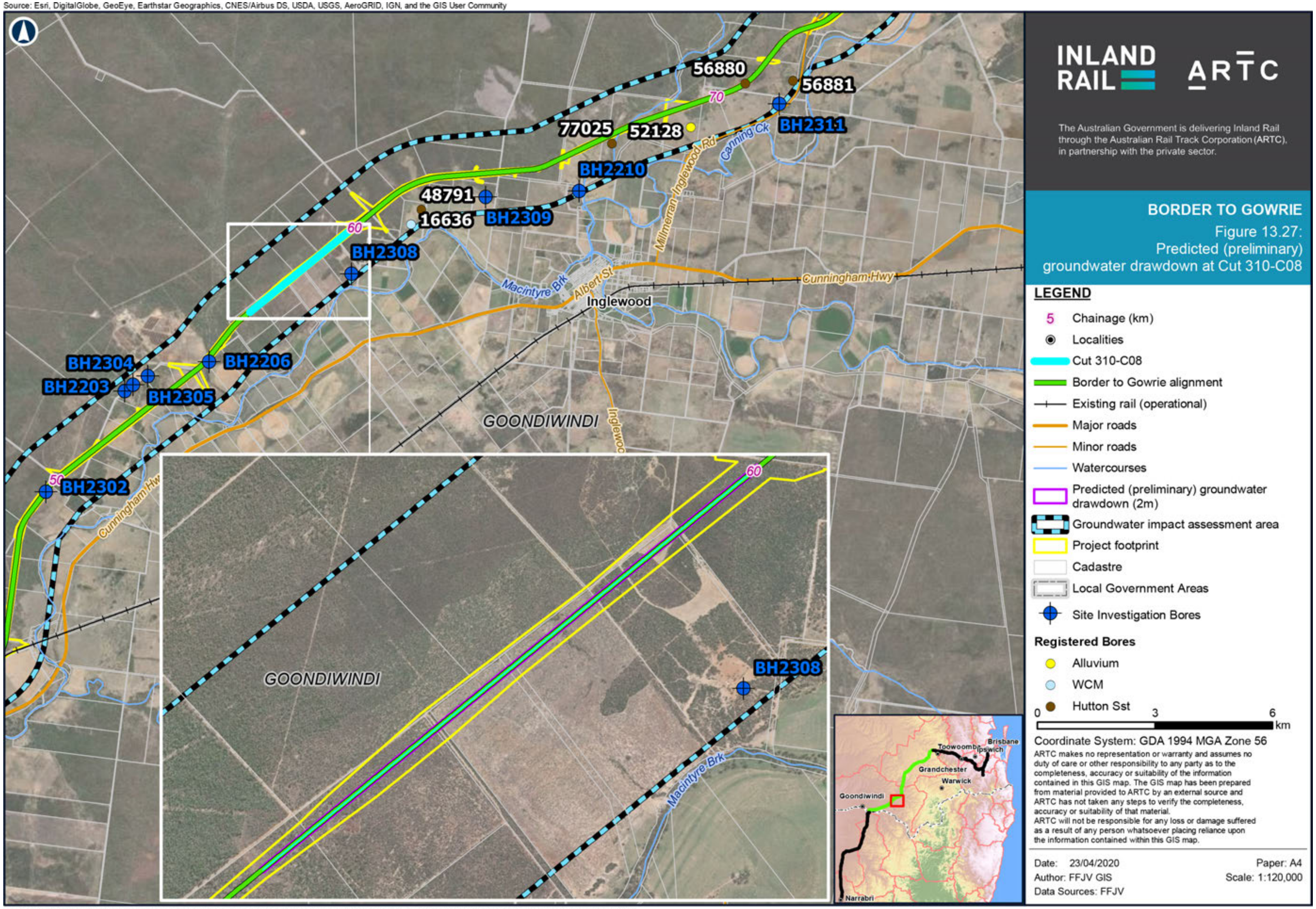
Environment and science	Model section, chainage (km)	Estimated drawdown at rail centreline (m)	Extent of drawdown from centreline (m)	Drawdown threshold applied (m)[1]
310–C08	Ch 57.67	3.7	Up to 15	2
310–C25	Ch 114.46	<1.0	N/A	N/A
310–C31	Ch 164.60	<1.0	N/A	N/A
310–C37	Ch 174.52	12.2	Up to 60	5
310–C44	Ch 188.91	11.7	Up to 80	5

Table note:

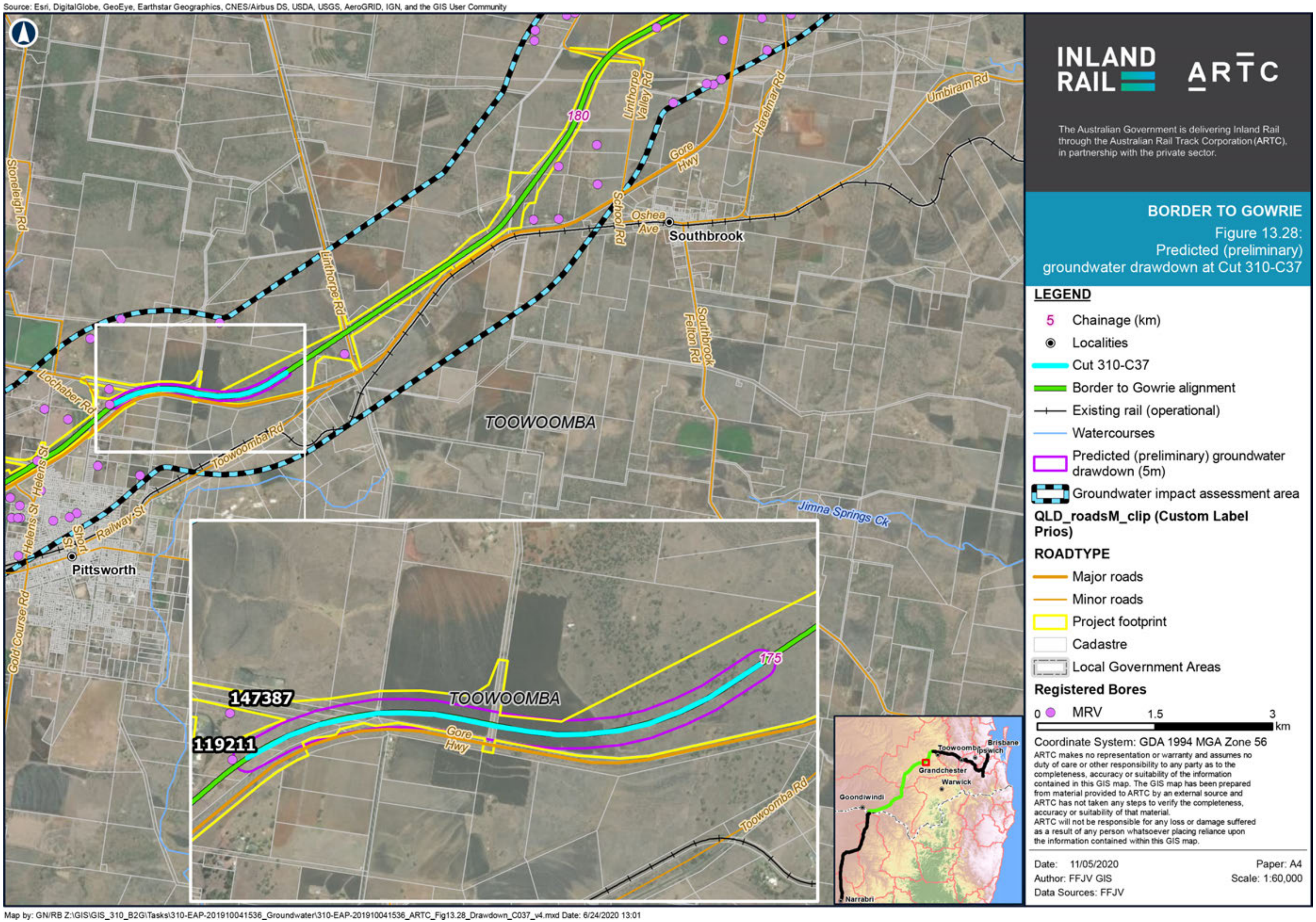
1 Drawdown thresholds of 2 m and 5 m are from the Guideline: Baseline assessment guideline (ESR/2016/1999) (DES, 2017f)

The predicted extent of drawdown at cuts 310–C08, 310–C037 and 310–C44 are shown in Figure 13.27, Figure 13.28 and Figure 13.29, respectively.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_ARTC_Fig13.27_Drawdown_C08_v3.mxd Date: 6/24/2020 12:17


Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
INLAND RAIL
ARTC
The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.
BORDER TO GOWRIE
Figure 13.28: Predicted (preliminary) groundwater drawdown at Cut 310-C37
LEGEND
5 Chainage (km)
Localities
Cut 310-C37
Border to Gowrie alignment
Existing rail (operational)
Watercourses
Predicted (preliminary) groundwater drawdown (5m)
Groundwater impact assessment area
QLD_roadsM_clip (Custom Label Prios)
ROADTYPE
Major roads
Minor roads
Project footprint
Cadastre
Local Government Areas
Registered Bores
MRV
0 1.5 3 km
Coordinate System: GDA 1994 MGA Zone 56
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Date: 11/05/2020
Author: FFJV GIS
Data Sources: FFJV
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Linthorpe Rd
School Rd
Oshea Ave
Harelmar Rd
Southbrook Felton Rd
Stoneleigh Rd
Lochaber Rd
Helens St
Short St
Railway St
Gold Course Rd
Jimna Springs Ck
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Grandchester
Warwick
Goondiwindi
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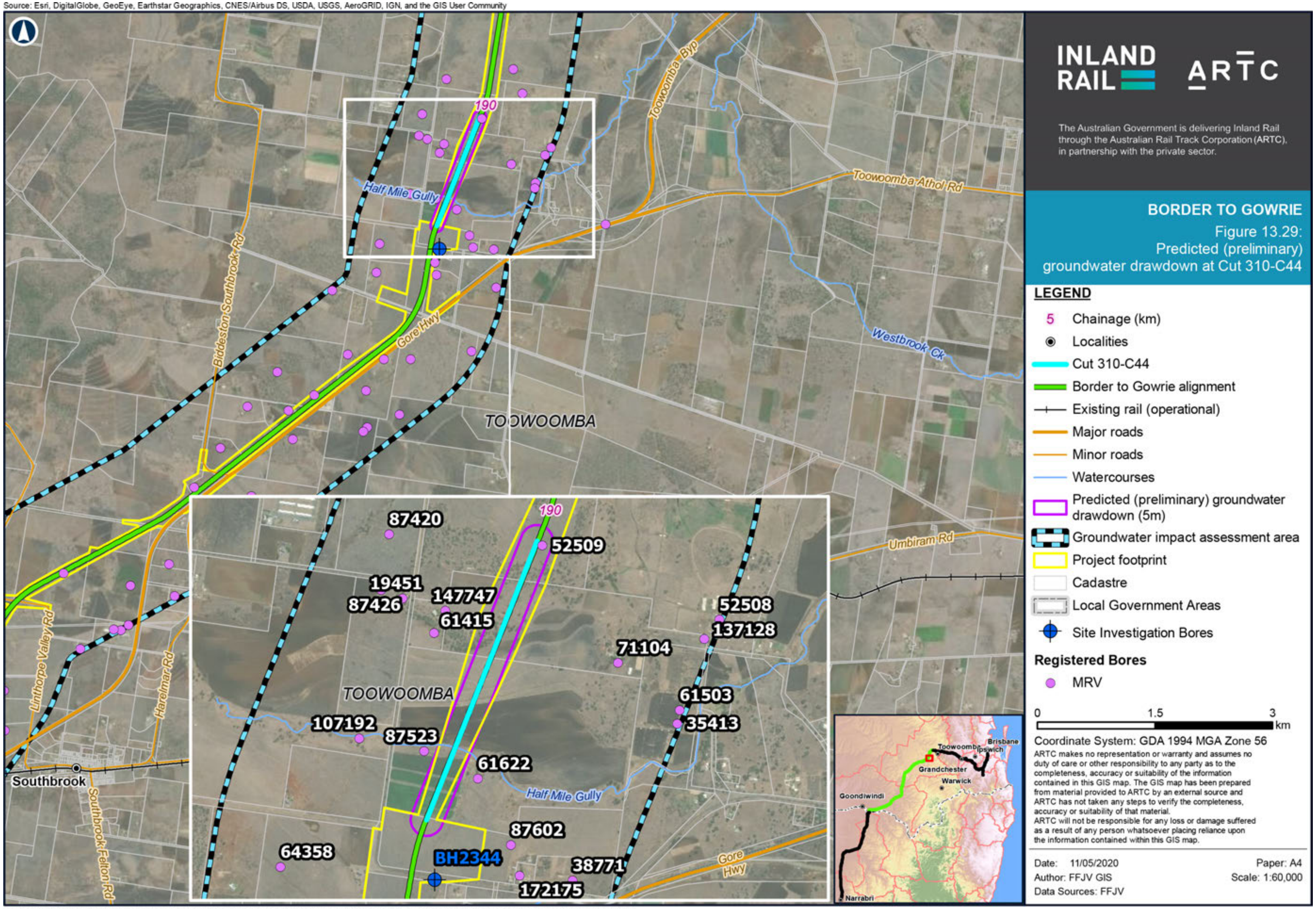
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



BORDER TO GOWRIE

Figure 13.29: Predicted (preliminary) groundwater drawdown at Cut 310-C44

Map by: GN/RB Z:\GIS\GIS_310_B2G\Tasks\310-EAP-201910041536_Groundwater\310-EAP-201910041536_ARTC_Fig13.29_Drawdown_C44_v4.mxd Date: 6/24/2020 12:39

13.7.3 Construction

Construction for the Project includes several activities that have the potential to impact on groundwater resources. These activities include site preparation, bulk earthworks (cut-and-fill sections), drainage construction, haul road and access track construction, bridge pilings and the excavation of borrow pits for construction materials.

Table 13.15 presents the potential impacts on groundwater as a result of the construction-phase activities for the Project.

TABLE 13.15 POTENTIAL CONSTRUCTION IMPACTS ON GROUNDWATER

Impacting process	Potential impacts	Likelihood of impact
Groundwater resources		
Site clearing and grading	Removal of vegetation reducing evapotranspiration, which can influence the groundwater discharge of shallow aquifers (i.e. result in higher groundwater levels). EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.	The Project footprint has been delineated to include the minimum extent of land required to safely and efficiently construct and operate the Project. The Project alignment has also been aligned to maximise the use of existing rail corridor, where possible. As a result, approximately one third of the total Project alignment is located in existing rail corridor. The total area proposed to be cleared and graded for construction purposes is considered to be negligible in comparison to the total recharge surface area of the alluvial aquifers that underlay the Project. Consequently, there is likely to be little impact on the groundwater resources due to site clearing and grading activities
	Compaction of ground resulting in reduced groundwater recharge. EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.	
	Alteration of possible existing areas where ponding surface water occurs naturally, which could reduce groundwater recharge in these areas. EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.	
Loss or damage to existing groundwater bores, including impaired access	Existing groundwater bores within the Project footprint are likely to be decommissioned to enable construction and operation of the Project. Groundwater bores that are not decommissioned may be damaged or become inaccessible due to temporary or permanent Project activities. EVs with potential to be impacted: irrigation, stock water, farm supply/use, and drinking water.	Thirty registered bores are located within the Project footprint. It is anticipated that each of these registered bores, in addition to any unregistered bores within the Project footprint, will need to be decommissioned to enable construction of the Project. Decommissioning of bores will be in accordance with the *Minimum Construction Requirements for Water Bores in Australia* (Edition 3) (National Uniform Drillers Licensing Committee, 2012). During the detail design phase, landowners affected by the Project will be consulted to confirm the location of registered bores and to establish the presence of any unregistered bores within the Project footprint. Where a groundwater bore is expected to be decommissioned or have access to it impaired as a result of the Project, 'make good' measures will be agreed in consultation with the affected landowner. Such measures may include the provision of an alternate water supply/new bore (most likely outcome for private bores within Project footprint).

Impacting process	Potential impacts	Likelihood of impact
Drawdown due to seepage	Drawdown of localised groundwater levels may occur as a result of seepage from the exposed face of cuts that intersect the underlying groundwater table. This drawdown has the potential to temporarily affect the availability of groundwater from registered bores in proximity to the works, which are not otherwise decommissioned by the Project. Drawdown also has potential to affect GDEs within the radius of impact. EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.	As discussed in Section 13.7.1, predictive modelling results indicate that drawdown of the water table may be experienced at three deep cuts (i.e. C08, C37, and C44) as a result of seepage (refer Table 13.14). There are no registered bores located outside of the Project footprint that are also within the extent of predicted drawdown. Where the productivity of an established bore is identified as being impacted by Project activities, 'make good' measures will be agreed in consultation with the affected landowner. Such measures may include: ‣ Changing the bore pump so that it is better suited to the decreased water level in the bore ‣ Deepening the bore to allow it to intersect a deeper part of the aquifer ‣ Reconditioning of the water bore to improve its hydraulic efficiency ‣ Increased monitoring of the bore water levels and efficiency to provide a level of confidence to the landowner that the impacts are being effectively managed. Seepage from the faces of cuts will be minimised via the application of engineering controls. For example, the reference design has allowed for the application of a 300 mm drainage blanket to be applied to the face of all cuts where groundwater is encountered within 2 m of the base of the cutting. Alternative seepage control measures will be considered and assessed through the detail design, on a cut-by-cut basis.
	Subsidence/settlement of compressible substrates and possible damage to adjacent structures, such as embankments, culverts and utilities. EVs with potential to be impacted: aquatic and terrestrial ecosystems.	Deep cuts, in which the water table is expected to be encountered, are located within competent substrate, such as basalt and sandstone, where the likelihood of settlement is less probable than in unconsolidated substrates.
Construction of new fill embankments	Establishment of new embankments may cause the obstruction of natural drainage pathways, resulting in more frequent inundation of areas upstream of the embankments. This more frequent inundation could result in groundwater mounds forming underneath these areas. Groundwater mounding may also result from the compacting of soils following the addition of embankment soils. In addition, groundwater depressions may form in areas that formerly received recharge (i.e. down gradient of the emplaced embankments). EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.	There are 77 embankment sections (fill) in the reference design. The subgrade beneath these embankments is primarily Cainozoic Alluvium and MRV, with some overlaying the WCM. The depth to groundwater is typically over 5 m for the Border Rivers and Condamine Alluvium and WCM, with the risk of mounding considered to be generally low in this substrate. Where embankments are located on the MRV, groundwater mounding is generally only possible in areas where the fractured rocks are hydraulically connected to flooded alluvial units or outcrops in flooded areas. Appendix R: Groundwater Technical Report provides further discussion in regard to groundwater level variation with respect to embankments.

Impacting process	Potential impacts	Likelihood of impact
Establishment of borrow pits	Temporary borrow pits may be established as a source of material for construction of the Project. Subject to their location, shallow groundwater may be intersected during the development of borrows pits, particularly if depths of greater than 5 mbgl are required. These localised interactions with the water table could impact on the hydraulic regime (i.e. disrupt groundwater flow or induce drawdown). EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.	Twelve potential/existing borrow pit locations have been identified. More detailed feasibility assessments of each borrow pit location will be undertaken during the detail design phase of the Project (post-EIS) to determine material usability, volumes, environmental and social impacts (including groundwater). Following assessment, locations where groundwater is identified as likely to be intersected will be considered less viable than borrow pit locations where groundwater is unlikely to be intersected.
Construction water supply	Potential impacts to groundwater elevations may occur where bore water is sourced to supply water for construction activities. EVs with potential to be impacted: Irrigation, stock water, farm supply/use, drinking water.	Commercial and private land uses in the region have a strong reliance on access to groundwater for domestic and agricultural purposes. This reliance on groundwater as a resource is even stronger during periods of drought, as is currently being experienced. Information from the Queensland Water Entitlements Database (DNRME, 2018b) and consultation feedback from DNRME indicates that the alluvium and Main Range Volcanics aquifer units in the area are close to full allocation through existing water entitlements (refer Section 13.6.5). The use of groundwater to supplement the construction water demand for the Project is not preferable due to: ▸ The existing pressure placed on groundwater as a resource in the region ▸ The licensing and approval requirements to establish new groundwater bores ▸ The flow rates required to meet construction water demands are unlikely to be appropriately met through reliance on groundwater ▸ Challenges regarding the management of groundwater quality. The use of existing sustainable groundwater allocated entitlements to supplement the construction demand for the Project may be considered if private owners of registered bores have capacity under their water entitlement that they wish to sell to ARTC or the principal contractor under private agreement. Therefore, the volumes extracted would be within the existing licensing limits and the extent of drawdown experienced would be localised and consistent with that which is currently permissible for each licensed bore. Domestic needs will be prioritised above construction water supply and existing sustainable allocated water entitlements will be sourced where possible.

Impacting process	Potential impacts	Likelihood of impact
Construction water supply (continued)		The alluvial and MRV aquifers within the impact assessment area are currently near or overallocated; therefore, it is unlikely that a temporary water permit would be issued for the additional take of water from these units. In the instance a temporary water permit is warranted during construction, the licensed extraction volume would 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.
Dewatering	Temporary excavations during construction (i.e. trenching, boring for piles, etc.) may encounter groundwater. In these instances, it may be necessary to extract the water from the excavation in order to maintain structural integrity of the excavation and to enable safe establishment of the planned infrastructure. Piling for the establishment of bridge piers can cause alteration of aquifer parameters (lower permeability), altered groundwater flow patterns (mounding or drawdown up and down gradient of the piles; upward leakage along the pile/soil interface) and reduction in groundwater resources through extraction of wet soil/rock during piling. EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.	If dewatering is required in support of construction activities, the duration of the impacts is likely to be temporary as the construction works are limited in duration. Impact is not anticipated to extend long after construction works are completed, if at all, dependant on the localised recharge of the affected aquifer unit.
Alterations of existing groundwater flow pathways due to new infrastructure or modified landform	Deep cuttings could create voids that intersect shallow groundwater and perturb the antecedent groundwater flow regime. Piles or other structures spaced closely together have potential to influence the natural groundwater flow regime. Reduced permeability of the substrate beneath embankments may modify the flow direction of shallow groundwater in portions of the alluvium and possibly the saturated portion of weathered bedrock. EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.	It is possible for the antecedent groundwater flow regime to be interrupted to deep cut locations, particularly at C08, C37, and C44; however, the length of the cuts in comparison to the overall aquifer is negligible. Further, C37 and C44 are predicted to intersect the MRV aquifer, which, due to the fractured nature of this aquifer, is unlikely to be impacted outside of the localised area to the cuts. The foundation pilings associated with bridges for this Project will be spaced a distance apart, to be of sufficient spacing and diameter to avoid impacts on existing groundwater flow. The distance/spacing is cut/bridge-specific and will be finalised during the detail design phase.

Impacting process	Potential impacts	Likelihood of impact
Groundwater quality		
Contamination /accidental discharge	Contamination of groundwater may arise as a result of: - Unintended spills and leaks of hydrocarbons (i.e. oils, fuels and lubricants) and other chemicals related to the use of heavy plant and equipment (accidental discharge) - Water mixtures and emulsions related to washdown areas (accidental discharge) - Upward seepage along piles/soil interfaces of saltier groundwater from the deeper confined aquifers into the fresher alluvium aquifers - Groundwater bores installed for environmental monitoring or water supplies have the potential to create a vertical pathway between aquifers if not installed correctly or if the bores deteriorate due to abandonment. EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.	Direct infiltration of contaminants in areas of low relief with shallow water levels is likely to be reduced due to the dominant fine-grained sediments of the soil profile (clays and silts). The ephemeral nature of the majority of surface water bodies along the Project is also likely to reduce the chance of contaminants in surface water infiltrating into shallow aquifers during dry months. If used in sufficient volume, water applied during the construction phase of the Project has the potential to infiltrate past the root zone and contribute to rising water tables/levels in shallow aquifers. Leakage (accidental discharge) from water storage areas may also contribute to rising water levels. Refer to Chapter 8: Land Resources for additional details.
Acid rock drainage (ARD) or potential acid sulphate soils (PASS)	Intersection of sulphide-bearing rocks in cuts or use of sulphide-bearing materials in embankment fill could present an ARD risk following exposure of the rocks to oxygen and subsequent runoff (leachate), which could impact on EVs (i.e. aquatic GDEs and groundwater users). Rainfall infiltration into cuttings with sulphide-bearing minerals above the saturated zone may also pose an ARD (leachate) risk even if the entire cut is in the unsaturated zone (above groundwater). PASS also present a risk though excavation of cuts in soils susceptible to acid-forming conditions, which can then result in leached conditions entering the environment. EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.	Geology within the Project footprint indicates a potential for the Kumbarilla Beds and WCM to host disseminated sulphide minerals (i.e. pyrite), particularly within shale and mudstone units. Given that cuts will primarily be into the weathered to extremely weathered units portions of the Kumbarilla Beds and WCM, the risk could be naturally mitigated as sulphides minerals may have already been oxidised. Unweathered areas of the Kumbarilla Beds and WCM will be avoided, where possible, through the detail design phase. Refer to Chapter 8: Land Resources for additional details.

13.7.4 Operation

This section provides a discussion of the potential impacts on groundwater resources and related EVs as a result of operation of the Project.

TABLE 13.16 POTENTIAL IMPACTS OF OPERATION

Impacting process	Potential impacts	Discussion of potential impacts
Groundwater resources		
Loss or damage to existing groundwater bores, including impaired access	Long-term access restrictions to existing landowner bores due to the severance of properties. EVs with potential to be impacted: irrigation, stock water, farm supply/use, and drinking water.	During the detail design phase, landowners affected by the Project will be consulted to confirm the location of registered bores and to establish the presence of any unregistered bores within the Project footprint. Where possible, the detail design will be developed to provide continued access to private infrastructure, including groundwater bores, across the rail corridor. Where a groundwater bore is expected to have access to it impaired as result of the Project, 'make good' measures will be agreed in consultation with the affected landowner. Such measures may include the provision of an alternate water supply/new bore (most likely outcome for private bores within Project footprint).
Embankments	Mounding of groundwater levels may result due to long-term surface loading of alluvial soils from embankments and other construction activities along the Project alignment where groundwater is shallow. Possible areas for compressible alluvial soils include localised portions of Macintyre Brook, Canning Creek, and Condamine River floodplains associated with abandoned river channels and tributaries. EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.	Impacts will be localised due to the linear nature of the Project and the typical depth to groundwater, based on available information, being greater than 5 mbgl in the alluvium.
Maintenance works (operation) water supply	The Project's operational water requirements are anticipated to be minor relative to the construction-phase requirements. Water may be required to support localised maintenance activities, such as high-pressure cleaning of culverts. The volumes required will be dependent on the specific activities and frequency of undertaking, and therefore cannot be quantified at this stage of the Project. Maintenance works are not expected to be reliant on groundwater for the sourcing of water.	An assessment of the suitability of each source will need to be made for each maintenance activity requiring water, based on the following considerations: - Legal access - Volumetric requirement for the activity - Water quality requirement for the activity - Source location relative to the location of need.
Drawdown due to seepage	Predictive numerical modelling indicates that long-term seepage may occur at cut location C08, C37, and C44.	As discussed in Section 13.7.1, predictive modelling results indicate that three deep cuts (i.e. C08, C37, and C44) are estimated to result in seepage, which may cause lowering of the water table in these areas (refer Table 13.14). There are no registered bores located outside of the Project footprint that are also within the extent of predicted drawdown.

Impacting process	Potential impacts	Discussion of potential impacts
Drawdown due to seepage (continued)		Seepage from the faces of cuts will be minimised via the application of engineering controls. For example, the reference design has allowed for the application of a 300 mm drainage blanket to be applied to the face of all cuts where groundwater is encountered within 2 m of the base of the cutting. Alternative seepage control measures will be considered and assessed through the detail design, on a cut-by-cut basis.
Dewatering	Temporary excavations during maintenance of infrastructure (e.g. trenching) may encounter groundwater. In these instances, it may be necessary to extract the water from the excavation in order to maintain structural integrity of the excavation and to enable safe establishment of the planned infrastructure. EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, and cultural and spiritual values.	If dewatering is required in support of maintenance activities, the duration of the impacts is likely to be temporary. Impact is not anticipated to extend long after the maintenance works are completed, if at all, dependant on the localised recharge of the affected aquifer unit.
Alterations of existing groundwater flow pathways due to new infrastructure or modified landform	Long-term impacts on groundwater flow are not anticipated given the spacing of the pilings for the rail alignment.	Localised impacts may occur in the vicinity of the three deep cuts predicted to have long-term seepage; however, due to the limited cut extent when compared to the overall aquifer, it is expected the groundwater flow regime will re-equilibrate to the cuts constructed in/through unconsolidated sediments. Flow within the fractured MRV are expected to be limited to the cut and immediate vicinity.
Groundwater quality		
Contamination	Contamination of groundwater may arise as a result of unintended spills and leaks of hydrocarbons (oils, fuels and lubricants) and other chemicals related to maintenance activities (accidental discharge) or rail incidents (e.g. loss of load). EVs with potential to be impacted: aquatic and terrestrial ecosystems, irrigation, stock water, farm supply/use, drinking water, cultural and spiritual values.	In the instance a spill, leak or any accidental discharge occurs during normal operation activities, the impact is likely to be superficial in nature and not expected to impact on shallow aquifers. Maintenance crews and emergency response teams will be equipped with spill kits and environmental response equipment to intercept spills and leaks and prevent such incidents from impacting groundwater.

13.7.5 Summary

The majority of potential impacts related to groundwater are considered temporary in nature and primarily associated with the construction phase of the Project. Impacts that may occur through the operation phase are, in most instances, an extension of issues that will initially arise through the construction phase of the Project.

Final construction design, engineering controls and monitoring are generally considered to be adequate to mitigate potential impacts to groundwater. In the few locations where construction activities have the potential to intersect shallow groundwater, construction techniques have been identified for the Project such that impacts will be appropriately mitigated and managed through the adopted engineering controls. Where impacts to groundwater infrastructure cannot be avoided (e.g. decommissioning of bores or loss of access), 'make good' measures will be agreed in consultation with the affected landowner. Such measures may include the provision of an alternate water supply/new bore.

13.8 Mitigation measures

This section provides discussion of mitigation measures and controls that have been incorporated into the reference design development process, as appropriate and where possible (refer Section 13.8.1), as well as those measures that are proposed to be adopted for future phases of Project delivery (refer Section 13.8.2 and Section 13.8.3).

13.8.1 Mitigation through the reference design phase

Development of the reference design for the Project has progressed in parallel with the impact assessment process. As a result, design solutions for avoiding, minimising or mitigating impacts have been incorporated into the reference design as appropriate and where possible.

Mitigation measures and controls that have been factored into the design, or otherwise implemented during the reference design phase for the Project, are summarised in Table 13.17.

TABLE 13.17 INITIAL MITIGATION MEASURES OF RELEVANCE TO GROUNDWATER

Aspect	Initial mitigation measures

Groundwater resources	▸ The Project uses the existing South Western Line and Millmerran Branch Line rail corridors as much as possible (71.2 km), thereby minimising the need to develop land and impact on water resources that have not previously been subject to disturbance for transport infrastructure purposes
	▸ Geotechnical and groundwater investigations have been undertaken within the Project footprint to determine geotechnical conditions. Investigations have been targeted to specific locations, such as:
	  ▸ Locations of bridge abutments
	  ▸ Locations of significant cuts
	  ▸ Locations of significant fill.
	▸ Geotechnical and groundwater field data has been used to derive design criteria for structures and rail formation. This has enabled the Project to be designed to cater for field-verified geotechnical and groundwater conditions.
	▸ Design and ratings of earthworks in support of culverts, viaducts, and bridges are in accordance with *AS 5100 Bridge Design* (Standards Australia, 2017b) and *AS/RISSB 7636 Railway Structures* (Standards Australia, 2013b) and other applicable Australian Standards
	▸ The reference design has allowed for the application of a 300 mm drainage blanket to be applied to the face of all cuts where groundwater is encountered within 2 m of the base of the cutting. Alternative seepage control measures will be considered and assessed through the detail design, on a cut-by-cut basis.
	▸ The reference design has been developed to achieve as close to a net balance in earthworks as is practicable, thereby reducing the potential to impact water resources (e.g. dewatering of cuttings and embankment placement). For the most part, this has been achieved through:
	  ▸ Aligning the Project to avoid, where possible, steep terrain and topographical constraints to minimise earthworks and provide for more efficient track geometry and grade
	  ▸ Considering the shape and size of batters to encourage cut-and-fill balancing
	  ▸ Optimising the number, width and depth of cuts to avoid the generation of material that would be considered surplus to Project requirements.

Groundwater quality	▸ The Project footprint has been minimised to that required to safely and efficiently construct and operate the Project, thereby minimising the spatial opportunity for Project activities to interface with groundwater ▸ Groundwater sampling was conducted on all 30 monitoring bores installed for the Project for the collection of baseline water quality, durability, and salinity parameters. This data has been used to establish design criteria for structures and rail formation.

13.8.2 Proposed mitigation measures

In order to manage and mitigate potential impacts associated with the Project, several mitigation measures have been proposed for implementation in future phases of Project delivery. These proposed mitigation measures have been identified to address Project-specific issues and opportunities.

Table 13.18 identifies the relevant Project phase, the aspect to be managed and the proposed mitigation measure. The mitigation measures presented in Table 13.18 have then been factored into the assessment of residual impact significance, as documented in Table 13.21.

Chapter 22: Outline Environmental Management Plan provides further context and the framework for implementation of these proposed mitigation and management measures.

TABLE 13.18 PROPOSED MITIGATION MEASURES RELEVANT TO GROUNDWATER RESOURCES AND QUALITY

Delivery phase	Aspect	Mitigation and management measures
Detail design	Interaction with groundwater by elements of the Project	▸ Further geotechnical and hydrogeological investigations will be undertaken in parallel to the detail design process to ensure site-specific geotechnical and groundwater conditions are reflected in the finalised design solution. Investigations will be targeted to specific locations, such as: ▸ Locations of bridge abutments ▸ Locations of significant cuts ▸ Locations of significant fill. ▸ Predictive numerical modelling will be re-run using additional information obtained from further geotechnical and hydrogeological investigations, in addition to finalised cut dimensions. This revised modelling will be completed to better understand seepage estimates and groundwater level variation resultant from cuts. Seepage analysis will be used to advise drainage blanket specifications, or alternative design controls, for deep cuts into hard rock. ▸ Site inspections of proposed cut locations will be conducted to visually examine surface outcrops for sulphide minerals or remnant products indicative of sulphide mineralisation. This would inform the need for management of potential ARD from cuttings in sedimentary units prior to construction works. ▸ The management of ARD (leachate) potential, if identified through additional site investigation, would be in accordance with *Preventing Acid and Metalliferous Drainage: Leading Practice Sustainable Development Program for the Mining Industry* (Commonwealth of Australia, 2016) ▸ Culverts and embankments will be designed 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. ▸ Where embankment height allows, toe benching and drainage blankets are to be provided for all transverse slopes greater than seven degrees (1V:8H) ▸ Where embankment height allows, full embankment benching is to be provided for all transverse slopes greater than 14° (1V:4H) ▸ The reference design provides for a minimum 300 mm drainage blanket to be applied in all cuttings where there is known or suspected groundwater to within 2 m of the base of the cutting. Alternative, more effective, seepage control measures will be considered and assessed through the detail design phase, on a cut-by-cut basis.

Delivery phase	Aspect	Mitigation and management measures
Detail design (continued)	Impacts to registered bores	- Landowners affected by the Project will be consulted to confirm the location of registered bores and to establish the presence of any unregistered bores within the Project footprint that may be decommissioned to enable construction and operation of the Project. Where a groundwater bore is expected to be decommissioned or have access to it impaired as result of the Project, 'make good' measures will be agreed in consultation with the affected landowner.

	Sourcing of construction water	- The construction water requirements (i.e. volumes, quality, demand curves, approvals requirements and lead times) will be confirmed as the construction approach is refined. The ultimate water sourcing strategy for the Project will be documented in a Construction Water Plan developed for the Project. The Construction Water Plan will be developed involving all levels of government and other entities. In developing the Construction Water Plan, ARTC will investigate and assess sustainable water solutions to support the Project that will not impact on the function of business, industry and communities along the Project alignment. Sources of construction water will be finalised as the construction approach is refined during the detail design and tender phases of the Project (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 landowners under private agreement
		  - Confirmation of access agreement with local governments for sourcing of mains water.
		- The use of groundwater to supplement the construction demand for the Project may be considered if private owners of licensed/registered bores have capacity under their water licence or entitlement that they wish to sell to, or trade with, ARTC under a private agreement.

	Groundwater quality	- Continue collection of baseline groundwater monitoring data (levels and quality) from monitoring bores established for the Project through the EIS process, as well as from additional bores installed through the detail design process, in accordance with the Baseline GMMP (refer Section 13.8.3). Data will be collected to provide a robust dataset for characterisation of the primary aquifers of relevance over a time sufficient to identify seasonal variation trends.
		- Groundwater monitoring and sample collection will be conducted in accordance with recognised groundwater sampling guidelines such as *Monitoring and Sampling Manual* (DES, 2018a) and *Groundwater Sampling and Analysis—A Field Guide* (Sundaram et.al., 2009)
		- Collected data will be used to establish a groundwater condition baseline for the Project against which construction-phase impacts can be monitored and compared (refer Section 13.8.3). Baseline groundwater monitoring data will be used to:
		  - Derive location/bore-specific groundwater monitoring procedures
		  - Establish location/bore-specific impact thresholds
		  - Establish responses to impact threshold exceedances, including 'make good' agreements.
		These details will be incorporated into the Construction GMMP, which will be subject to approval from DNRME and DES prior to implementation.
		- A Contaminated Land Management Sub-plan will be developed and incorporated into the CEMP. This sub-plan will document management controls for works on land that is known or suspected of being contaminated and outline the process to identify, document and manage contaminated sites (refer Chapter 8: Land Resources)

Delivery phase	Aspect	Mitigation and management measures
Pre-construction	Impacts to registered bores	▸ There are 30 registered bores within the Project footprint for the reference design. These bores, plus unregistered bores that also occur within the Project footprint, are likely to be decommissioned for the progression of the Project. Bores identified within the construction footprint will be decommissioned in accordance with the *Minimum Construction Requirements for Water Bores in Australia* (Edition 3) (National Uniform Drillers Licensing Committee, 2012).
	Sourcing of construction water	▸ Private agreements will be negotiated to secure access to registered bores for use of sustainable groundwater supplies during construction, if required by the Project as part of the construction water strategy (refer above).
Construction	Water resources	▸ The Construction GMMP will be implemented (refer above and Section 13.8.3) ▸ Opportunities to re-use/recycle water during construction will be identified and implemented where feasible.
	Sourcing of construction water	▸ In circumstances where groundwater access is secured through private agreement, the licensed capacity of existing bores will not be exceeded. Flow and volume monitoring during extraction will be required for each bore, with extraction logs maintained.

	Groundwater quality	▸ Suspected contaminated soils or materials, if encountered, will be managed in accordance with the unexpected finds protocol/procedure documented in the Contaminated Land Management Sub-plan
		▸ Opportunities to treat and re-use contaminated materials within the rail corridor will be assessed and subjected to a risk assessment
		▸ Vehicle and plant maintenance will be undertaken in designated laydown areas, on hardstand surfaces. This will minimise risk of contaminants from incidental spills or leaks (accidental discharge) from entering aquifers via infiltration or surface runoff.
		▸ Refuelling will only occur at designated locations within the Project footprint and sited at suitable separation distances from sensitive receptors, including surface water features and drainage lines. These refuelling locations will be equipped with onsite chemical and hydrocarbon absorbent socks/booms and spill kits.
		▸ Bulk storage areas for dangerous goods and hazardous materials will be located away from areas of social and environmental receptors such that offsite impacts or risks from any foreseeable hazard scenario will not exceed the dangerous dose for the defined land use zone (i.e. either sensitive, commercial/ community, or industrial, in accordance with the intent of the SPP).
		▸ A Hazardous Materials Management Sub-plan will be prepared and implemented as a component of the CEMP. The sub-plan will be required to:
		  ▸ Identify the materials required to be stored and used in support of construction, including volumes of each
		  ▸ Identify the laydown areas that will be used for storage of hazardous materials and designated locations for storage of hazardous materials within the bounds of those laydown areas
		  ▸ Specify how dangerous goods and hazardous materials will be handled, stored and transported for the Project
		  ▸ Describe the response procedures in the event of an incident involving hazardous materials or dangerous goods
		  ▸ Establish the waste storage and disposal procedures for hazardous materials and dangerous goods.
		▸ Chemicals stored and handled as part of construction activities will be managed in accordance with:
		  ▸ The *Work Health and Safety Act 2011* (Qld) (WHS Act) and Regulation
		  ▸ *AS 2187 Explosives—storage, transport and use* (Standards Australia, 1998a)
		  ▸ *AS 1940:2017 Storage and Handling of Flammable and Combustible Liquids* (Standards Australia, 2017a)
		  ▸ *AS 3780:2008 The Storage and Handling of Corrosive Substances* (Standards Australia, 2008a)
		  ▸ The requirements of chemical safety data sheets.

Delivery phase	Aspect	Mitigation and management measures
Construction (continued)	Groundwater quality (continued)	▶ 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 onsite chemical and hydrocarbon absorbent socks/booms and spill kits. ▶ Drilling and excavation activities during construction will make use of drilling fluids and chemicals that are environmentally neutral and biodegradable. Mobile plant, drill rigs and equipment will be maintained in accordance with manufacturer requirements and inspected frequently to minimise breakdowns and decrease the risk of contamination. ▶ All excavated material that is suspected to contain sulphides will be stockpiled, lined and covered, and managed to minimise rainfall infiltration and leaching. Where possible, treatment and onsite reuse is preferred to offsite disposal. A case-by-case assessment of the suitability of material for treatment and reuse will be required, in accordance with the Project's spoil management strategy (Appendix Y: Spoil Management Strategy).
	Encountering PASS and/or ARD	▶ All excavated material that is suspected to contain sulphides will be stockpiled, lined and covered, and managed to minimise rainfall infiltration and leaching. Where possible, treatment and onsite reuse is preferred to offsite disposal. A case-by-case assessment of the suitability of material for treatment and reuse will be required, in accordance with the Project's spoil management strategy (refer Appendix Y: Spoil Management Strategy). ▶ If ARD potential is identified through pre-construction investigations (refer above), seepage water from the relevant deep cuts will be sampled at weekly intervals to monitor for the occurrence of acid rock oxidation. This monitoring will involve the onsite screening of the seepage water for pH (trending down) and EC (trending up) and comparison to the baseline groundwater results. Further laboratory analyses for the key analytes (i.e. pH, TDS, EC, TSS, alkalinity, and dissolved metals) will be required if pH and EC trends indicate the potential for oxidation occurring and will be used to validate the presence or absence of ARD potential to mitigate potential leachate to the environment. ▶ If ARD-contaminated discharge water/leachate is found to be generated from the deep cuts, this water may 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.
Operation	Impacts to registered bores	▶ An Operation GMMP will be developed in consultation with the relevant regulatory agencies to specify the groundwater monitoring requirements, if any, over the initial operation years of the Project (refer Section 13.8.3). The need for monitoring during operation will be informed by groundwater observations and data collected during construction of the Project.
	Groundwater quality	▶ Before a train travels on the Inland Rail network, operators must make sure that the classes of dangerous goods, and the identification numbers of vehicles carrying dangerous goods, are recorded in the train consist documentation. Dangerous goods must be loaded, labelled, and marshalled in accordance with the *Australian Code for the Transport of Dangerous Goods by Road and Rail* (Commonwealth of Australia, 2018b). ▶ 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. All fuel and chemical spills will be dealt with in a manner consistent with relevant health and safety guidelines. ▶ Procedures for the management of hazardous chemical spills and leaks will be developed and incorporated into the Operation EMP for the Project. These procedures will be in accordance with ARTC's Work Instruction for Chemicals (WHS-WI-214) and Emergency Management Plan (RLS-PR-044) (available on ARTC's extranet).

Delivery phase	Aspect	Mitigation and management measures
Operation (continued)	Groundwater quality (continued)	▶ The ARTC's Work Instruction for Chemicals (WHS-WI-214) (available on ARTC's extranet) will be applied for all maintenance activities requiring the transport of dangerous goods within the rail corridor. The work instruction includes the following control measures to reduce the risk associated with dangerous goods storage: ▶ Where practical, dangerous goods (specifically detonators) must be transported in their original packaging and stored separately from one another on the vehicle ▶ All dangerous goods must be adequately restrained within the vehicle's confines to prevent movement during transit, e.g. gas bottles restrained to headboard or in designated ventilated storage compartments ▶ The combined (aggregate) quantity of dangerous goods must not exceed 1,000 L or kg ▶ Any individual receptacle used for transporting dangerous goods must have capacity less than 500 L or kg or dangerous goods licencing for both the vehicle and driver will apply ▶ All vehicles carrying mixed loads of dangerous goods must display the appropriate mixed class placard at least on the front and rear of the vehicle ▶ The vehicle must be fitted with appropriate safety equipment for the load as per ARTC operation procedures, including double-sided triangle reflector signals, fire extinguisher(s) and personal protective equipment.

13.8.3 Groundwater Management and Monitoring Program

The GMMP provides for an ongoing assessment of the potential groundwater impacts discussed in Section 13.7. The GMMP incorporates principles of performance assessment and adaptive management—a structured, iterative process for decision making. The GMMP will be assessed and updated before the commencement of each future Project phase (pre-construction/baseline, construction and operation) such that the GMMP for subsequent phases is based on the outcomes of the previous phase. This process of GMMP development and development over sequential Project phases is shown on Figure 13.30.

13.8.3.1 Baseline Groundwater Management and Monitoring Program

The 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 development of Project-specific WQO trigger values. The Baseline GMMP will be developed and implemented during the detail design stage to inform refinement of design and ensure a suitable groundwater baseline dataset is established before the commencement of construction.

The pre-construction/baseline dataset is to be the reference dataset for future groundwater monitoring and, as such, may be supplemented with existing groundwater data inclusive of publicly available and verified data. A continuation of the EIS groundwater monitoring is currently ongoing to inform natural seasonal variations within the aquifers. This monitoring will continue in anticipation of the formal Baseline GMMP being established.

An indicative network of monitoring bores for the Baseline GMMP is summarised in Table 13.19. The indicative network is subject to landowner negotiations and access and will be refined during the detail design phase. If bores specified in Table 13.19 cannot be accessed, or are unsuitable for monitoring for other reasons, an alternative existing bore may be nominated. In the absence of a suitable alternative existing bore, dedicated environmental monitoring bores may be installed. These environmental monitoring bores would be sited in locations to provide adequate coverage up and down hydraulic gradient in areas of potential groundwater impact and to further understand the heterogeneity of the Condamine Alluvium.

The baseline dataset will be compiled, and the Construction GMMP developed, prior to the commencement of the construction of the Project.

The following provides a framework for groundwater level and quality monitoring, data management and reporting from which the Baseline GMMP will be developed.

Groundwater level monitoring

Groundwater levels for bores within the indicative monitoring network are to be monitored using automated pressure transducers (groundwater level loggers) to record measurements at least every 12 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 and to allow for identification of groundwater users in proximity to the Project.

Manual measurements on all bores within the indicative monitoring network is proposed monthly during establishment of the baseline groundwater dataset to allow for a quality control check against the pressure transducers as this will be the basis of comparison for the Project. Pressure transducer data will be downloaded on a bimonthly basis, during the Baseline GMMP, to coincide with groundwater quality monitoring and manual water level measurements.

Data collected during the baseline groundwater monitoring program will account for natural (seasonal) or anthropogenic fluctuations of groundwater levels prior to construction. This is important for the alluvial aquifers, as the water levels in these sediments: are key to the design, construction, and operation of the Project; are the most likely to vary over time due to climate and local groundwater abstraction; and will allow for identification of non-Project related influences on groundwater levels. For example, dewatering/pumping for construction works/water supply being undertaken for works at Commodore Mine expansion project may create an area of influence measurable in proximity to the Project with potential to impact on groundwater resources and/or private bores. This information is important to capture to ensure discernibility between the impacts of the Project and those from other influences.

The baseline monitoring program will be completed in enough time prior to commencement of construction works to allow for assessment of the data and the development of the Construction GMMP.

Groundwater quality monitoring

Groundwater quality samples will be collected from bores within the indicative monitoring network on a bimonthly basis (to coincide with the groundwater level monitoring program, refer Section 13.8.3.1). Groundwater samples will be subject to in-field and laboratory analyses. The quality data collected during the baseline program will be used to assess potential impacts of the Project on local groundwater resources and on proposal-specific WQOs through all stages of the Project.

Data collected during the baseline groundwater monitoring program will account for natural (seasonal) or anthropogenic fluctuations of groundwater levels prior to construction. This is especially applicable to the shallow aquifers that are 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.

The baseline quality dataset will also be used to indicate the potential for ARD prior to construction works and inform the suitability of local groundwater for construction water purposes, if required.

Field parameters to be collected during sampling include:

- pH
- EC
- Temperature
- Redox potential
- 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 establish a baseline for future monitoring of Project impacts:

- pH, EC and total dissolved solids
- Major anions (i.e. HCO_3^-, Cl^- and SO_4^{2-})
- Major cations (i.e. Ca^{2+}, Mg^{2+}, Na^+, K^+ and Si)
- Dissolved and total metals (i.e. Al, As, B, Cd, Cr, Cu, Mn, Pb, Ni, Se, Mo, Ag, Zn, Fe and Hg)
- Nutrients (i.e. ammonia, nitrite, nitrate, TN and TP).

The baseline (pre-construction) monitoring program will be completed in sufficient time, prior to commencement of construction works, to allow for assessment of the data, including trends; this data will be used to develop groundwater-quality trigger levels (warning and action levels).

Groundwater monitoring and sample collection will be conducted in accordance with recognised groundwater sampling guidelines such as *Monitoring and Sampling Manual* (DES, 2018a) 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.

Data management and reporting

The following data and reporting requirements would be implemented:

- All groundwater data will be validated with suitable QA/QC protocols applied
- Monitoring data will initially be assessed on a quarterly basis to identify trends and compare to trigger levels (baseline and pre-construction). This will also enable the Baseline GMMP to be revised, if required.

13.8.3.2 Construction Groundwater Management and Monitoring Program

The Construction GMMP will be developed using a risk-based approach, with monitoring and sampling requirements dependent on the likelihood of construction activities encountering groundwater and the location of such activities. Monitoring will be localised to areas where construction activities have potential to impact on groundwater quality and/or levels, as identified in Section 13.7. The localised task and risk-based monitoring will be performed at locations (distance and depth/aquifer) up- and down-gradient of the site where construction activities are occurring. For example, where construction activities are surficial in nature, no monitoring of deep aquifers would be warranted; however, surficial construction tasks may require TDS and pH monitoring within the alluvial aquifers to ensure the baseline levels are not impacted as a result of local works (task-specific monitoring).

The surface water monitoring program for the Project will be used to inform and complement the Construction GMMP. For example, in the instance that a surface water sample, in an area of known hydraulic connectivity with the alluvial aquifers, returns an elevated result during the construction phase, this may trigger a groundwater sample to be procured from the local alluvial aquifer to inform of any impacts; however, if surface water quality results are within/below acceptable values, sampling of the alluvial aquifers in this area may not be warranted, construction task, WQO, and residual significance dependant.

13.8.3.3 Operation Groundwater Management and Monitoring Program

The Operation GMMP will be based on groundwater data and observations collected during construction of the Project. Monitoring may be warranted over the initial years of construction if construction data indicates that local groundwater conditions are yet to return to baseline and/or stabilise following completion of construction activities. Monitoring may also be warranted in response to a spill/incident. Operation monitoring results will be assessed against the Construction GMMP and baseline dataset, as appropriate.

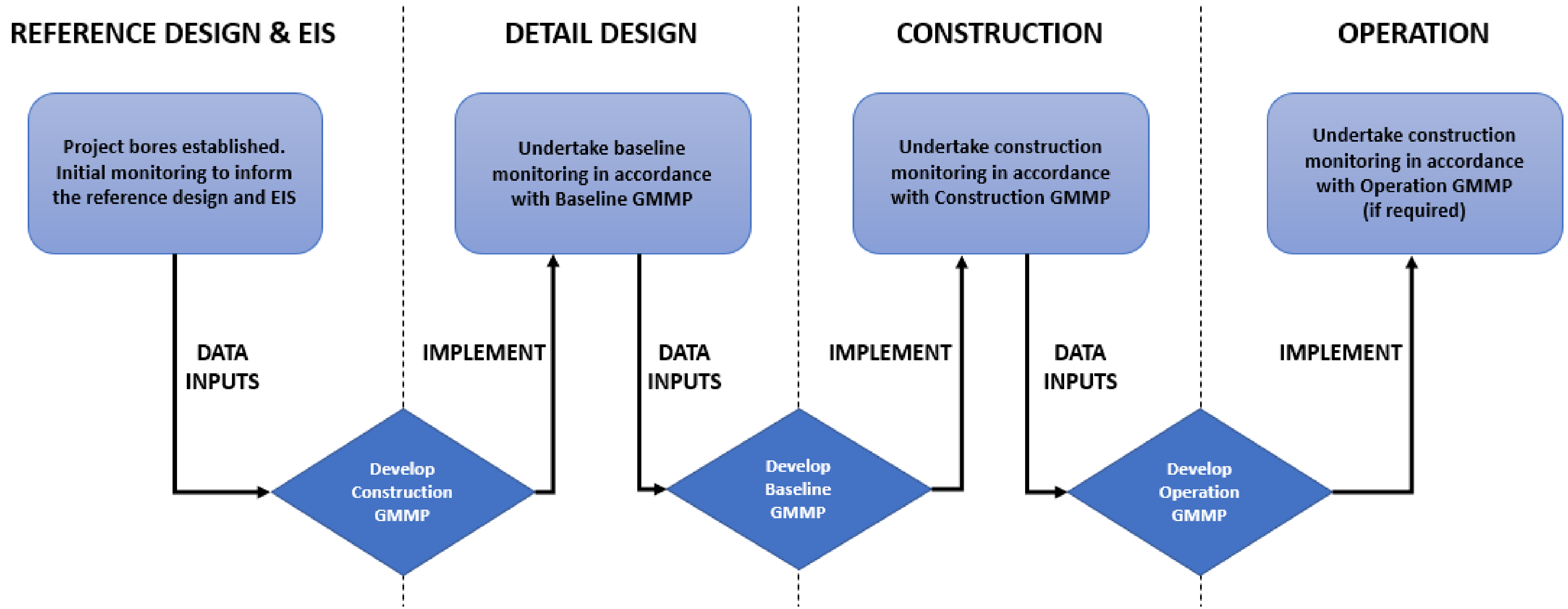


FIGURE 13.30 DEVELOPMENT AND IMPLEMENTATION OF THE GROUNDWATER MANAGEMENT AND MONITORING PROGRAM OVER SEQUENTIAL PROJECT PHASES

TABLE 13.19 INDICATIVE GROUNDWATER MANAGEMENT AND MONITORING PROGRAM NETWORK OF MONITORING BORES

Chainage (km)	Bore ID	Easting[1]	Northing[1]	Bridge or Cutting	Aquifer	Screen interval (mbgl)	Monitoring type	Rationale
55.0	310–BH2206	302299	6853323	C08	WCM	16.7 to 25.7	Water levels and quality	Monitor water levels and quality surrounding deep cutting C08
59.0	310–BH2308	305930	6855563		WCM	9 to 14.45	Water levels and quality	
136.0	310–BH2231	338076	6918598	Dry Creek Bridge	Alluvium	11.4 to 17.4	Water levels and quality	Background alluvium levels for bridge structure
142.8	310–BH2233	340530	6922012	Condamine River rail bridges	Alluvium	9.5 to 12.5 and 18.5 to 24.45	Water levels and quality	Background Condamine Alluvium levels—monthly data available from DNRME
143.0	RN42231089	338799	6922879		Alluvium	XX	Water levels only	
143.2	310–BH2234	340696	6922345		Alluvium	17 to 24.5	Water levels and quality	
148.8	310–BH2235	344710	6926073	Condamine River North Branch rail bridge	Alluvium	31.0 to 40.0	Water levels and quality	Background alluvium levels for bridge structure
172.6	RN119211	365749	6935428	C037	MRV	66 to 75	Water levels and quality	Landowner bore within the Project footprint and down gradient of C037
173.0	RN56564	366137	6934525		MRV	XX to 56	Water levels and quality	Background levels and quality for C037
188.0	310–BH2344	377527	6944383	C044	MRV	9 to 14.95	Water levels and quality	Background levels and quality for C044
188.6	RN35264	377548	6944943		MRV	XX to 62.4	Water levels and quality	Within the Project footprint and C044 drawdown envelope
189.8	RN52509	378064	6946048		MRV	6 to 43	Water levels and quality	Within the Project footprint and C044 drawdown envelope

Table notes:

1 MGA94 Z56

XX = unknown construction detail

13.8.3.4 Summary

A summary of the monitoring and requirements of the GMMP is presented in Table 13.20.

TABLE 13.20 SUMMARY OF GROUNDWATER MANAGEMENT AND MONITORING PROGRAM REQUIREMENTS

GMMP requirements	Baseline (pre-construction)	Construction	Operation
Groundwater level monitoring	▸ Pressure transducers/level loggers record measurements 12 hourly intervals ▸ Pressure transducer data downloaded bimonthly ▸ Manual measurements monthly	A Construction GMMP will be developed at the end of the baseline period and will be subject to review and approval by DNRME and DES. Groundwater level monitoring will be conducted at the locations and frequency nominated in the approved Construction GMMP.	An Operation GMMP will be developed at the end of the construction period and will be subject to review and approval by DNRME and DES. Groundwater level monitoring will be conducted at the locations and frequency nominated in the approved Operation GMMP.
Groundwater quality monitoring	▸ Bimonthly	Groundwater quality monitoring will be conducted at the locations and frequency nominated in the approved Construction GMMP.	Groundwater quality monitoring will be conducted at the locations and frequency nominated in the approved Operation GMMP.
Reporting	▸ Quarterly data comparison	Annual reporting proposed. Subject to DNRME/DES approval of the Construction GMMP.	Annual reporting proposed. Subject to DNRME/DES approval of the GMMP.

13.9 Impact assessment summary

Potential impacts to groundwater values associated with construction and operation of the Project are outlined in Table 13.21. These impacts have been subjected to significance assessment as per the methodology introduced in Chapter 4: Assessment Methodology and described in Section 13.4.2.4.

The initial impact assessment assumes that the design considerations (or initial mitigation measures) factored into the reference design phase (refer Table 13.17) have been implemented.

Additional mitigation and management measures (refer Table 13.18) were then applied, as appropriate, to future phases of the Project to reduce the level of potential impact and derive a residual significance of impact.

The initial and residual significance of potential impacts are presented in Table 13.21 to demonstrate the effectiveness of mitigation measures.

TABLE 13.21 SIGNIFICANCE ASSESSMENT FOR GROUNDWATER

Aspect	Phase	Initial significance[1]			Residual significance[2]	
		Sensitivity	Magnitude	Significance	Magnitude	Significance
Impacts to existing bores (registered and non-registered)	Pre-construction and construction	Moderate	Moderate	Moderate	Low	Low
	Operation		Moderate	Moderate	Low	Low
Subsidence/consolidation due to groundwater extraction or dewatering and/or loading	Pre-construction and construction	Moderate	Moderate	Moderate	Low	Low
	Operation		Low	Low	Low	Low
Altered groundwater levels (increase or decrease) affecting groundwater users and GDEs (including impacts due to embankments and seepage to cuts)	Pre-construction and construction	Moderate	Low	Low	Moderate	Low
	Operation		Low	Low	Low	Low
Altered groundwater flow regime	Pre-construction and construction	Moderate	Moderate	Low	Low	Low
	Operation		Low	Low	Low	Low
Contamination or altered water quality impacting vulnerable groundwater resources (spills or induced flow, borehole intersections. Upwards leakage along pile/soil interface).	Pre-construction and construction	Moderate	High	High	Moderate	Moderate
	Operation		Low	Low	Low	Low
ARD impacting on EVs (i.e. GDEs)	Pre-construction and construction	Moderate	Moderate	Moderate	Low	Low
	Operation		Low	Low	Low	Low
Vegetation removal and surface alteration affecting recharge/discharge, increasing associated salinity risks	Pre-construction and construction	Moderate	Moderate	Moderate	Low	Low
	Operation		Low	Low	Low	Low

Table notes:

1 Includes implementation of initial mitigation measures specified in Table 13.17

2 Assessment of residual significance once the mitigation measures specified in Table 13.18 have been applied

13.10 Cumulative impacts

It is a requirement of the ToR for this Project that the potential for cumulative impacts be considered. This section provides a discussion on the potential for cumulative impacts in relation to groundwater. Further details on the potential for cumulative impacts to arise as a result of the Project, in combination with others, is presented in Chapter 21: Cumulative Impacts. Details on the assessment methodology for cumulative impacts is presented in Chapter 4: Assessment Methodology.

Projects with spatial and/or temporal overlap can result in cumulative impacts. Cumulative impacts may:

- Differ from those of an individual project when considered in isolation
- Be positive or negative
- Differ in severity and duration depending on the spatial and temporal overlap of projects occurring in an area.

Twenty-three projects were initially identified as having potential to contribute to cumulative impacts in combination with the Project. These projects are either currently operational, expected to undergo future expansion or are currently going through an approval process. A full list of the 23 projects, with a description of each, is presented in Chapter 21: Cumulative Impacts.

Projects and operations surrounding the impact assessment area were evaluated in terms of potential of each to impact groundwater receptors of relevance to the Project. Cumulative impacts to groundwater are most likely to occur where multiple projects intersect and/or take groundwater from the same shallow aquifer units. Impact modelling indicates that no registered bores located outside of the Project footprint are expected to experience groundwater drawdown as a result of Project activities; therefore, due to the localised potential of groundwater impacts associated with the Border to Gowrie Project and the distance and nature of many of the surrounding projects considered, only 4 of the initial 23 projects are considered to have potential to result in cumulative impacts on groundwater. These projects are listed in Table 13.22.

TABLE 13.22 PROJECTS CONSIDERED FOR THE CUMULATIVE IMPACT ASSESSMENT

Projects	Location	Description	Construction dates
Commodore Mine and Millmerran Power Station	Domville, Queensland The Project is aligned adjacent to potential future coal reserves for the mine	The Commodore Mine is an open cut coal mine, which provides coal for the 850 MW Millmerran Power Station (MiningLink, n.d.). The Millmerran Power Station is a coal-fired power station that supplies enough electricity to power approximately 1.1 million homes (Power Technology, 2018).	Operational, but subject to possible future expansion of footprint
North Star to NSW/QLD Border (Inland Rail)	Rail alignment from North Star, NSW to the NSW/QLD border Adjoins the Project at its southern limit	New 37 km rail corridor to connect North Star (NSW) to the QR South West Rail Line just over the NSW/QLD border.	2021–2024
Gowrie to Helidon (Inland Rail)	Rail alignment from Gowrie to Helidon, Queensland Adjoins the Project at its northern limit	New 26 km dual-gauge track between Gowrie (northwest of Toowoomba) and Helidon (east of Toowoomba), extending through the LGAs of Toowoomba and Lockyer Valley. The Project includes a 6.38 km tunnel to create an efficient route through the steep terrain of the Toowoomba Range.	2021–2025
Asterion Medicinal Cannabis Project	Wellcamp, Queensland Adjoins the Project footprint 1 km south of Toowoomba–Cecil Plains Road	A high-tech medicinal cannabis cultivation, research and manufacturing facility. The project involves construction of a 40-hectare glasshouse to produce 20,000 plants per day at full capacity. Medicinal-grade cannabis grown at the facility will be manufactured into a range of medicinal products, including single patient packs, cannabis oils, gels, salts and related products, destined solely for the medicinal market. This facility is anticipated to be the largest facility of its kind in the world.	2020–2021

Potential cumulative impacts that have been evaluated are presented in Table 13.23. Potential for cumulative impacts to groundwater levels and groundwater quality as a result of the projects listed above is provided in Table 13.23.

TABLE 13.23 SUMMARY OF POTENTIAL CUMULATIVE GROUNDWATER IMPACTS

	Potential cumulative impact	
Project	**Groundwater levels**	**Groundwater quality contamination**
North Star to NSW/QLD Border Project	There are no major cuts into the Border Rivers Alluvium required for the North Star to NSW/Queensland Border Project; therefore, drawdown impacts are likely to be restricted to localised and temporary dewatering activities. As such, cumulative impacts to groundwater levels in the Border Rivers Alluvium are considered unlikely.	Cumulative impacts on the quality of groundwater within the Border Rivers Alluvium may arise due to the compounding of spills and leaks from heavy machinery, drill rigs, etc. However, if a spill or leak were to occur, the volume of contaminant in any one instance is expected to be small; therefore, the likelihood of impact to groundwater is considered to be low.
Gowrie to Helidon Project	Both projects, at the point of interface, overlie the MRV; however, neither of the projects require cuts with potential to encounter groundwater at this location. Therefore, drawdown impacts are likely to be restricted to localised and temporary dewatering activities; as such, cumulative impacts to groundwater levels in the MRV are considered unlikely.	Cumulative impacts on the quality of groundwater within the MRV may arise due to the compounding of spills and leaks from heavy machinery, drill rigs, etc. However, if a spill or leak were to occur, the volume of contaminant in any one instance is expected to be small; therefore, the likelihood of impact to groundwater is considered to be low.
Commodore Mine and Millmerran Power Station	There is potential for overlap of dewatering impacts on shallow aquifers intersected by Project cuttings and dewatering from the Commodore Mine open pit. However, if drawdown occurs due to the Project in proximity to the Commodore Mine, it will be due to localised and temporary dewatering activities. As such, cumulative impacts to groundwater levels are considered unlikely.	Cumulative impacts on the quality of groundwater within shallow aquifers may arise due to the compounding of spills and leaks from heavy machinery, drill rigs, etc. However, if a spill or leak were to occur, the volume of contaminant in any one instance is expected to be small; therefore, the likelihood of impact to groundwater is considered to be low.
Asterion Medicinal Cannabis Project	Both projects, at the point of interface, overlie the MRV; however, due to the nature of the development, the Asterion Medicinal Cannabis Project is expected to have very little or no interaction with groundwater in the area. Therefore, cumulative impacts to groundwater levels are considered unlikely.	Cumulative impacts on the quality of groundwater within the MRV may arise due to the compounding of spills and leaks from heavy machinery, drill rigs, etc. However, if a spill or leak were to occur, the volume of contaminant in any one instance is expected to be small; therefore, the likelihood of impact to groundwater is considered to be low.

TABLE 13.24 ASSESSMENT OF GROUNDWATER CUMULATIVE IMPACTS

Project	Potential cumulative impact	Aspect	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
North Star to NSW/QLD Border Project	Change in groundwater levels	Probability of impact	Low (1)	5	Low	The potential for cumulative impacts to groundwater levels is considered to be low; therefore, specific mitigation measures to address cumulative impacts are not warranted. The potential for the Project to contribute to such impacts is considered to be appropriately managed through the development and implementation of the GMMP, including the establishment of baseline conditions and construction-phase monitoring.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of receiving environment	Medium (2)			
	Groundwater quality and contamination	Probability of impact	Low (1)	6	Low	The potential for cumulative impacts to groundwater quality is considered to be low; therefore, specific mitigation measures to address cumulative impacts are not warranted. The potential for the Project to contribute to such impacts is considered to be appropriately managed through: ▸ The development and implementation of the GMMP, including the establishment of baseline conditions and construction-phase monitoring ▸ The development and implementation of a Hazardous Materials Management Sub-plan for the Project, thereby ensuring the safe handling, storage and usage of hazardous materials and dangerous goods.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of receiving environment	Medium (2)			
Gowrie to Helidon Project	Change in groundwater levels	Probability of impact	Low (1)	5	Low	The potential for cumulative impacts to groundwater levels is considered to be low; therefore, specific mitigation measures to address cumulative impacts are not warranted. The potential for the Project to contribute to such impacts is considered to be appropriately managed through the development and implementation of the GMMP, including the establishment of baseline conditions and construction-phase monitoring.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of receiving environment	Medium (2)			

Project	Potential cumulative impact	Aspect	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
	Groundwater quality and contamination	Probability of impact	Low (1)	6	Low	The potential for cumulative impacts to groundwater quality is considered to be low; therefore, specific mitigation measures to address cumulative impacts are not warranted. The potential for the Project to contribute to such impacts is considered to be appropriately managed through: ▸ The development and implementation of the GMMP, including the establishment of baseline conditions and construction-phase monitoring ▸ The development and implementation of a Hazardous Materials Management Sub-plan for the Project, thereby ensuring the safe handling, storage and usage of hazardous materials and dangerous goods.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of receiving environment	Medium (2)			
Asterion Medicinal Cannabis Project	Change in groundwater levels	Probability of impact	Low (1)	5	Low	The potential for cumulative impacts to groundwater levels is considered to be low; therefore, specific mitigation measures to address cumulative impacts are not warranted. The potential for the Project to contribute to such impacts is considered to be appropriately managed through the development and implementation of the GMMP, including the establishment of baseline conditions and construction phase monitoring.
		Duration of the impact	Low (1)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of receiving environment	Medium (2)			
	Groundwater quality and contamination	Probability of impact	Low (1)	6	Low	The potential for cumulative impacts to groundwater quality is considered to be low; therefore, specific mitigation measures to address cumulative impacts are not warranted. The potential for the Project to contribute to such impacts is considered to be appropriately managed through: ▸ The development and implementation of the GMMP, including the establishment of baseline conditions and construction-phase monitoring ▸ The development and implementation of a Hazardous Materials Management Sub-plan for the Project, thereby ensuring the safe handling, storage and usage of hazardous materials and dangerous goods.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of receiving environment	Medium (2)			

Project	Potential cumulative impact	Aspect	Relevance factor	Sum of relevance factors	Impact significance	Comments and management measures
Commodore Mine and Millmerran Power Station	Change in groundwater levels	Probability of impact	Low (1)	6	Low	The potential for cumulative impacts to groundwater levels is considered to be low; therefore, specific mitigation measures to address cumulative impacts are not warranted. The potential for the Project to contribute to such impacts is considered to be appropriately managed through the development and implementation of the GMMP, including the establishment of baseline conditions and construction-phase monitoring.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of receiving environment	Medium (2)			
	Groundwater quality and contamination	Probability of impact	Low (1)	6	Low	The potential for cumulative impacts to groundwater quality is considered to be low; therefore, specific mitigation measures to address cumulative impacts are not warranted. The potential for the Project to contribute to such impacts is considered to be appropriately managed through: ▶ The development and implementation of the GMMP, including the establishment of baseline conditions and construction-phase monitoring ▶ The development and implementation of a Hazardous Materials Management Sub-plan for the Project, thereby ensuring the safe handling, storage and usage of hazardous materials and dangerous goods.
		Duration of the impact	Medium (2)			
		Magnitude/intensity of the impact	Low (1)			
		Sensitivity of receiving environment	Medium (2)			

Table notes:

Relevance factors between 1 and 3 were determined using professional judgement to select the most appropriate relevance factor for each aspect and summing the relevance factors.

Sum of relevant factors definition:

- Low (1–6): Negative impacts need to be managed by standard environmental management practices. Monitoring to be part of general Project monitoring program.
- Medium (7–9): Mitigation measures likely to be necessary and specific management practices to be applied. Targeted monitoring program required, where appropriate.
- High (10–12): Alternative actions should be considered and/or mitigation measures applied to demonstrate improvement. Targeted monitoring program necessary, where appropriate.

13.11 Conclusions

This chapter has been prepared to evaluate potential impacts of the Project on groundwater resources and addresses the ToR requirements with respect to groundwater. This chapter has identified existing conditions of the impact assessment area in accordance with industry standard methodology and relevant legislation. Through an assessment of existing conditions, Project activities with the potential to adversely impact on groundwater resources were identified.

Project activities, throughout the Project lifecycle, can impact on groundwater resources via:

- Loss or damage to existing landowner bores or groundwater use from the bore (quality/yield degradation)
- Groundwater level reduction
- Alteration of aquifer parameters and/or flow patterns
- Subsidence/settlement of compressible substrates
- Contamination/reduction of groundwater quality
- ARD
- Groundwater level mounding
- Alteration to groundwater recharge/discharge mechanisms.

The majority of potential impacts related to groundwater for the Project are considered temporary in nature and related to the construction phase of the Project. All potential impacts to groundwater resources through Project activities are considered to be manageable with the implementation of mitigation measures specified in Table 13.18.

In the few deep cut locations where construction activities have the potential to intersect shallow groundwater (cuts C08, C37, and C44), construction techniques have been identified for the Project such that impacts are considered to be appropriately mitigated and managed through the adopted engineering controls.

Implementation of a GMMP that embraces adaptive management principles, as detailed in Section 13.8.3, will ensure that specific potential impacts identified for each phase of the Project can be managed based on specific activities, locations, and WQOs to protect groundwater resources and users.

The potential for cumulative impacts to groundwater levels and quality due to other projects occurring in the vicinity of the Project has been assessed. The likelihood of cumulative impacts to these aspects is considered to be low due to the largely localised and temporary nature of impacts to groundwater that may arise due to the Project.