CHAPTER 14

Groundwater

HELIDON TO CALVERT ENVIRONMENTAL IMPACT STATEMENT

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14. Groundwater

14.1 Summary

The Project alignment is generally oriented west to east, traversing the Lockyer Creek catchment area (west of Little Liverpool range) and Bremer River Catchment (east of the Little Liverpool range). The Project alignment intersects a number of defined watercourses including Lockyer Creek, Laidley Creek and Western Creek.

The EIS investigation corridor (groundwater study area) was based on a 1 kilometre (km) buffer from the Project alignment, where the Project alignment is defined as the railway alignment between Helidon and Calvert (refer Figure 14.1).

The groundwater study area is predominately located within the floodplains between the base of the Toowoomba Range in the west (near Helidon) and the Little Liverpool Range in the east (near Calvert). The western portion of the groundwater study area is typically underlain by the outcropping Woogaroo Subgroup sediments that form the higher relief along this section of the Project (the Helidon Hills). In the central portion of the groundwater study area, the Gatton Sandstone is overlain by alluvial sediments of Lockyer Creek and Laidley Creek. The eastern portion of the alignment is underlain by the Koukandowie Formation, which forms the highest relief in the groundwater study area, where it crops out to form the Little Liverpool Range. On the eastern flanks of the range, the Koukandowie Formation is overlain by Western Creek alluvial sediments.

The hydrostratigraphic units relevant to the groundwater study area are the shallow alluvial systems along river valleys (Cenozoic to recent age), the Koukandowie Formation and Gatton Sandstone (Jurassic to Cretaceous age) and the Woogaroo Subgroup (Triassic to Lower Jurassic age).

Typically, the water table is a subdued version of topography, with depth to groundwater increasing beneath topographic highs and tending to be shallower in lower-lying reaches. The water table will occur in the alluvial sediments of Laidley Creek and Lockyer Creek through much of the central portion of the groundwater study area, and Western Creek alluvial sediments east of Little Liverpool Range. The Woogaroo Subgroup (west), Gatton Sandstone (central) and Koukandowie Formation (east) will form the water table aquifer where they outcrop along limited sections of the groundwater study area.

Depths to groundwater in the alluvial sediments are anticipated to be between 5 metres (m) and 15 m, with shallow groundwater typically occurring near active watercourses where fill/embankments and/or bridges are proposed. No cuttings are proposed through alluvial sediments, but groundwater mounding may occur below significant embankments in areas of shallow groundwater and compressible materials.

In the main outcrop areas of the Woogaroo Subgroup and Koukandowie Formation the depth to water table is expected to be in the order of 15 m, where deeper cuts are proposed. Five cuts were identified as potentially intersecting groundwater based on the limited groundwater data available (Golder Associates, 2020, refer Appendix A within Appendix N: Groundwater Technical Report). Based on available data at the time of writing of this document, the eastern portal has potential to intersect groundwater.

Where groundwater levels are above the base of cut elevations, consideration of potential geotechnical implications (such as wall failure and floor heave), reduced groundwater levels and flow at receptors, and the quality and quantity of groundwater discharge to receptors (for example to surface water courses) will be required.

Water quality data for the Clarence–Moreton Basin and baseline groundwater sampling geotechnical monitoring bores indicate variable water quality within and across the key hydrogeological formations, with groundwater in the alluvial sediments generally fresher than the underlying sediments. Water supply and town water are the primary purposes reported for registered bores within the groundwater study area. Other uses of groundwater include stock, farming, and rural domestic supply. A significance assessment was carried out for identified potential impacts on groundwater resources in terms of groundwater levels, groundwater flow, and water quality. With proposed mitigations implemented, the significance of impacts are considered low across the majority of the alignment.

The potential for reduced groundwater levels was identified as a moderate residual risk to impact groundwater users due to a drained Little Liverpool Range tunnel. This is based on results of modelling undertaken. An uncertainty analysis was undertaken in the impact assessment, in which groundwater levels were assumed to be approximately 10 m higher than the modelled base case. Groundwater-level monitoring post-modelling indicates that the Scenario 1 groundwater levels are representative of seasonal fluctuation. Under this scenario, the predicted 5 m drawdown did not extend to the nearest registered bore to the tunnel (RN106453) located approximately 240 m southwest. The low-to-moderate potential terrestrial groundwater dependent ecosystems (GDEs) approximately 1 km to the northeast are not predicted to intersect with the modelled 5 m drawdown extent.

Potential degradation of groundwater quality during the construction phase due to spills and uncontrolled releases, water mixtures and emulsions from wash-down areas, and wastewater streams was also identified as a moderate residual risk.

Residual significance risks were identified as being low for all other potential impacts identified including loss of registered bores through destruction or loss of access, reduced groundwater levels from seepage to cuttings impacting groundwater users (bores and GDEs), and changes to groundwater levels due to loading from embankments (i.e. upstream mounding and damming, and downstream groundwater level reductions).

A groundwater monitoring program is proposed. The proposed monitoring program will aid in an adaptive management approach and allow potential Project impacts to be identified.

14.2 Scope of chapter

The groundwater chapter includes a description of the existing hydrogeological regime (environment), a description of the potential impacts from the Project, an impact assessment of the Project on groundwater resources, and an outline of proposed measures to mitigate these impacts.

The existing environment is described, and potential impacts assessed over the short-term and long-term. The results of the impact assessment and proposed mitigation measures have been outlined along. Potential cumulative impacts have also been considered.

Full details of the groundwater impact assessment are provided in Appendix N: Groundwater Technical Report.

14.3 Terms of Reference requirements

This chapter has been prepared in accordance with the groundwater-related Terms of Reference (ToR) for an environmental impact statement: Inland Rail—Helidon to Calvert Project October 2017 (the Department of State Development, Infrastructure, Local Government and Planning (DSDILGP) (formerly Department of State Development, Manufacturing, Infrastructure and Planning).

The ToR applicable to this EIS chapter are outlined in Table 14.1. Compliance of the EIS against the full ToR is documented in Appendix B: Terms of Reference Compliance Table.

TABLE 14.1: TERMS OF REFERENCE—GROUNDWATER

	Terms of Reference requirements	Where addressed
	Information requirements	
11.24.	The EIS must also provide details on the current state of groundwater and surface water in the region as well as any use of these resources	Section 14.6 Appendix N: Groundwater Technical Report, Sections 4, 5, 6 and 7 Chapter 13: Surface water and hydrology Appendix J: Matters of National Environmental Significance Technical Report Appendix L: Surface Water Quality Technical Report
	Existing environment	
11.36.	Identify the water-related environmental values and describe the existing surface water and ground water regime within the study area and the adjoining waterways in terms of water levels, discharges and freshwater flows	Section 14.6 Appendix N: Groundwater Technical Report, Sections 4 to 7 Chapter 13: Surface water and hydrology Appendix L: 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 study area associated with climatic and seasonal factors, and flows	Section 14.6.4 Appendix N: Groundwater Technical Report, Sections 4, 6 and 7 Appendix W: Geotechnical Factual Report Chapter 13: Surface water and hydrology Appendix L: Surface Water Quality Technical Report

	Terms of Reference requirements	Where addressed
11.40.	Undertake a landholder bore survey to identify the location and source aquifer of licensed groundwater extraction in areas potentially impacted by the Project (e.g. near tunnels and cuttings)	Section 14.6.6 Appendix N: Groundwater Technical Report, Section 6.4.1
	Impact assessment	
11.41.	The assessment of impacts on water will be in accordance with the DEHP Information guideline for an environmental impact statement – ToR Guideline – Water, where relevant, located on the DEHP website	Sections 14.9 and 14.11 Appendix N: Groundwater Technical Report, Sections 3 and 13 Chapter 13: Surface water and hydrology Appendix L: Surface Water Quality Technical Report
11.52.	Provide details of any proposed impoundment, extraction (i.e. volume and rate), discharge, use or loss of surface water or groundwater. Identify any approval or allocation that would be needed under the Water Act	Sections 14.4, 14.7.4 and 14.9.2 Appendix N: Groundwater Technical Report, Sections 2.2 and 11.1 Chapter 3: Project approvals Chapter 6: Project description Chapter 13: Surface water and hydrology Appendix L: Surface Water Quality Technical Report
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 b) Direct and indirect impacts arising from the Project c) Impacts to aquatic ecosystems, including groundwater-dependent ecosystems and environmental flows	Sections 14.7, 14.8, 14.11 Appendix N: Groundwater Technical Report, Sections 8 to 11 Appendix W: Geotechnical Factual Report, Appendix A Chapter 13: Surface water and hydrology Appendix L: Surface Water Quality Technical Report Appendix M: Hydrology and Flooding Technical Report
11.55.	Provide information on the proposed water usage by the project, including details about: a) details of the estimated supply required to meet the demand for construction and full operation of the project, including timing of demands b) details of the quality and quantity of all water supplied to the site during the construction and operational phases based on minimum yield scenarios for water re-use, rainwater re-use and any bore water volumes c) a plan outlining actions to be taken in the event of failure of the main water supply d) sufficient hydrogeological information to support the assessment of any temporary water permit applications	Sections 14.8 and 14.9.2 Appendix N: Groundwater Technical Report, Sections 8 to 10 Chapter 6: Project description Chapter 13: Surface water and hydrology Appendix L: Surface Water Quality Technical Report
11.58.	Identify relevant Water Plans and Resources Operations Plans under the Water Act. Describe how the Project will impact or alter these plans. The assessment should consider, in consultation with the Department of Natural Resources and Mines (DNRM), any need for: a) A resource operations licence b) An operations' manual c) A distribution operations licence d) A water licence e) A water management protocol	Sections 14.4 and 14.6.2 Appendix N: Groundwater Technical Report, Section 2.3.2 and 6.4.2 Chapter 3: Project approvals Chapter 13: Surface water and hydrology Appendix L: Surface Water Quality Technical Report

	Terms of Reference requirements	Where addressed
11.59.	Identify other water users that may be affected by the proposal and assess the Project's potential impacts on other water users	Sections 14.6.6 and 14.9 Appendix N: Groundwater Technical Report, Sections 6.4 and 11 Chapter 13: Surface water and hydrology Appendix L: Surface Water Quality Technical Report
	Mitigation measure	
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 14.10.2 Appendix N: Groundwater Technical Report, Section 12.2 Chapter 9: Land resources Chapter 13: Surface water and hydrology Chapter 23: Draft Outline Environmental Management Plan Appendix L: Surface Water Quality Technical Report
11.62.	Describe measures to minimise impacts on surface water and ground water resources	Section 14.10 Appendix N: Groundwater Technical Report, Section 12 Chapter 13: Surface water and hydrology Chapter 23: Draft Outline Environmental Management Plan Appendix L: Surface Water Quality Technical Report
11.63.	Provide a policy outline of compensation, mitigation and management measures where impacts are identified	Section 14.10 Appendix N: Groundwater Technical Report, Section 12 Chapter 13: Surface water and hydrology Chapter 23: Draft Outline Environmental Management Plan Appendix L: Surface Water Quality Technical Report

14.4 Legislation, policies, standards, and guidelines

This chapter has been prepared with consideration to key Commonwealth and State legislation and policies. An overview of those relevant to the groundwater study is provided in Table 14.2 with further detail provided in Appendix N: Groundwater Technical Report.

TABLE 14.2: SUMMARY OF RELEVANT LEGISLATION AND POLICIES

Legislation/policy	Summary/Relevance to Project
Commonwealth	
Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)	The EPBC Act is the Australian Government's central piece of environmental legislation. It provides a legal framework to protect and manage nationally and internationally important environmental assets, defined in the EPBC Act as matters of national environmental significance (MNES). On 17 March 2017, the delegate of the Commonwealth Minister for the Environment determined the Inland Rail—Helidon to Calvert Project to be a 'controlled action' under the EPBC Act, due to the likely potential impacts on listed threatened species and communities (reference number EPBC 2017/7883).

Legislation/policy	Summary/Relevance to Project
State	
Water Act (2000)	The *Water Act 2000* (Water Act) provides for the sustainable management of water and the management of impacts on underground water and for other purposes. The Water Act covers water in a watercourse, lake or spring, underground water (or groundwater), overland flow water, or water that has been collected in a dam. The Project involves works which may intersect shallow groundwater units and as such the provisions of the Water Act apply.
Water Regulation (2016)	The Water Regulation 2016 (Water Regulation) is subordinate legislation made under the Water Act and prescribes administrative and operational matters for the Act (including for example: prescribing activities for which taking of water is authorised without an entitlement, prescribe requirements for decommissioning water bores, and provide rules for managing underground water not managed through a water plan). The Project will require water for construction water supply (potentially including groundwater and surface water), and as such provisions of the Water Regulation apply.
Environmental Protection Act 1994 (EP Act)	The objective of the EP Act aims to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains ecological processes on which life depends i.e. ecologically sustainable development. The EP Act defines an environmental value (EV) as: ▸ A quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety ▸ Another quality of the environment identified and declared to be an environmental value under an environmental protection policy or regulation.
Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP Water and Wetland Biodiversity)	The EPP Water and Wetland Biodiversity is subordinate legislation to achieve the objective of the EP Act in relation to Queensland waters. The objective of the EPP (Water and Wetland Biodiversity) is achieved by the: ▸ Identification of EVs and management goals for Queensland waters ▸ Stating water quality guidelines and water quality objectives (WQOs) to enhance or protect the identified EVs ▸ Provision of a framework for making consistent, equitable and informed decisions about Queensland waters ▸ Monitoring and reporting on the condition of Queensland waters. EVs relevant to the Project are considered in Section 14.6.9.

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

14.5 Methodology

14.5.1 Groundwater study area

The EIS investigation corridor (herein referred to as the groundwater study area) is defined as the area within a
1 km of the centre line of the Project alignment. The groundwater study area is illustrated in Figure 14.1. The groundwater study area includes all activities associated with the Project that have the potential to directly or indirectly affect the groundwater resources and was used to identify groundwater users (including registered bores and potential GDEs).

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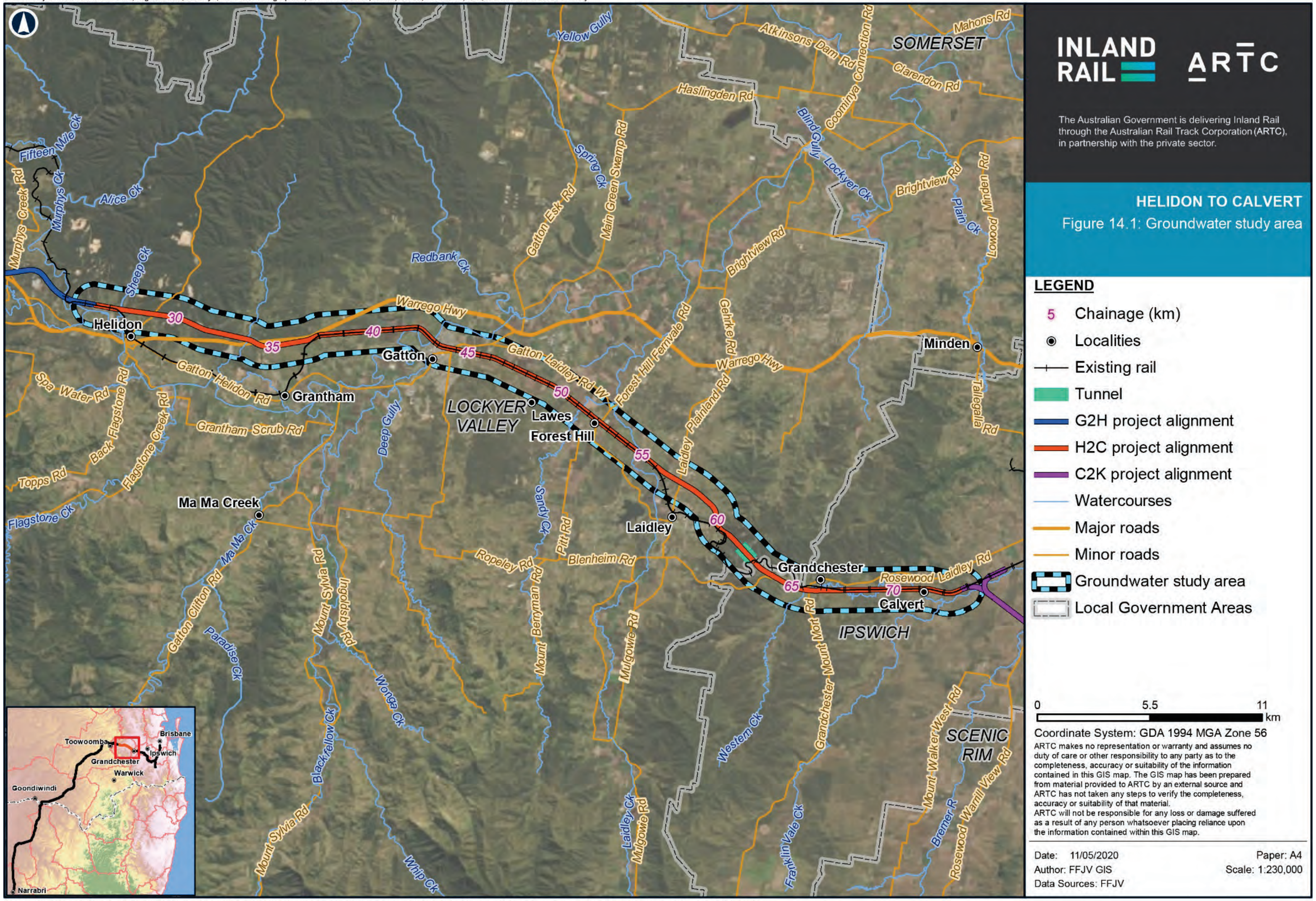

Figure 14.1: Groundwater study area

Map by: RB/DTH/LCT/GN/KG Z:\GIS\GIS_3300_H2C\Tasks\330-EAP-201810021057_H2C_Project_Figures\330-EAP-201810021057_ARTC_Fig14.1_Groundwater_study_area_v3.mxd Date: 11/05/2020 15:16

14.5.2 Assessment methodology

An approach to the groundwater impact assessment has been adopted by ARTC that maintains consistency across the Inland Rail Program (Inland Rail).

Following the identification and assessment of baseline EVs, the potential impacts of the Project have been described and assessed, and potential mitigation measures identified. Potential cumulative impacts have also been considered.

A significance assessment approach has been adopted to assess potential groundwater impacts. This is a qualitative approach.

The sensitivity of the EVs and the magnitude of the impacts are the key elements considered to determine significance. These aspects were assessed via a significance matrix to allow the appropriate significance classifications to be determined (refer Table 14.3).

TABLE 14.3: CLASSIFICATION ADOPTED FOR THE SIGNIFICANCE ASSESSMENT

Significance	Description
Major	Arises when an impact will potentially cause irreversible or widespread harm to an EV that is irreplaceable because of its uniqueness or rarity. Avoidance through appropriate design responses is the only effective mitigation.
High	Occurs when the proposed activities are likely to exacerbate threatening processes affecting the intrinsic characteristics and structural elements of the EV. While replacement of unavoidable losses is possible, avoidance through appropriate design responses is preferred to preserve its intactness or conservation status.
Moderate	Results in degradation of the EV due to the scale of the impact or its susceptibility to further change even though it may be reasonably resilient to change. The abundance of the EV ensures it is adequately represented in the region, and that replacement, if required, is achievable.
Low	Occurs where an EV is of local importance and temporary or transient changes will not adversely affect its viability provided standard environmental management controls are implemented.

14.5.3 Data assessment

Data used in this assessment includes publicly available information and findings from the Project-specific geotechnical assessment. Regional (catchment) scale studies have also been reviewed to describe the existing groundwater resources.

The description of existing hydrogeological regime is based on the information sources summarised in Table 14.4.

TABLE 14.4: DATA SOURCES FOR GROUNDWATER ASSESSMENT OF THE PROJECT

Data	Source
Hydrology/climate	▸ Historical Climate Database—Bureau of Meteorology (BoM) (**bom.gov.au/climate/data**) ▸ Inland Rail Section 330—Helidon to Calvert Preliminary Hydrogeological Interpretive Report (Golder Associates, March 2020) ▸ Inland Rail: Phase 2—Helidon to Calvert Geotechnical Factual Report (Golder Associates, January 2019) ▸ Queensland Globe datasets (**qldglobe.information.qld.gov.au**)
Soil types	▸ Inland Rail Section 330—Helidon to Calvert Preliminary Hydrogeological Interpretive Report (Golder Associates, March 2020)
Geology/ Hydrostratigraphy	▸ Inland Rail Section 330—Helidon to Calvert Preliminary Hydrogeological Interpretive Report (Golder Associates, March 2020) ▸ Department of Natural Resources, Mines and Energy (DNRME) (now Department of Regional Development, Manufacturing and Water (DRDMW)) groundwater database (online) ▸ Inland Rail: Phase 2—Helidon to Calvert Geotechnical Factual Report (Golder Associates, January 2019) ▸ Queensland Globe datasets (**qldglobe.information.qld.gov.au**)

Data	Source
Groundwater levels and quality	▸ DNRME (now DRDMW) groundwater database (online) ▸ Inland Rail Section 330—Helidon to Calvert Preliminary Hydrogeological Interpretive Report (Golder Associates, March 2020) ▸ Clarence–Moreton Bioregional Assessment (May 2014) (**bioregionalassessments.gov.au/assessments/clarence-moreton-bioregion**) ▸ Inland Rail: Phase 2—Helidon to Calvert Geotechnical Factual Report (Golder Associates, January 2019) ▸ Queensland Globe datasets (**qldglobe.information.qld.gov.au**)
GDEs	▸ BoM: GDE Atlas: (**bom.gov.au/water/groundwater/gde/map.shtml**) ▸ Clarence–Moreton Bioregional Assessment (May 2014) (**bioregionalassessments.gov.au/assessments/clarence-moreton-bioregion**) ▸ Queensland Globe datasets (**qldglobe.information.qld.gov.au**)
Groundwater use and management	▸ DNRME (now DRDMW groundwater database (online) ▸ DNRME (now DRDMW) groundwater entitlements database (online) ▸ BoM National Groundwater Information System **bom.gov.au/water/groundwater/ngis** ▸ Clarence–Moreton Bioregional Assessment (May 2014) ▸ *Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017* ▸ *Water Plan (Moreton) 2007*

14.5.4 Phased approach

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

i) A description of the existing hydrogeological environment

ii) An assessment of the potential impacts of the Project on that environment.

A staged approach was adopted. This included:

- **Stage 1—Desktop study**

  Available geological and hydrogeological literature and data were reviewed to inform a detailed description of the existing hydrogeological regime and identification of groundwater from publicly available databases, including registered groundwater bores and use, were reviewed. Relevant studies and reports were also referenced, including geotechnical site investigation works.

- **Stage 2—Groundwater impact assessment**

  Potential short- and long-term impacts on the existing groundwater regime and users, at local and regional scales, were assessed. Proposed construction and rail operations, with respect to the current geological and hydrogeological setting, were used as the basis of assessment.

  Geotechnical predictive modelling was completed for the Little Liverpool Range tunnel and adjacent portal cuts, and five cuts along the alignment (Golder Associates, 2020; refer Appendix A within Appendix N: Groundwater Technical Report). The modelling was reviewed and interpreted to assess potential impacts on groundwater resources due to the construction and operation of the tunnel and cuts.

- **Stage 3—Significance assessment**

  A qualitative significance assessment was undertaken for all potentially impacted EVs for which there are no relevant quantified guidelines to measure potential impacts. This approach considers the sensitivity (or vulnerability) of an EV and the magnitude of the potential impact to identify a significance rating.

  The evaluation of significance classifications, with or without mitigation measures, was then completed. The results are considered to inform recommended mitigations and management measures.

- **Stage 4—Reporting**

  This groundwater chapter was developed using factual site-specific and publicly available data, predictive numerical modelling, and interpretation to perform an assessment of the potential impacts as a result the Project on groundwater resources. This chapter is to be read in conjunction with Appendix N: Groundwater Technical Report.

14.6 Description of existing groundwater conditions

14.6.1 Hydrostratigraphy

The primary aquifers considered relevant to the Project are summarised in Table 14.5 and the surface geology across the groundwater study area is presented in Figure 14.2.

TABLE 14.5: GROUNDWATER OCCURRENCE WITHIN THE GROUNDWATER STUDY AREA

Stratigraphic unit	Main occurrences	Approximate. proportion of alignment (%)	Thickness (m)[1]	Lithology	Comments
Alluvium	Floodplains between Toowoomba Range (west of Helidon) and the Little Liverpool Range near Calvert—associated with Lockyer Creek, and Laidley Creek and their tributaries. Also associated with Western Creek floodplain to the east of the Little Liverpool Range.	72	Upper range: 20–35	Clay, silt, sand and gravel; in a generally fining upward sequence.	Aquifer (unconfined)
Walloon Coal Measures	Present at the eastern extent of the groundwater study area (east of the Little Liverpool Ranges). Overlain by alluvial sediments of Western Creek.	2	Upper range: 400–600	Lithic and silty sandstone with interbedded mudstone and siltstone.	Aquifer/aquitard
Koukandowie Formation	Crops out as the topographic high of the Little Liverpool Range. Sub-crops below Western Creek alluvial sediments on the eastern flanks.	7	> 1,000 (upper range)	Interbedded sandstone, siltstone, claystone and minor coal	Low permeability fractured rock aquifer/aquitard
Gatton Sandstone	Present at the western extent of the Project and central Section between Toowoomba Range and Little Liverpool Range. Small areas of outcrop, but typically overlain by alluvial sediments of Lockyer Creek and Laidley Creek.	8	> 1,000 (upper range)	Medium- to coarse-grained sandstone	Low permeability fractured rock aquifer/aquitard
Woogaroo Subgroup	Forms the Helidon Hills north of Helidon, the southern flanks of which are intersected by the Project.	11	1,000 to 1,200 (Upper range)	Interbedded conglomerate, quartz, sand and fine-grained gravel, silty sandstone and laminated claystone.	Porous and fractured rock aquifer (unconfined to confined)

Table note:

1. Data sourced from the Clarence–Moreton Bioregional Assessment (Raiber et al., 2014) and reflects the upper thickness range in the region, not specifically within the groundwater study area.

14.6.2 Groundwater occurrence

The water table is typically a subdued version of topography, with the depth to groundwater increasing beneath topographic highs in the groundwater study area (for example the Helidon Hills and Little Liverpool Range). Shallower groundwater will occur in lower lying reaches within the groundwater study area (such as close to surface water drainage lines).

Depths to shallow groundwater will be affected by processes and influences including the interaction between local net recharge and the hydraulic conductivity of units, presence of shallow aquitards, surface water features and groundwater extraction.

The water table will occur in the alluvial sediments of Laidley Creek and Lockyer Creek through much of the central part of the groundwater study area, and Western Creek alluvial sediments east of the Little Liverpool Range. The Woogaroo Subgroup (west), Gatton Sandstone (central) and Koukandowie Formation (east) form the water table aquifer where they outcrop along limited sections of the groundwater study area.

Groundwater level data were available for September/October 2018 for 12 of 13 monitoring bores installed along the Project alignment as part of the geotechnical investigation (Golder Associates, 2019, refer Appendix W: Geotechnical Factual Report). Collection of further baseline data will provide additional spatial and temporal conditions/variations to inform final design and allow current understanding to be confirmed or refined. A summary of data referenced as part of the EIS is provided in Table 14.6.

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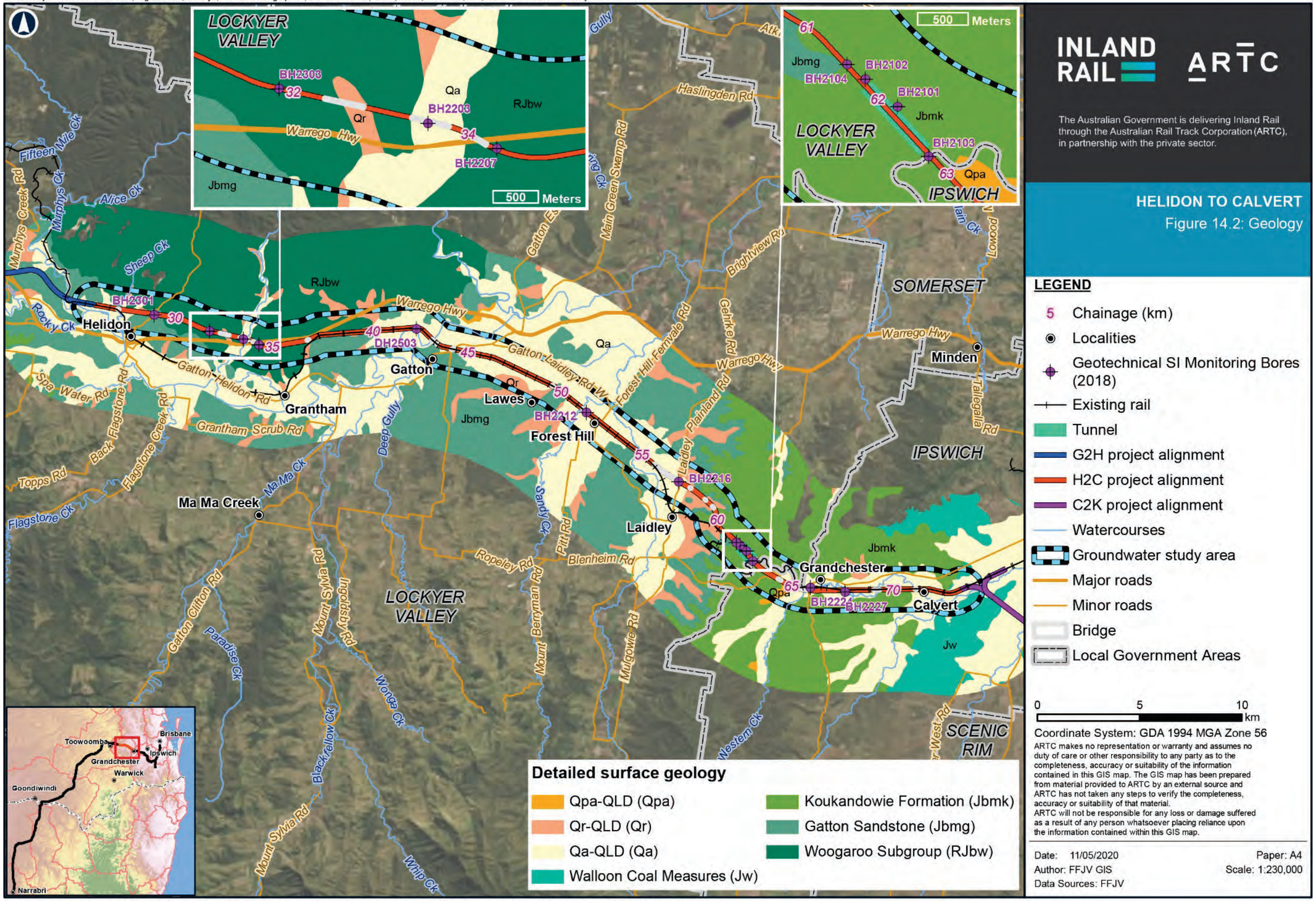

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TABLE 14.6: GROUNDWATER LEVEL DATA

Bore ID[1]	Aquifer	Filter pack interval (mbgs)	Depth to groundwater (mbgs)[2]	Groundwater elevation (m AHD)[2]	Comment
330-01-BH2101	Koukandowie Formation	100–129	82.5	162.5	Ch 62.20 km tunnel section.
330-01-BH2102	Marburg Subgroup (Koukandowie Formation)[3]	25–50	26.4	138.6	Ch 61.75 km tunnel section. Water table elevation.
330-01-BH2103	Gatton Sandstone (Koukandowie Formation)[3]	16–30	13.1	140.9	Ch 62.75 km tunnel section. Water table elevation.
330-01-BH2104	Koukandowie Formation	15–31	15.6	142.4	Ch 61.50 km tunnel section. Water table elevation.
330-01-BH2203	Alluvium	6–12.2	Dry	Dry	Ch 33.50 km bridge section. Water table > 12 mbgs.
330-01-BH2207	Woogaroo Subgroup	11.5–20.5	9.7	131.4	Ch 34.50 km bridge section. Possible water table elevation.
330-01-BH2212	Gatton Sandstone	23–27	Not reported	Not reported	Ch 51.50 km bridge section. Screened below alluvium.
330-01-BH2216	Gatton Sandstone	18.5–22.5	2.9	94.1	Ch 57.25 km bridge section. Screened across Alluvium and Gatton Sandstone.
330-01-BH2224	Gatton Sandstone	8.5–21.5	Not reported	Not reported	Ch 66.00 km bridge section. Screened across Alluvium and Gatton Sandstone.
330-01-BH2227	Koukandowie Formation	16–20	Not developed or tested prior to March 2019.		Ch 67.75 km bridge section.
330-01-BH2301	Gatton Sandstone	12–30	28.3	159.7	Ch 29.00 km cut section. Water table elevation.
330-01-BH2303	Gatton Sandstone (Woogaroo Subgroup)[3]	15–30	24.3	150.7	Ch 32.00 km cut section. Water table elevation.
330-01-DH2503	Gatton Sandstone	8–15	13.0	92.0	Ch 42.00 km fill section. Water table elevation.

Table notes:

mbgs—metres below ground surface; m AHD—Australian Height Datum; Ch—chainage.

1. All bores, with the exception of 330-01-DH2503, from 2018 H2C geotechnical investigation (Golder Associates, 2019, refer Appendix W: Geotechnical Factual Report).
2. Approximated from review of hydrographs for Sep/Oct 2018 (Appendix G of Golder Associates, 2019, refer Appendix W: Geotechnical Factual Report).
3. Aquifer in brackets refers to Golder Associates, 2020, refer Appendix A within Appendix N: Groundwater Technical Report description.

Regional mapping indicated a mean groundwater depth of 5 m to 15 m in Lockyer Valley basin alluvium for a wet period in 2008 to 2012 (Raiber et al., 2016). Under current management and climatic conditions, the Lockyer Valley alluvial aquifer remains under stress, with pumping often continued until bore yields decline significantly. However, groundwater levels partially recover during high rainfall years, and since the break of drought in 2008, and the flooding of 2011, significant recovery of groundwater levels has occurred in the Lockyer Valley (Raiber et al., 2016).

Mean groundwater level elevations for the Gatton Sandstone and Woogaroo Subgroup were presented by Raiber et al. (2016) for the Lockyer Valley and Bremer River basins. The pattern was similar in both formations, indicating mean groundwater elevations in the order of 100 m to 150 m AHD west of Gatton (approximately Ch 43.00 km), decreasing to 75 m to 100 m AHD east of Gatton. This is broadly consistent with those recorded as part of the ongoing Project geotechnical investigations (refer Table 14.6).

Four geotechnical site investigation monitoring bores (BH201 to BH204) were installed in the Marburg Subgroup (Koukandowie Formation and Gatton Sandstone) to target groundwater levels near the proposed Little Liverpool Range tunnel and portals. A groundwater divide is evident with depths to groundwater of around 15 m below ground surface (140 m AHD) near the western and eastern portals (BH2104 and BH2103), increasing to a depth of 80 m below ground surface (160 m AHD) beneath the topographic high of the Little Liverpool Range (at BH2101). Groundwater will flow west (beneath the western flanks) and east (beneath the eastern slopes). The height of groundwater above the tunnel and the hydraulic gradient either side of the divide will affect the rate of flow to the tunnel and portals. Since hydraulic heads increase during high rainfall episodes/seasons and decrease during extended periods of no/low rainfall, seasonality is also a factor controlling groundwater flow.

Intermediate and regional groundwater flow systems in alluvial sediments flow to the northeast and north through the western groundwater study area. These flow systems typically follow surface catchments as they ultimately drain into the Brisbane River. East of the Little Liverpool Range, groundwater within the alluvial sediments flows to the east and northeast as the Western Creek drains into the Bremer River system (refer Figure 14.3). Local groundwater flow systems will be influenced by surface water–groundwater interaction where there is a hydraulic connection.

Groundwater levels in the shallow bedrock, including the Woogaroo Subgroup, generally reflect the topography and flow to the northeast; however, local variations in flow directions are possible. Mapping of Woogaroo Subgroup and Gatton Sandstone groundwater elevations indicate that groundwater flow paths are influenced by the Lockyer Creek and Bremer River systems (refer Figure 14.3). The potentiometric surface shows that lower groundwater elevations correspond to alluvial sediments suggesting these act as regional discharge areas for the underlying and flanking Clarence–Moreton Basin sedimentary sequence. In the groundwater study area, the Koukandowie Formation outcrops in the Little Liverpool Range, and groundwater flow direction is controlled by a groundwater divide coinciding with the main ridge line, as described above.

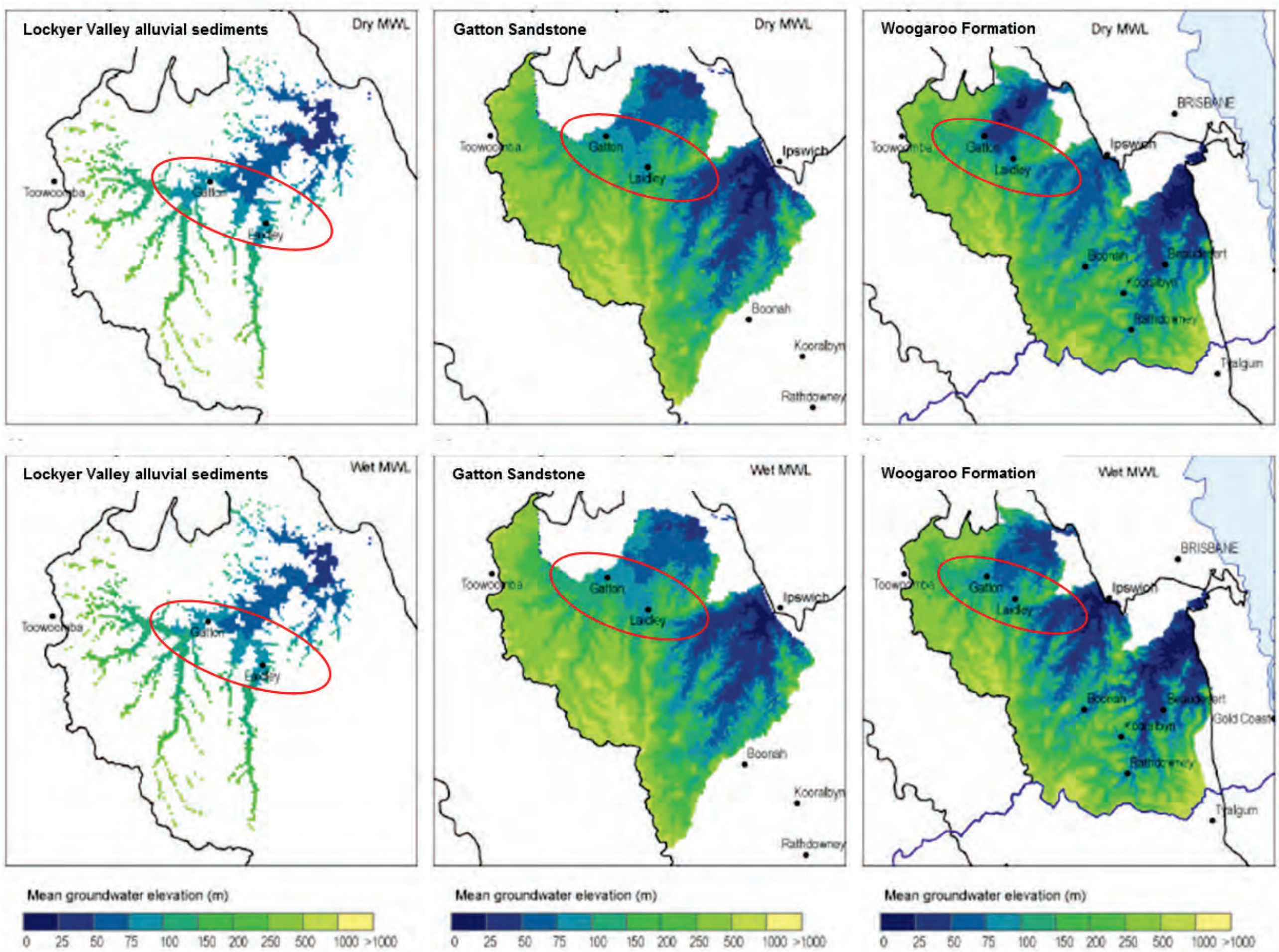

FIGURE 14.3: MEAN GROUNDWATER LEVEL ELEVATION DURING DRY PERIOD (2000 TO 2007) AND A WET PERIOD (2008 TO 2012)

Source: Raiber et al., 2016

14.6.3 Groundwater recharge and discharge

14.6.3.1 Recharge

There is a net monthly and annual deficit of rainfall across the groundwater study area as average evaporation exceeds average rainfall for all months. Direct infiltration of rainfall to groundwater is unlikely during dry periods, when light rainfall events will be absorbed by soil moisture only to be subsequently lost to evapotranspiration. Overall net recharge is expected to occur in response to higher and more continuous rainfall events.

Groundwater recharge values were estimated by Raiber et al. (2016) and summarised in Golder Associates (2020), with rainfall recharge found to be in the order of 3 millimetres per year (mm/yr) to 4 mm/yr for the Walloon Coal Measures, Gatton Sandstone and Koukandowie Formation, and around 11 mm/yr for the alluvium aquifers. A higher recharge rate in the order of 30 mm/yr was considered typical for the Woogaroo Subgroup.

In areas with alluvial or colluvial materials, recharge is anticipated to be supplied by a combination of:

- Direct infiltration of rainfall and associated stream flow
- Seepage from ephemeral streams during periods of flow following rainfall
- Infiltration by surface water releases from Bill Gunn Dam (Lake Dyer) and Lake Clarendon Dam (off-stream storages that release water back into the creeks of the Central Lockyer as part of the Central Lockyer Water Supply Scheme)
- Sub-cropping rock below alluvium may also act as a source of recharge where upward vertical gradients and hydraulic connection occur, such as vertical discharge from the Gatton Sandstone into overlying alluvial sediments associated with watercourses (such as Lockyer Creek and Laidley Creek).

The two dams are located east of Gatton and are filled by diverting water from nearby creeks during significant rainfall events. The dams supply water for the Morton Vale Pipeline and recharge groundwater areas adjacent to Lockyer Creek (including Laidley Creek in the groundwater study area), as well as supply downstream area-based surface water entitlements. The water levels in both dams have been below minimum supply levels since 2018. Water supply from these dams will not be possible until rainfall is sufficient to allow Seqwater to increase the allocation above zero percent (Seqwater, 2019).

Recharge to the water table in rock formations occurs via direct infiltration of rainfall where the formations are exposed at the surface or blanketed by a thin layer of soil. For example, along ridgelines formed by the Woogaroo Subgroup (29.2 mm/yr) and Koukandowie Formation (2.7 mm/yr), and in lower-lying areas where the Gatton Sandstone (3.7 mm/yr) is not overlain by alluvial sediments. Recharge from overlying alluvial sediments may also occur where a downward hydraulic gradient occurs (i.e. where groundwater elevations in the alluvial sediments are higher than those in the underlying bedrock sediments). Regional groundwater elevations indicate that groundwater generally discharges to alluvial sediments from underlying sedimentary rocks (refer Figure 14.3); however, this may be locally and temporarily reversed following large rainfall or flooding events.

14.6.3.2 Discharge

In areas with alluvial or colluvial materials, discharge may occur via seepage to ephemeral streams and into underlying bedrock units during periods of higher groundwater levels. Discharge out of the groundwater study area will also occur as 'underflow' or 'baseflow' on alluvial sediments beneath creek channels (such as Lockyer and Laidley creeks). Evapotranspiration from vegetation growing in the creek beds and along the banks is also a primary discharge mechanism from this unit.

Discharge from the bedrock rock formations occurs via seepage into adjacent aquifers (including the overlying alluvial sediments when upward hydraulic gradients occur), and as throughflow to the north and north-east out of the groundwater study area. Discharge will also occur via evapotranspiration, typically along the ridgelines and in outcrop areas.

Groundwater discharge will also occur via pumping bores, particularly from the alluvial sediments that are heavily used in the Lockyer Valley. Groundwater users and source aquifers are discussed in Section 14.6.6.

14.6.4 Groundwater quality and yield

14.6.4.1 Groundwater quality

Groundwater quality is discussed here in terms of salinity, total dissolved solids (TDS) as milligrams per litre (mg/L) and/or electrical conductivity (EC) as microSiemens per centimetre (μS/cm)[1]. These parameters readily allow comparison of groundwater condition, hydrogeological mechanisms (i.e. recharge/discharge areas) and the potential uses that the groundwater is suitable for (i.e. the EV of the groundwater). Groundwater salinity is characterised as being freshwater (and potable) where TDS is 0 mg/L to 1,000 mg/L, brackish where TDS is 1,001 mg/L to 10,000 mg/L and saline where TDS is between 10,001 mg/L and 100,000 mg/L. For a TDS beyond 10,000 mg/L groundwater is considered brine (Fetter, 2014).

Typically, groundwater in the alluvium is fresher than groundwater in the underlying sedimentary bedrock (primarily the Gatton Sandstone in the groundwater study area), but spatially and temporally highly variable —ranging from fresh to very saline—in the Lockyer Valley alluvium. The primary controls of the spatial variability are the nature of connectivity of the alluvial aquifer with surface water and the underlying bedrock. For example, groundwater is commonly fresh, near the headwaters of the Lockyer Creek and in the upper parts of the tributaries to the Lockyer Creek (south of the groundwater study area)—marking the good-quality groundwater of the Main Range Volcanics as a major source of recharge to the alluvial aquifer (Rassam et al., 2014). Groundwater in the Lockyer Valley alluvium gradually becomes more saline (i.e. the quality decreases) down gradient, likely due to increasing influence of upwards leakage of more saline groundwater from the underlying bedrock (predominantly Gatton Sandstone within the groundwater study area, refer Table 14.7 and Table 14.8).

Water quality in the bedrock sediments varies from fresh to saline across the region for reasons including lithological variability, relative position in the basin, recharge processes, depth, and surface-water interaction (Rassam et al., 2014). The Woogaroo Subgroup, which is the deepest unit in the Clarence–Moreton Basin, contains the freshest groundwater of all sedimentary bedrock units, which reflects the higher recharge rate compared to the other hydrostratigraphic units. The potentially high yields of the Woogaroo Subgroup aquifer mean that it is extensively used for groundwater extraction in Queensland near the northern margin of the sedimentary basin in the Lockyer Valley, where the unit occurs at shallow depths (Raiber, 2017).

1. Electrical conductivity is a measurement of how well an aqueous solution can conduct an electrical current (in μS/cm). TDS can be approximated from EC using a conversion factor, which changes depending on the type of salts in the groundwater. TDS can also be measured directly by a laboratory. Salinity is like TDS in that it is an estimate of salt in the water, derived from EC using a conversion factor (typically 0.5).

An assessment of salinity and EC in the Clarence–Moreton Basin was provided by Rassam et al. (2014) based on multiple references and data sets. A summary is provided in Table 14.7, together with available data from bores within the groundwater study area.

TABLE 14.7: SUMMARY OF GROUNDWATER SALINITY

Aquifer unit	Salinity (mg/L)			EC (µS/cm)			Groundwater study area[1]
	Min	Mean	Max	Min	Mean	Max	
Lockyer Valley alluvium	91 (approx.)	1,904	18,000	-	3,327	-	1,200–6,600 µS/cm (Laidley Creek) 1,750–4,040 µS/cm (Lockyer Creek)—qualitative descriptor is 'potable'
Koukandowie Formation	359	4,248	14,496	-	6,607	-	No data available (Koukandowie Formation)
Gatton Sandstone	333	6,452	24,294	-	9,971#	-	1,042 µS/cm (Gatton Sandstone)[2] 700–3,890 µS/cm (Marburg Subgroup)—qualitative descriptors are 'potable' to 'brackish'
Woogaroo Subgroup	961	2,518	4,147	-	4,225	-	No data available—qualitative descriptors is 'potable'

Table notes:
- \# Higher mean due to different data source referenced in Rassam et al. (2014).
1. Data sourced from the DNRME (now DRDMW) groundwater database and is taken as the range for the bores identified within the unit.
2. A single value is recorded in the DNRME (now DRDMW) groundwater database for this unit within the groundwater study area.

Data is also available from groundwater sampling conducted in October 2018 at seven of the Project geotechnical site investigation monitoring bores (with field measurements taken at an additional two bores). Laboratory results for EC and TDS are summarised in Table 14.8 and are generally consistent with the findings of Rassam et al. (2014) for the wider Clarence–Moreton Basin (refer Table 14.7) with TDS values in groundwater from sedimentary bedrock formations in the groundwater study area typically brackish (i.e. between 1,001 mg/L and 10,000 mg/L TDS).

TABLE 14.8: SUMMARY OF GROUNDWATER SALINITY—GEOTECHNICAL SITE INVESTIGATIONS

Bore ID	Formation sampled	TDS (mg/L)	EC (µS/cm)
330-01-BH2101	Koukandowie Formation	-	1,746 (field EC)
330-01-BH2102	Koukandowie Formation	2,340	4,260
330-01-BH2103	Koukandowie Formation	2,170	3,810
330-01-BH2104[1]	Koukandowie Formation	2,390	4,260
330-01-BH2203	Alluvium	Insufficient water to procure quality sample	
330-01-BH2207[2]	Woogaroo Subgroup	995	1,730
330-01-BH2212	Gatton Sandstone	2,940	5,500
330-01-BH2216[3]	Gatton Sandstone	1,180	2,530
330-01-BH2224[3]	Gatton Sandstone	-	1,284 (field EC)
330-01-BH2227	Koukandowie Formation	No development or sampling undertaken to March 2019 due to access issues	
330-01-BH2301	Gatton Sandstone	Insufficient water to procure quality sample	
330-01-BH2303	Woogaroo Subgroup	999	1,720
330-01-DH2503	Koukandowie Formation	Insufficient water to procure quality sample	

Table notes:
1. Stated as BH22104 on laboratory Certificate of Analysis.
2. Stated as BH2307 on laboratory Certificate of Analysis (CoA) in Golder Associates (2018)—refer Appendix W: Geotechnical Factual Report.
3. BH2216 and BH2224 screened across alluvium and Gatton Sandstone.

Where it was not possible to obtain groundwater samples (BH2203, BH2227, BH2301, BH2503), the outcomes of the assessment have not been compromised.

14.6.4.2 Groundwater yield

Yields from bores in the alluvium vary between 0.5 litres per second (L/s) to 37.8 L/s across the groundwater study area (based on the data available—no relevant yield data from October 2018 field works). This high range of yield variability is attributed to the extent and nature of alluvial sediments that vary from coarse gravels to silty clays.

Regional studies have shown that the pre-Cenozoic aquifers within the Clarence—Moreton Basin sequence are generally low yielding. Average yields ranging from 0.5 L/s to 2.5 L/s in the sandstones, siltstones and conglomerates of the Bundamba Group, which includes the Woogaroo Subgroup, the Gatton Sandstone and the Koukandowie Formation (Rassam et al., 2014).

The Ripley Road Sandstone forms the upper unit of the Woogaroo Subgroup and is equivalent to the Precipice Sandstone of the Surat Basin (west of the Toowoomba Ranges). The unit comprises a coarse-grained and predominantly clean quartz rich sandstone as well as quartz-rich granule conglomerate. It is a reliable producer of good quality water, with yields of up to 6.3 L/s (DNRME (now DRDMW) groundwater database), providing base flow to the creeks where it is present within the Lockyer Creek.

A summary of bore yields in the groundwater study area is provided in Table 14.9. Yields are generally low for the sedimentary bedrock aquifers, but dependent on the lithology intersected (sandstone, siltstone, mudstone) and frequency, size and interconnectivity of fractures. Some higher yields are recorded for alluvial aquifer bores, generally consistent with regional studies. No yield data was available for the Gatton Sandstone in the groundwater study area based on a search of the DNRME (now DRDMW) groundwater database.

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

TABLE 14.9: STUDY AREA BORE YIELDS

Aquifer unit	No. of bores	Yield (L/s)		
		Min	Mean	Max
Alluvium	36	0.5	12.5	37.8
Koukandowie Formation	1	0.5	0.5	0.5
Gatton Sandstone	-	-	-	-
Marburg Subgroup (undifferentiated)	5	0.6	1.2	2.5
Woogaroo Subgroup	8	0.6	1.5	6.3

14.6.5 Hydraulic properties

Regional scale reviews of aquifer parameters have been carried out by Raiber et al. (2016) and Golder Associates (2020), and site-specific hydraulic conductivity values were estimated from testing carried out as part of the geotechnical investigations (Golder Associates, 2019; refer Appendix W: Geotechnical Factual Report). A summary is in Table 14.10 for units relevant to the groundwater study area.

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

TABLE 14.10: SUMMARY OF HYDRAULIC CONDUCTIVITY VALUES

Formation	Literature review (Raiber et al., 2016)		Literature review (Golder Associates, 2020[c])		Slug tests (Golder Associates, 2020[c])	
	No. of bores	Hydraulic conductivity (m/day)	No. of tests	Hydraulic conductivity (m/day)	No. of tests	Hydraulic conductivity (m/day)
Alluvium	193	0.09–1,500	NR	0.09–276	1	0.285
Marburg Subgroup (undifferentiated)	8	0.03–5.8	-	-	1	0.0007 to 0.0073
Marburg Subgroup: Koukandowie Formation	-	-	61	0.003–0.08	3b	0.25
Marburg Subgroup: Gatton Sandstone	2	1.1–4.9	88	0.17–0.12	6	0.0002 to 0.31
Woogaroo Subgroup	11	0.008–23.9	NR	0.04–4.3	1	0.001 to 0.49

Table notes:
NR—Not reported.
m/day—metres per day.
a. Raiber et al. (2016).
b. Falling head packer testing at three depths at 330-01-BH2101.
c. Refer Appendix A within Appendix N: Groundwater Technical Report.

14.6.6 Groundwater users

14.6.6.1 Registered bores

Based on a search of the DNRME (now DRDMW) groundwater database (accessed 5 March 2019), a total of 510 groundwater bores were identified within the groundwater study area. Two of unknown status, 124 decommissioned, abandoned or proposed, and the remaining 384 are designated as 'existing'. The DNRME (now DRDMW) groundwater database includes all licensed bores within the groundwater study area however there are potentially unregistered bores within the groundwater study area. Further explanation is provided in Section 14.6.6.3.

A summary of the 386 bores (384 existing and two unknown status) is provided in Table 14.11, and bore locations are shown on Figure 14.4a to Figure 14.4g. The number and distribution of bores reflect the heavy use of groundwater in the groundwater study area for water supply purposes, particularly from the alluvial aquifers of the Lockyer Valley.

TABLE 14.11: SUMMARY OF REGISTERED BORES WITHIN 1 KM OF PROJECT ALIGNMENT

Aquifer unit	Total number of bores	Depths2	Uses1
Alluvium	176	9 x shallow 160 x deep 7 x unknown	18 x **IN**; 6 x **SM**; 6 x **TW**; 92 x **WS**; 54 x unknown
Koukandowie Formation	1	1 x deep	1 x **WS**
Gatton Sandstone	1	1 x deep	1 x unknown
Marburg Subgroup (undifferentiated)	29	6 x shallow 23 x deep	1 x **IN**; 5 x **SM**; 19 x **WS**; 4 x unknown
Woogaroo Subgroup	16	16 x deep	2 x **SM**; 12 x **WS**; 2 x unknown
Unknown	163	24 x shallow 109 x deep 30 x unknown	1 x **SM**; 68 x **WS**; 92 x unknown

Table notes:
1. **IN**—Investigation; **SM**—Sub-artesian Monitoring; **TW**—Town Water; **WS**—Water Supply.
2. Shallow bores: less than or equal to 15 m and deep bores: greater than 15 m.

14.6.6.2 Groundwater entitlements

Water usage within the groundwater study area is dominated by irrigation use (92 per cent of all entitlements are irrigation). A summary of groundwater entitlements relevant to the groundwater study area is provided in Table 14.12. Water access licences data has been sourced from the DNRME (now DRDMW) groundwater entitlements database (accessed 21 February 2020).

TABLE 14.12: SUMMARY OF GROUNDWATER ENTITLEMENTS FROM AQUIFERS SURROUNDING THE PROJECT

Queensland Water Plan	Groundwater source	Licensed purpose	No. of entitlements	Water made available (ML/yr)	% of assigned water volume
Water Plan (GABORA) 2017	Marburg Subgroup (including Koukandowie Formation and Gatton Sandstone)[1]	Industrial	2	1	100[3]
		Domestic	1	12	
	Woogaroo Subgroup[2]	Domestic	5	4	100[3]
	Helidon Sandstone2	Amenities	1	4	100[3]
		Domestic	9	25	
		Industrial	2	51	
		Irrigation	4	5	
	Walloon Coal Measures	None	-	-	-
Water Plan (Moreton) 2007	Laidley Creek alluvium	Irrigation	103	50	< 2[4]
	Lockyer Creek alluvium	Industrial	2	Nil	
		Irrigation	174	Nil	
		Town water supply	1	Nil	
	Redbank Creek alluvium	Industrial	1	Nil	
		Irrigation	2	Nil	
	Sandy Creek alluvium	Irrigation	7	Nil	

Table notes:

ML/yr—megalitres per year.

1. This is listed under the Murphys Creek Marburg Groundwater Management Subgroup.
2. This is listed under the Murphys Creek Woogaroo Groundwater Management Subgroup.
3. Listed in Schedule 4: volume of unallocated water for water licenses to be granted from reserves of the *Water Plan (GABORA) 2017*.
4. The maximum allowable volume to be taken in each groundwater trading zone is 9,532 ML (Table 2 of Division 1 in the *Water Plan (Moreton) 2007)*.

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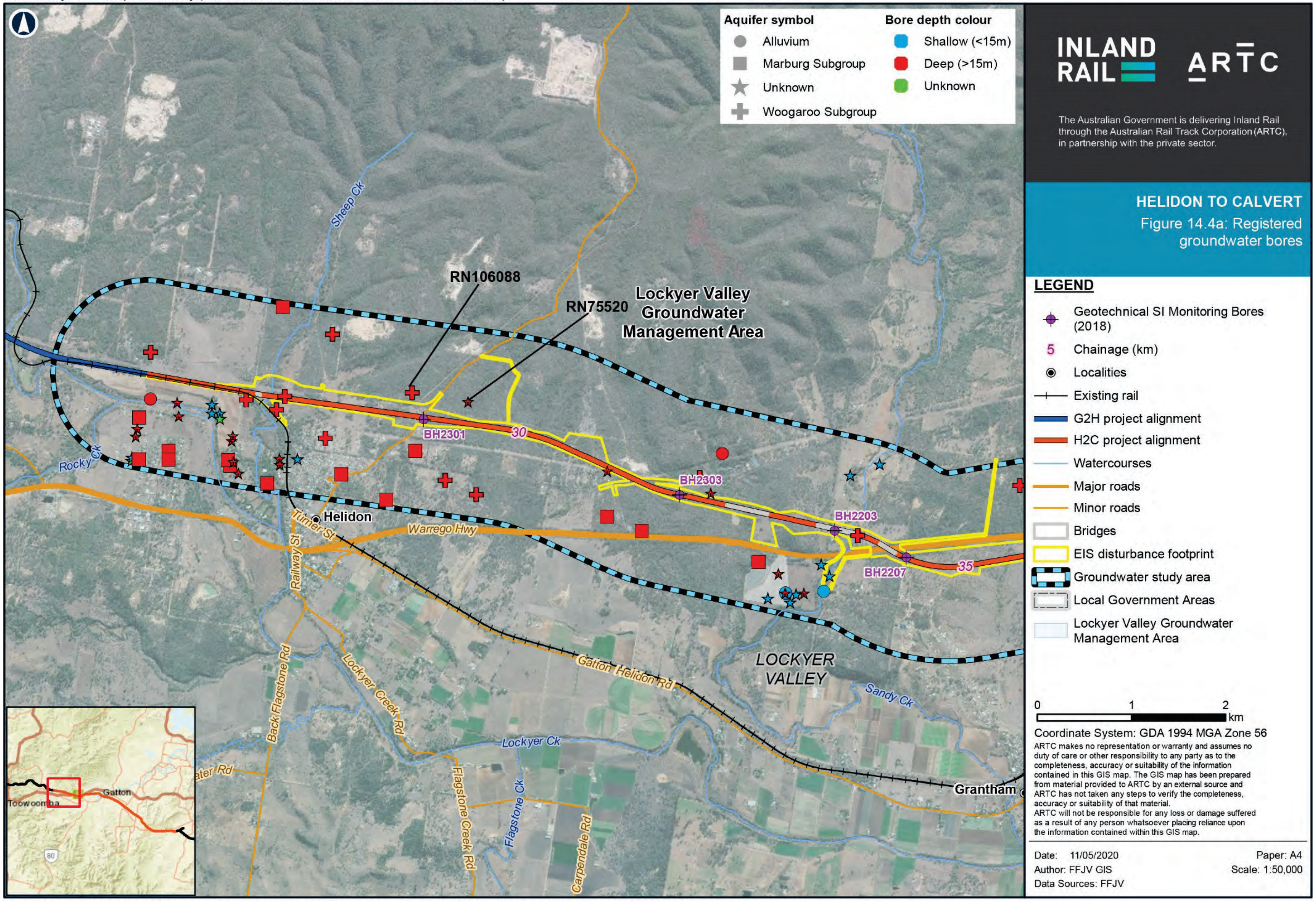

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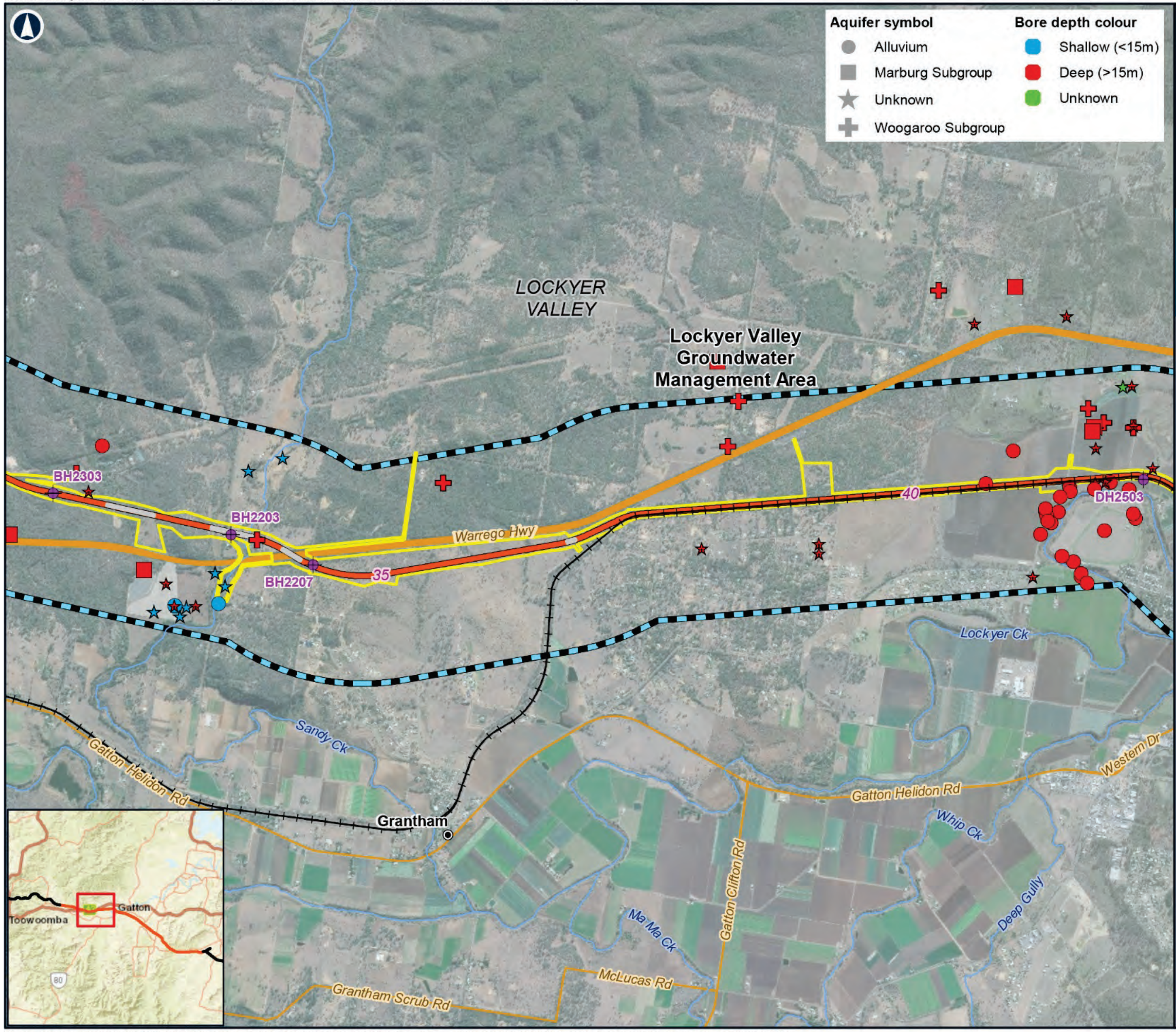

INLAND RAIL ARTC

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

HELIDON TO CALVERT

Figure 14.4b: Registered groundwater bores

LEGEND

- Geotechnical SI Monitoring Bores (2018)
- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Watercourses
- Major roads
- Minor roads
- Bridges
- EIS disturbance footprint
- Groundwater study area
- Local Government Areas
- Lockyer Valley Groundwater Management Area

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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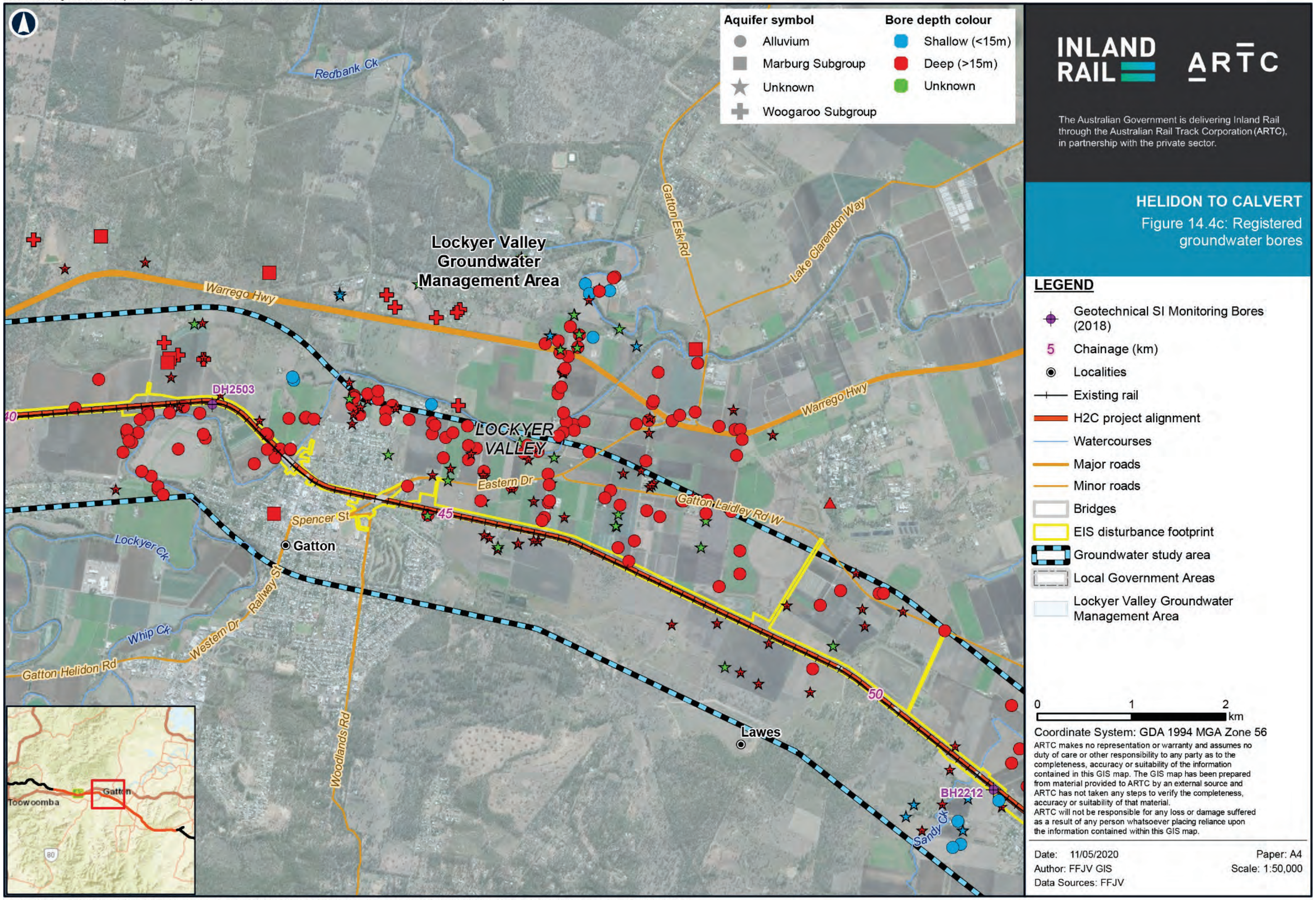

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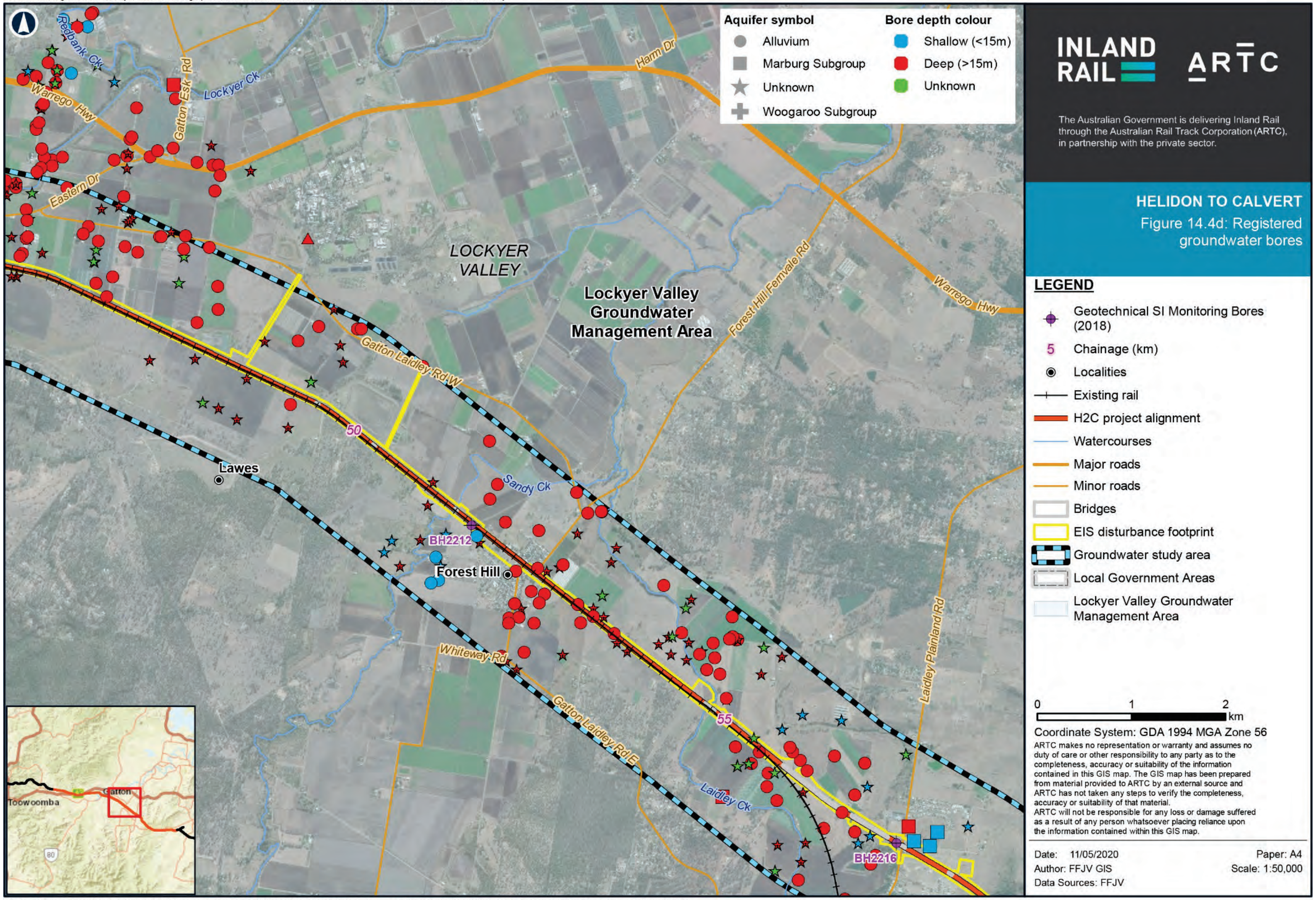

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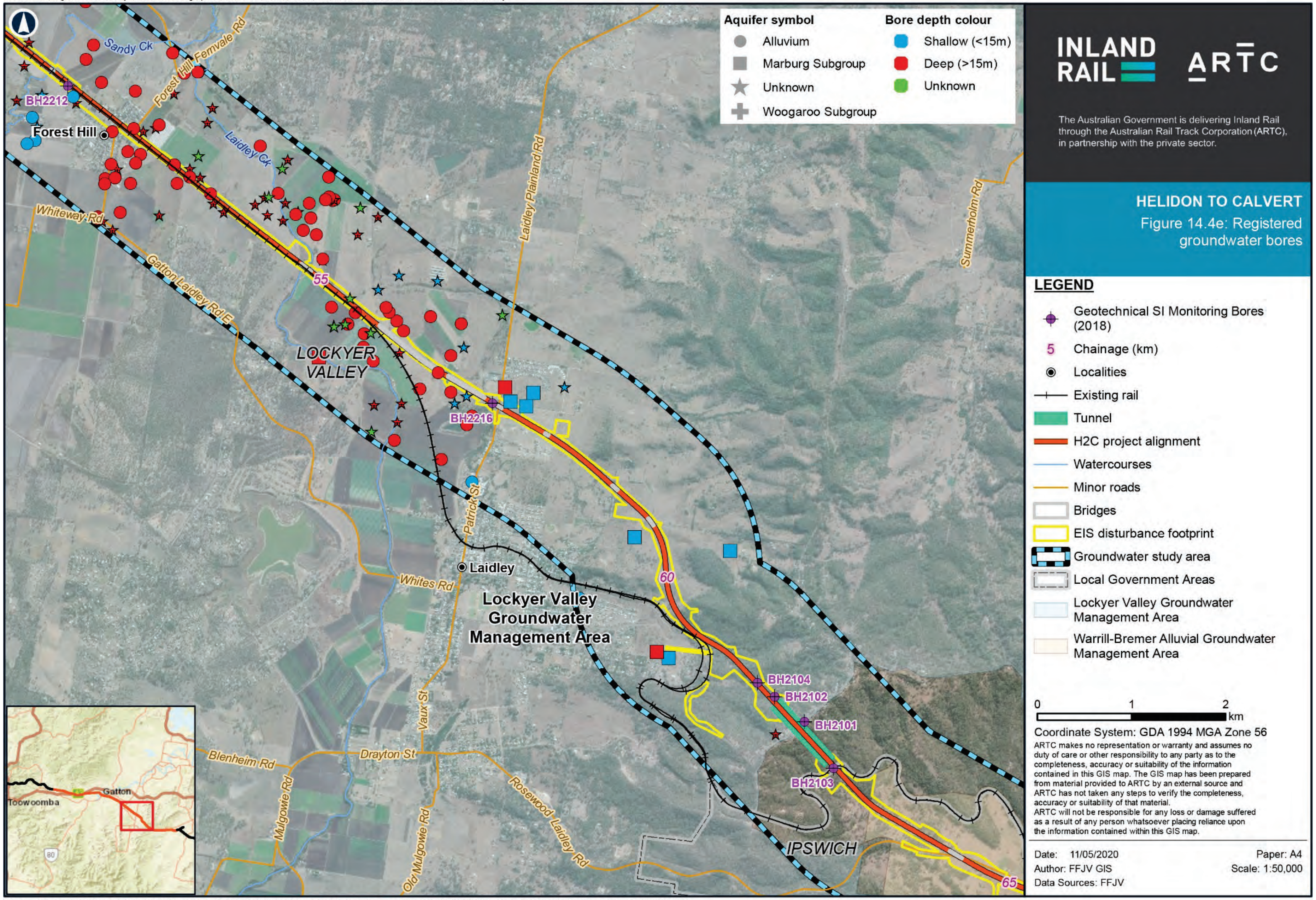

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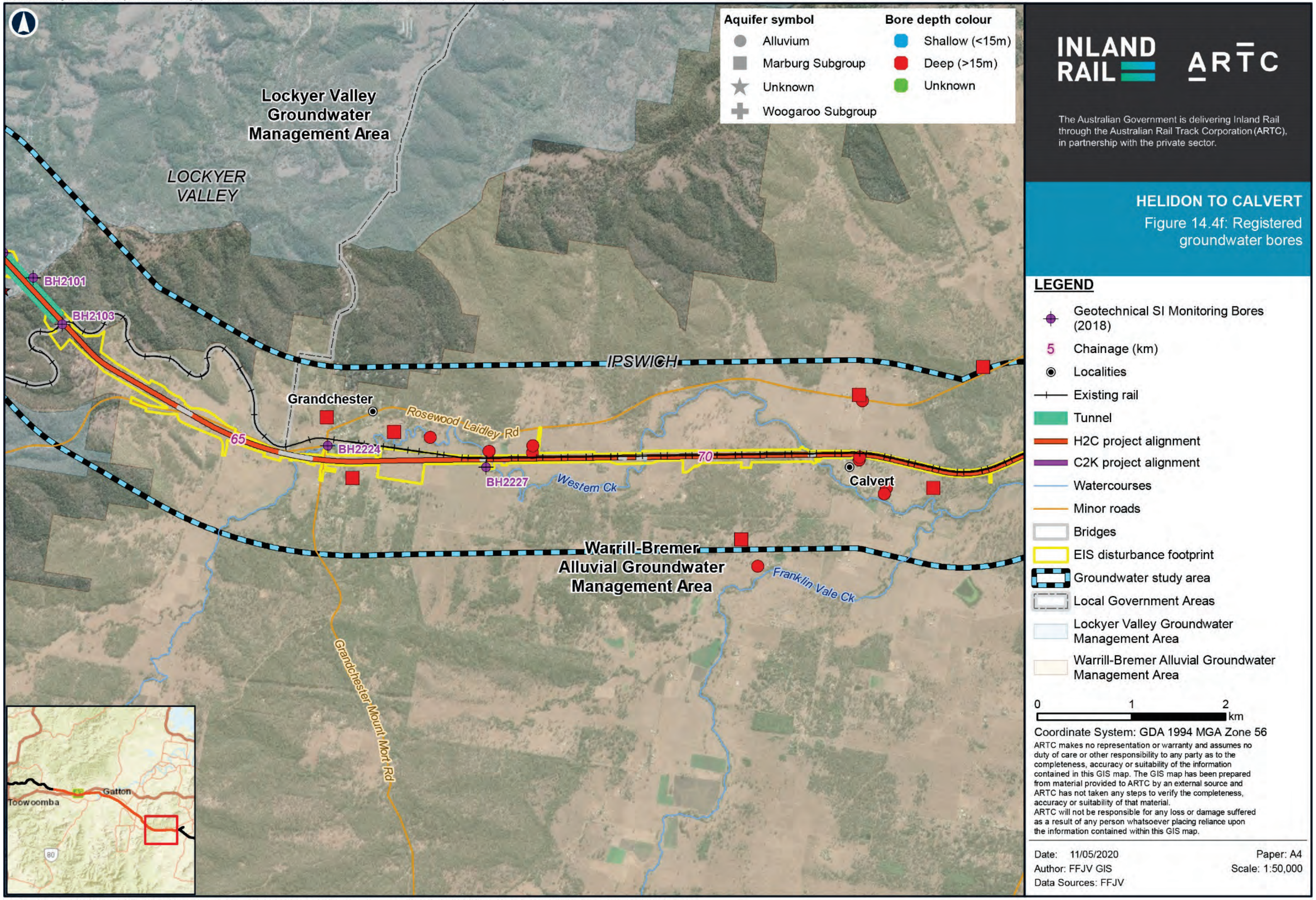

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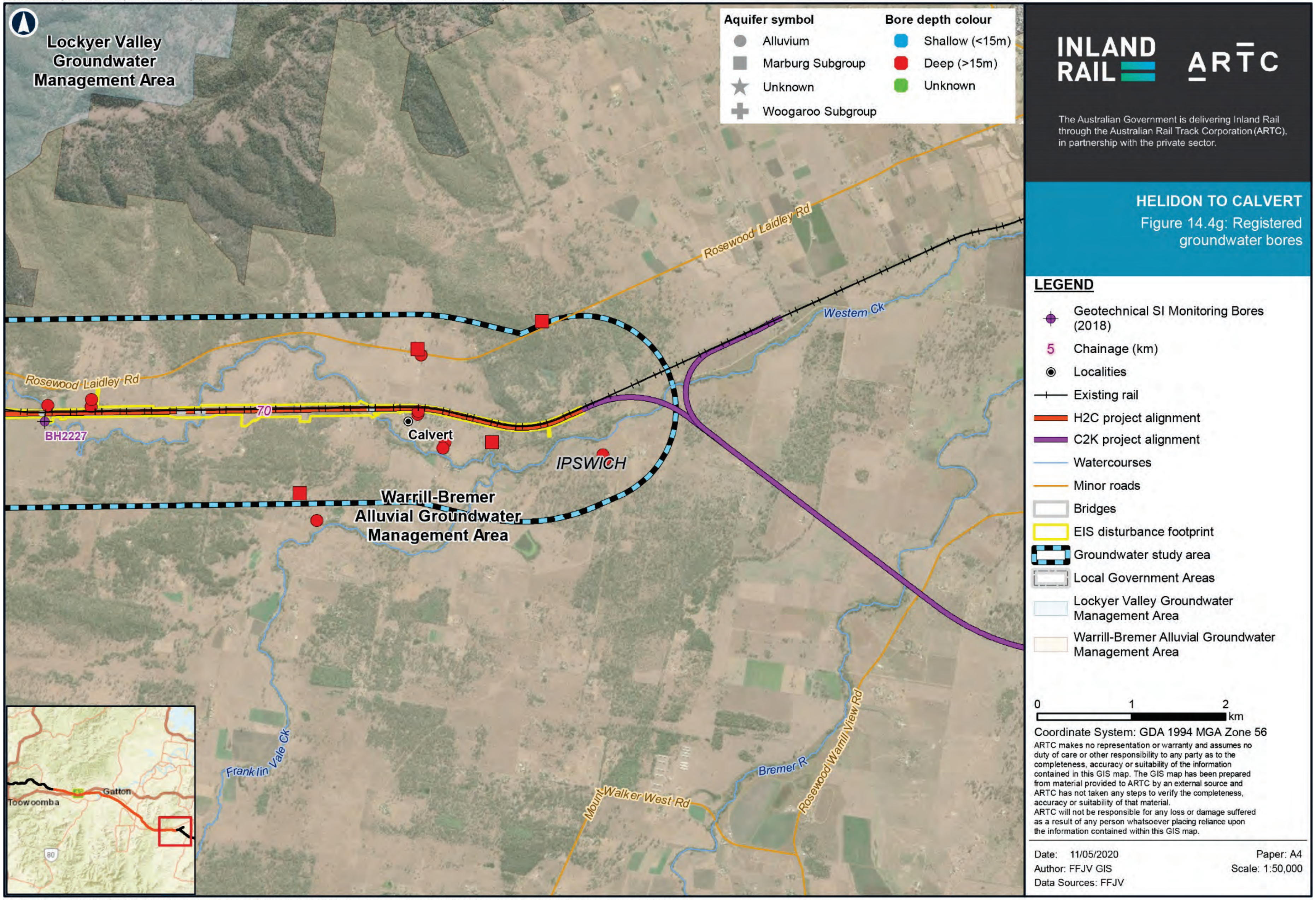

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14.6.6.3 Unregistered bores

The DNRME (now DRDMW) groundwater database includes all registered bores within the groundwater study area. However, there are potentially unregistered bores within the groundwater study area. Bores constructed before 2002 were not required to register with DNRME (now DRDMW) and, as a result, the DRNME groundwater database is not a complete record of bores within the groundwater study area; however, it is the most accurate and recent information available publicly. A groundwater bore survey will be required during the detailed design phase to capture groundwater bores within the groundwater study area through physical survey via liaison with landowners. This will include discussions with the landowners regarding the presence of any unregistered bores (old and new bores not yet registered with the DNRME (now DRDMW) groundwater database).

14.6.7 Groundwater dependent ecosystems

The Groundwater Dependent Ecosystems Atlas (GDE Atlas) was developed as a national dataset of Australian GDEs and potential GDEs (**bom.gov.au/water/groundwater/gde/map.shtml**). The GDE Atlas contains information on:

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

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

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

The identification of potential GDEs are based on national assessment and regional studies and does not confirm that the particular ecosystem is groundwater dependent.

No potential subterranean GDEs have been identified in the groundwater study area.

14.6.7.1 Potential aquatic groundwater dependent ecosystems

There are numerous moderate and low potential aquatic GDEs (from regional studies) within the groundwater study area, including Lockyer Creek, Laidley Creek and Western Creek (and their tributaries).

These GDEs are generally described as wetlands associated with alluvial aquifers on the BoM GDE Atlas (**bom.gov.au/water/groundwater/gde**).

There are no registered groundwater springs within the groundwater study area based on a review of the Queensland Globe website (**qldglobe.information.qld.gov.au**), with the nearest being Helidon Spring located 4 km south of Ch 26.00 km.

As no ground truthing of these environments was undertaken, it has been assumed that the modelled extent of the aquatic GDEs are a true and accurate indication of presence. The aquatic GDEs have been conservatively adopted as a potential sensitive receptor.

The locations of potential aquatic GDEs are shown on Figure 14.5a to Figure 14.5g.

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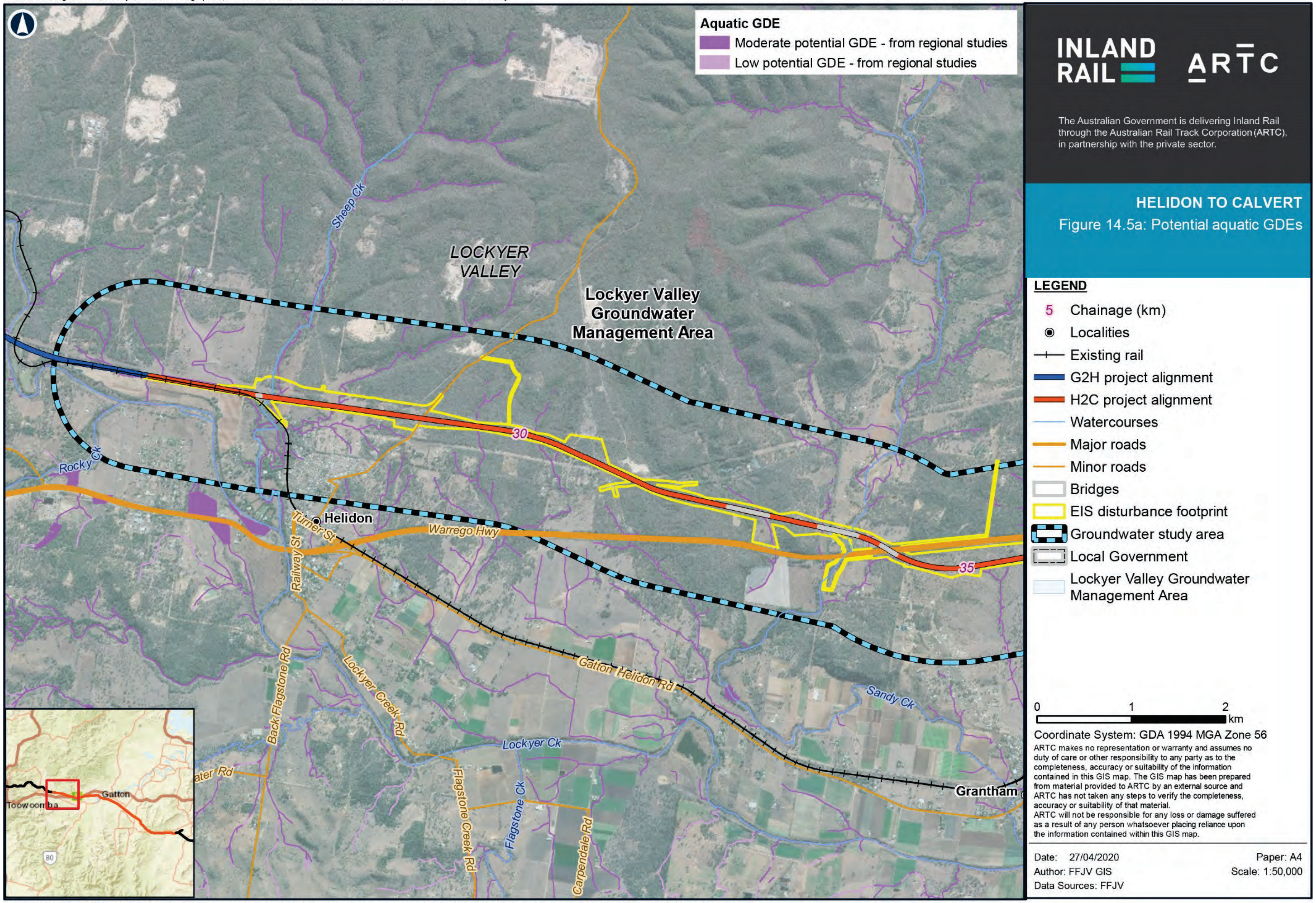

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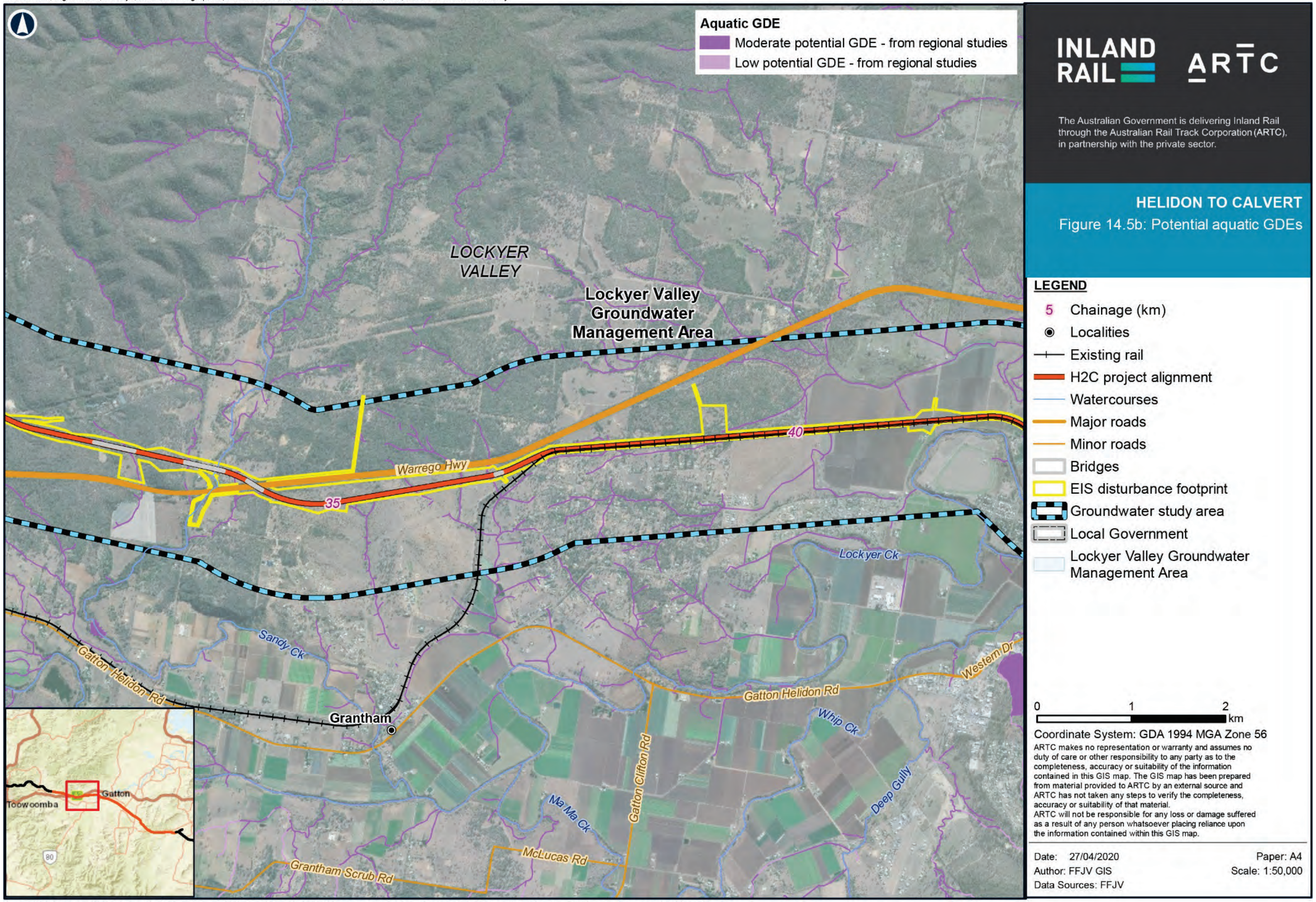

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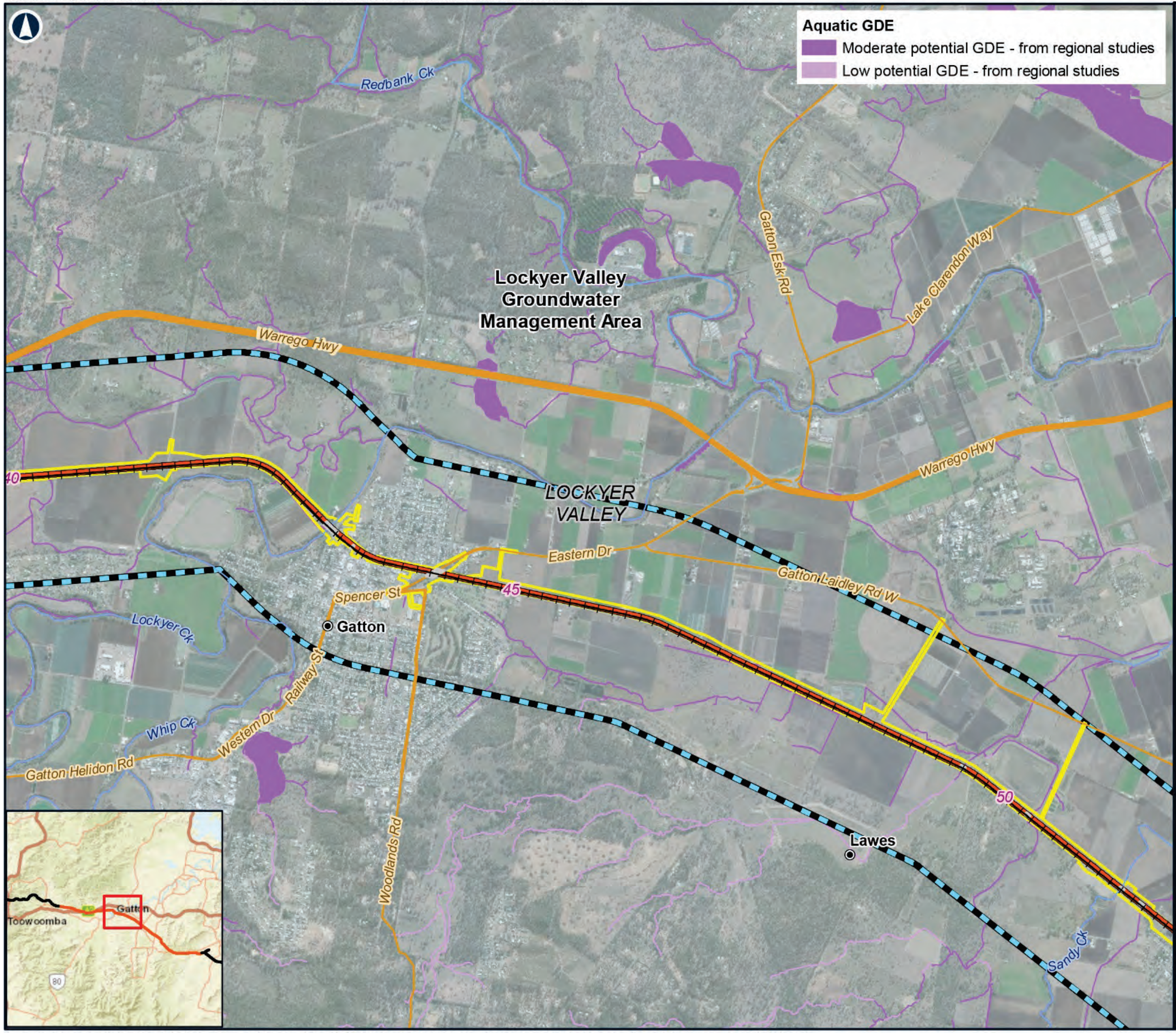

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Figure 14.5c: Potential aquatic GDEs

LEGEND

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Watercourses
- Major roads
- Minor roads
- Bridges
- EIS disturbance footprint
- Groundwater study area
- Local Government
- Lockyer Valley Groundwater Management Area

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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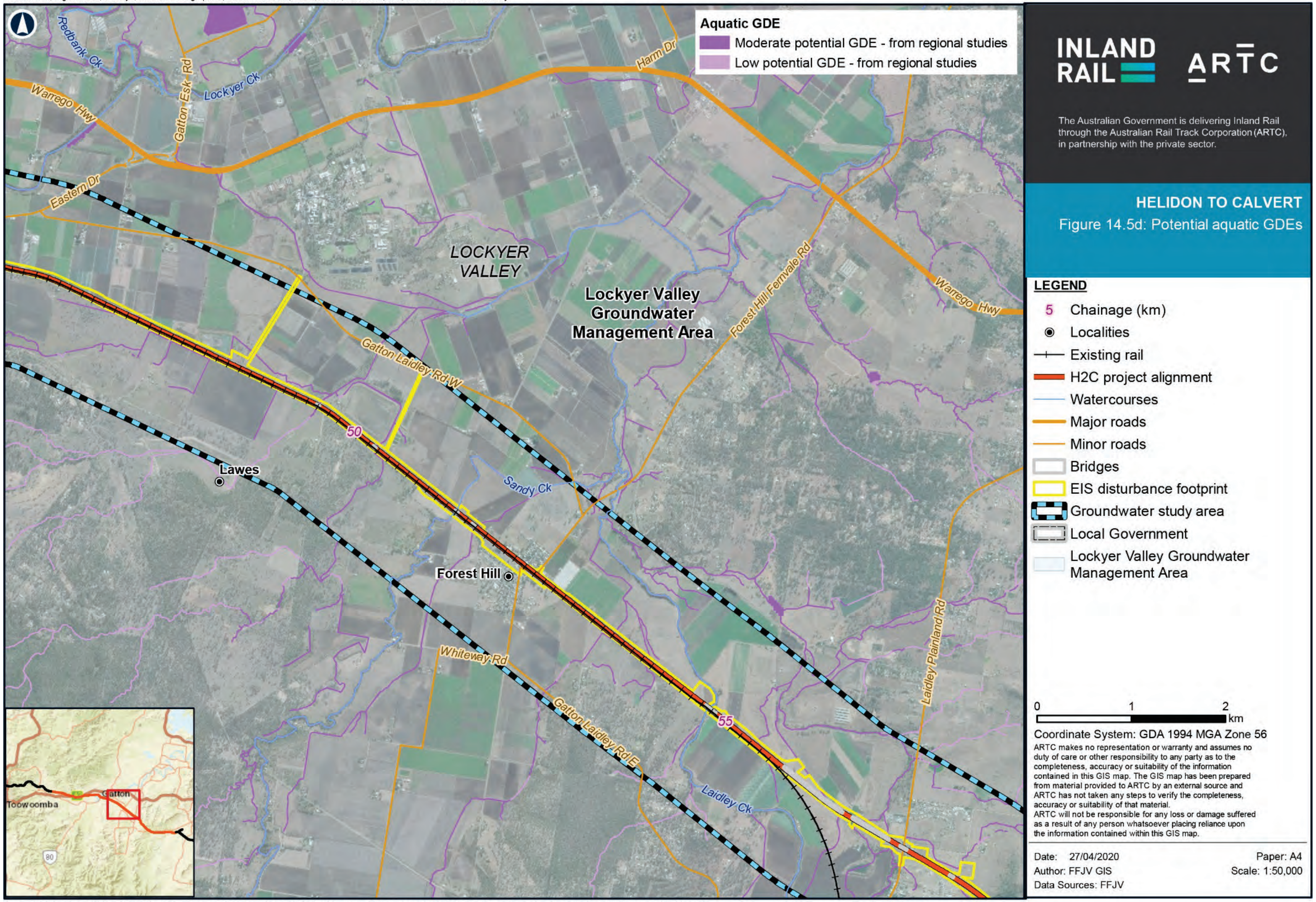

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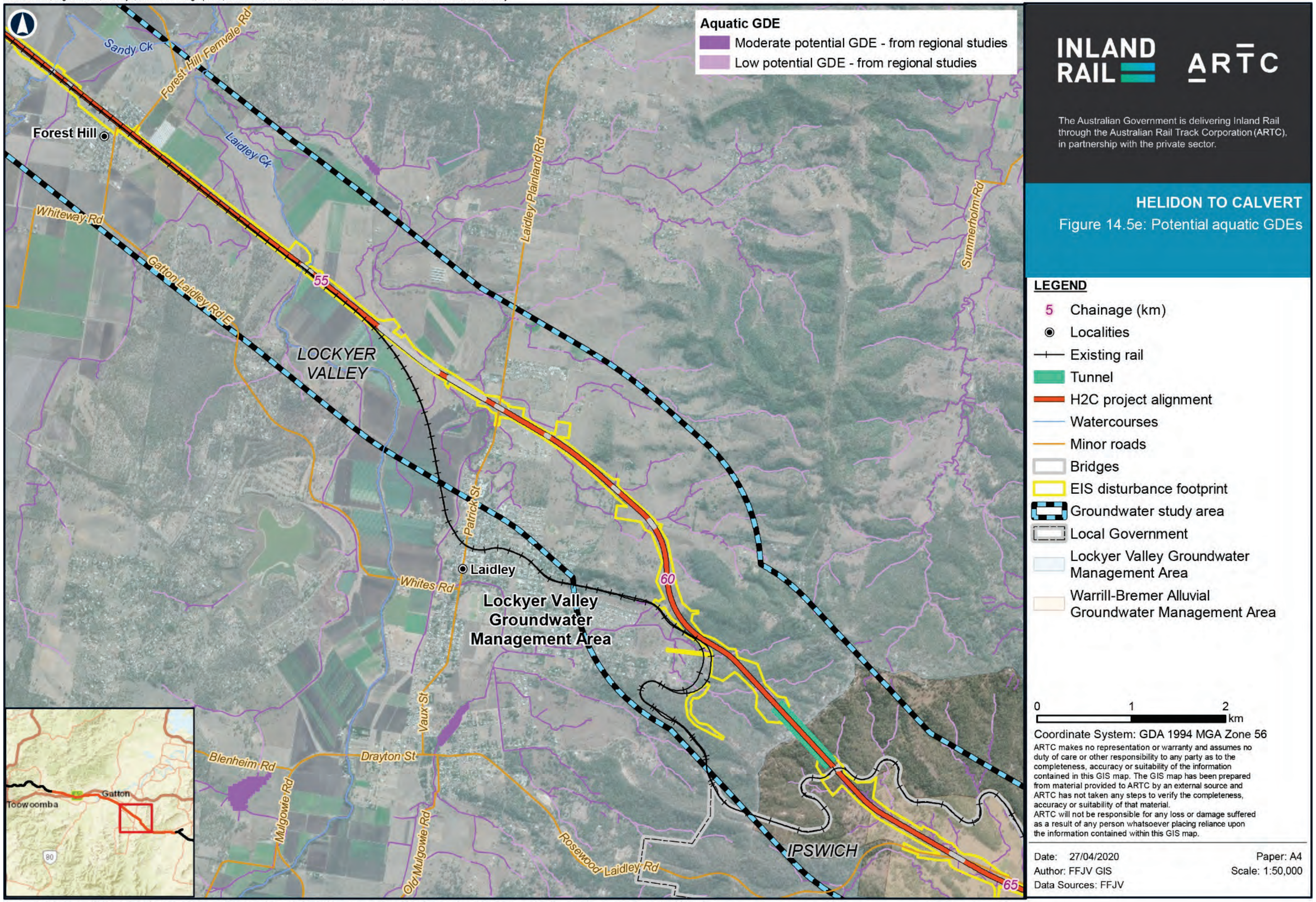

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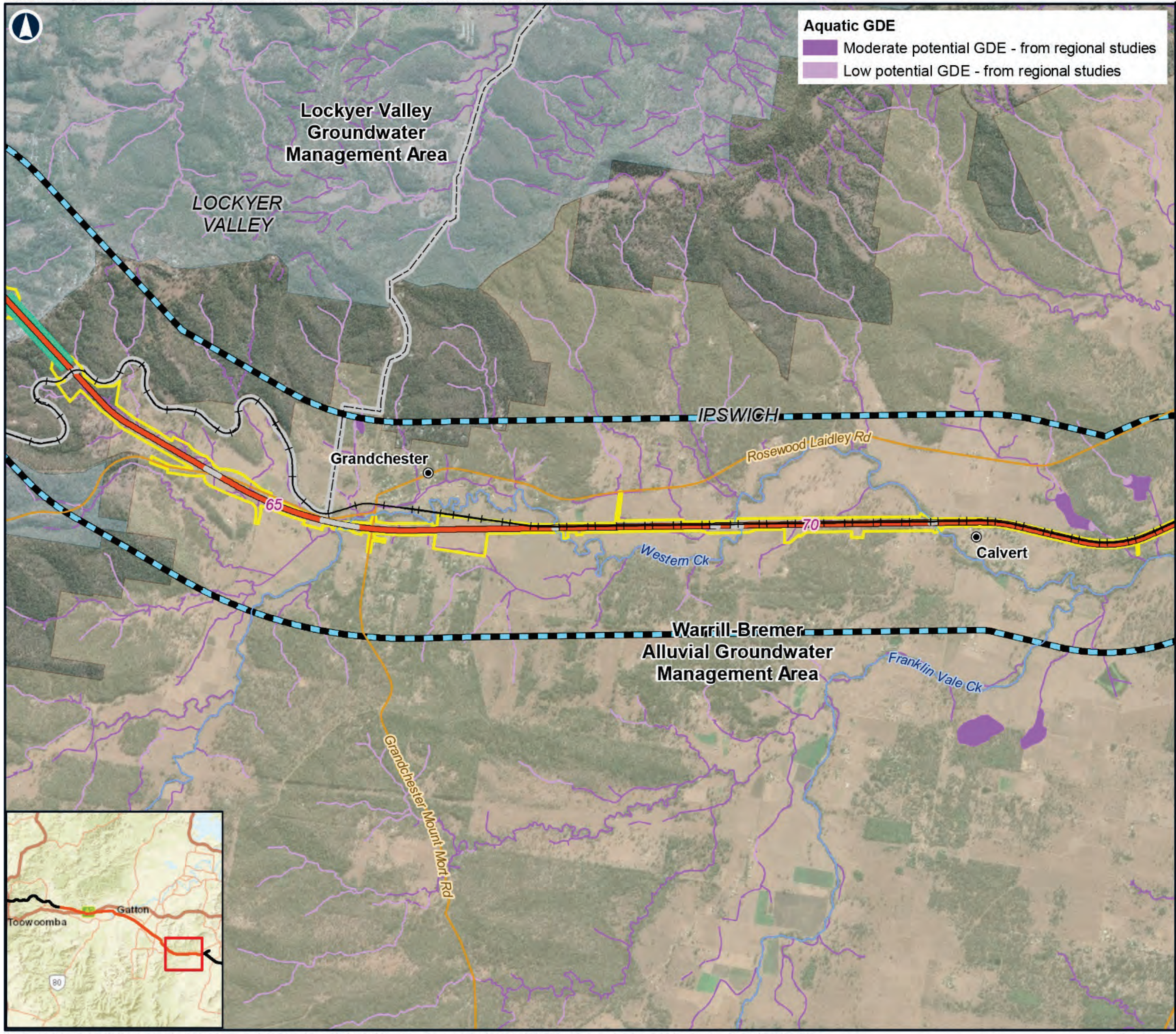

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Figure 14.5f: Potential aquatic GDEs

LEGEND

- 5 Chainage (km)
- Localities
- Existing rail
- Tunnel
- H2C project alignment
- C2K project alignment
- Watercourses
- Minor roads
- Bridges
- EIS disturbance footprint
- Groundwater study area
- Local Government
- Lockyer Valley Groundwater Management Area
- Warrill-Bremer Alluvial Groundwater Management Area

0 1 2 km

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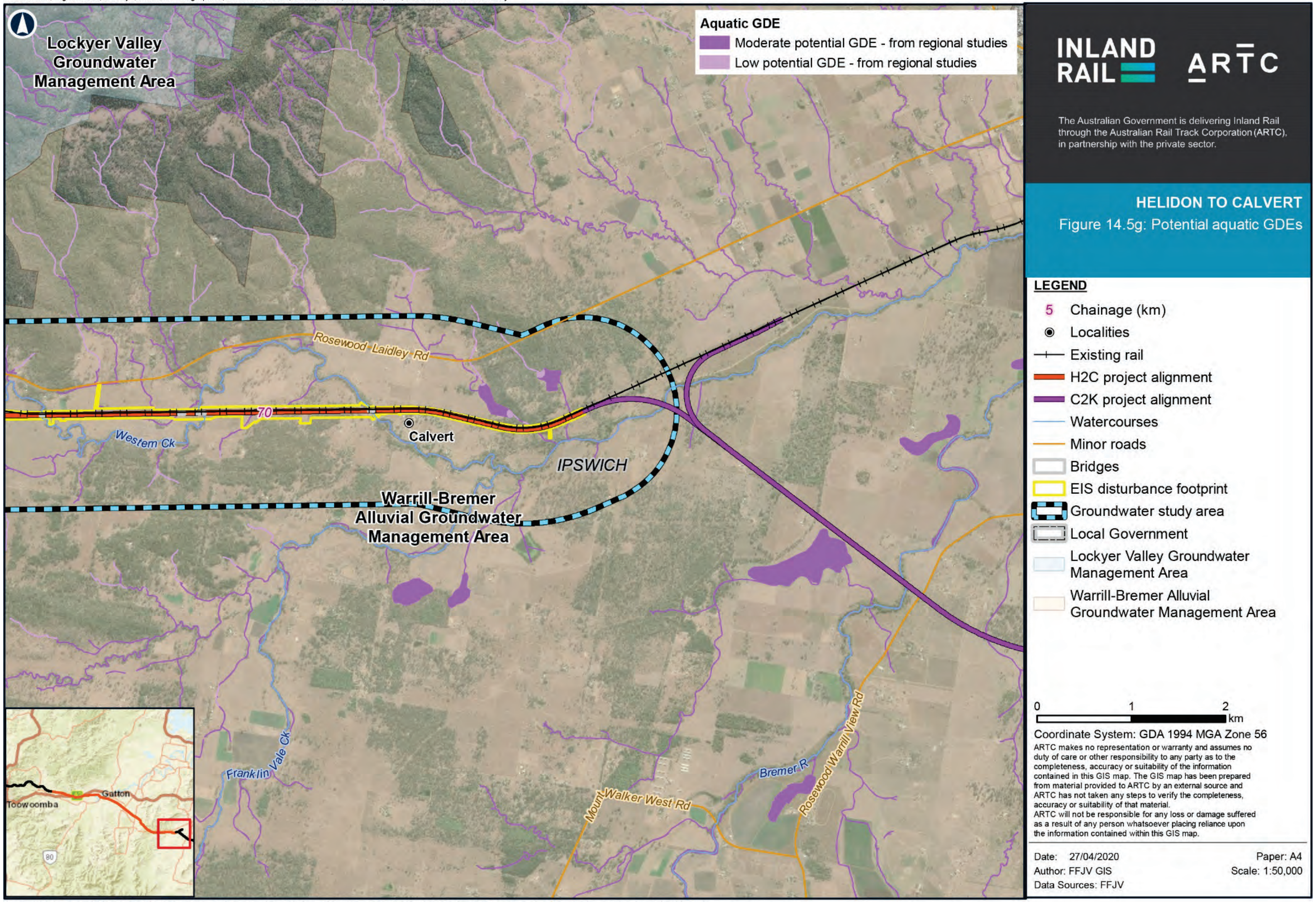

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14.6.7.2 Potential terrestrial groundwater dependent ecosystems

Numerous moderate potential terrestrial GDEs (from regional studies) occur in the groundwater study area between Helidon to Gatton (approx. Ch 26.00 km to Ch 44.00 km). Between Laidley and Calvert (approx. Ch 61.00 km to Ch 72.00 km) there are also numerous moderate-potential and low-potential GDEs (from regional studies). These are generally described as wetlands associated with alluvial aquifers on the GDE Atlas (**bom.gov.au/water/groundwater/gde**).

As no ground truthing of these environments was undertaken, it is assumed that the modelled extent of the terrestrial GDEs are a true and accurate presence. The terrestrial GDEs have been conservatively adopted as a potential sensitive receptor.

The locations of potential terrestrial GDEs are shown on Figure 14.6a to Figure 14.6g.

14.6.8 Surface water–groundwater interaction

Interaction between watercourses and shallow groundwater can occur in alluvial sediments, particularly where drainage channels are more deeply incised, and groundwater levels are shallow. For example, increasing groundwater salinity during droughts in parts of the Lockyer Valley alluvial aquifers has been linked to leakage from the underlying sedimentary bedrock (Gatton Sandstone), which contains more saline water (Raiber et al., 2017). Surface water-groundwater interaction is also expected at locations being recharged under the Central Lockyer Water Supply Scheme (discussed in Section 14.6.3.1).

The degree of interconnection will vary laterally due to local variations in alluvial sediment lithology, underlying bedrock geology and drainage channel morphology, as well as seasonally due to changes in groundwater elevations. At times watercourses may change from gaining systems (receiving baseflow from shallow groundwater) to losing systems (with surface water locally recharging the alluvial sediments).

An assessment of surface water–groundwater interaction for Laidley Creek (in the Lockyer Valley) was reported by Raiber et al. (2016). The dynamic interaction during the drought (2007 data), post breaking of the drought (2009) and subsequent flooding event (2011) is shown Figure 14.7 (from Raiber et al., 2016).

Groundwater levels were low in the alluvial aquifer and generally below streambed elevation during the drought, with salinity of the alluvial aquifer groundwater increasing over this period with greater contribution from the Gatton Sandstone. Post break of the drought (2009) the alluvial groundwater levels increased, and Laidley Creek recharged the aquifer (i.e. the creek was a losing stream). Following the extensive 2011 floods, groundwater levels from 2013 indicate that Laidley Creek became a gaining system (i.e. groundwater entered the creek as baseflow).

The complex temporal pattern of surface water-groundwater interaction in mid-reaches of other streams in the Clarence–Moreton bioregion highlights the challenges in defining whether river reaches are gaining or losing, and the need for long-term time-series groundwater-monitoring data (Raiber et al., 2016).

In areas of groundwater-surface water interaction, Project-related changes to groundwater levels, flow and/or quality therefore have the potential to affect receiving environments (creeks, rivers, wetlands and GDEs for example).

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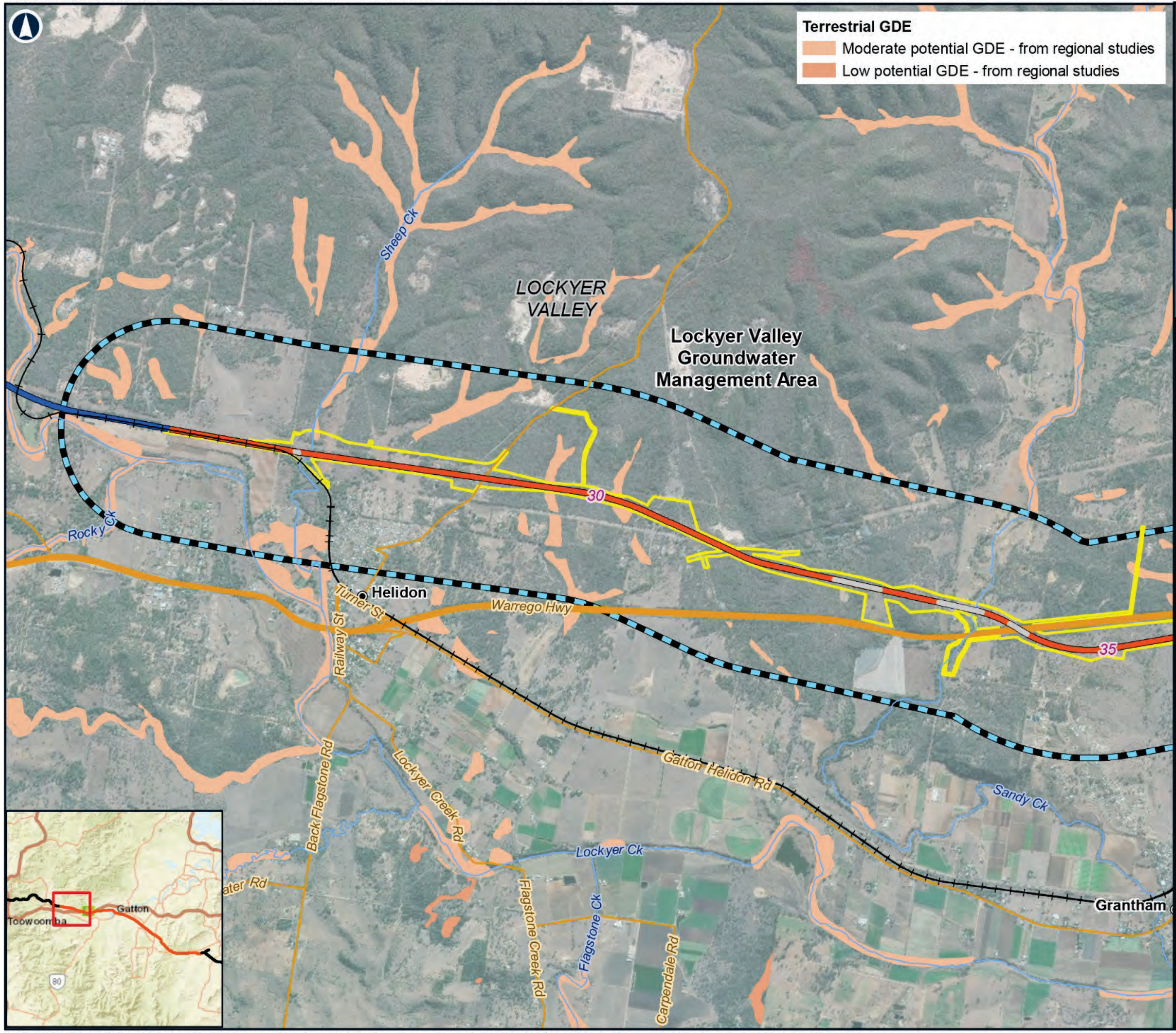

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Figure 14.6a: Potential terrestrial GDEs

LEGEND

- 5 Chainage (km)
- Localities
- Existing rail
- G2H project alignment
- H2C project alignment
- Watercourses
- Major roads
- Minor roads
- Bridges
- EIS disturbance footprint
- Groundwater study area
- Local Government
- Lockyer Valley Groundwater Management Area

0 1 2 km

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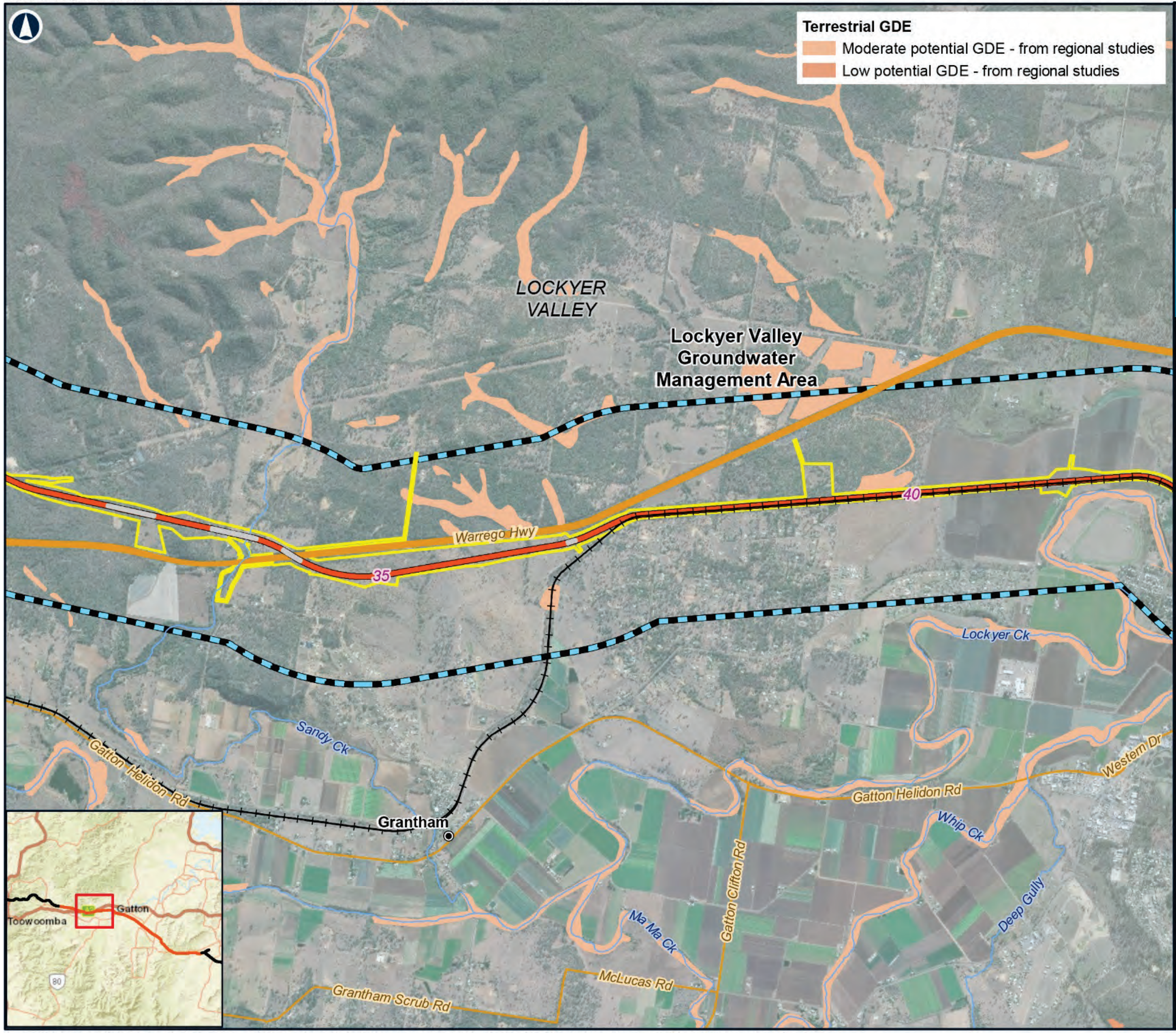

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Figure 14.6b: Potential terrestrial GDEs

LEGEND

- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Watercourses
- Major roads
- Minor roads
- Bridges
- EIS disturbance footprint
- Groundwater study area
- Local Government
- Lockyer Valley Groundwater Management Area

0 1 2 km

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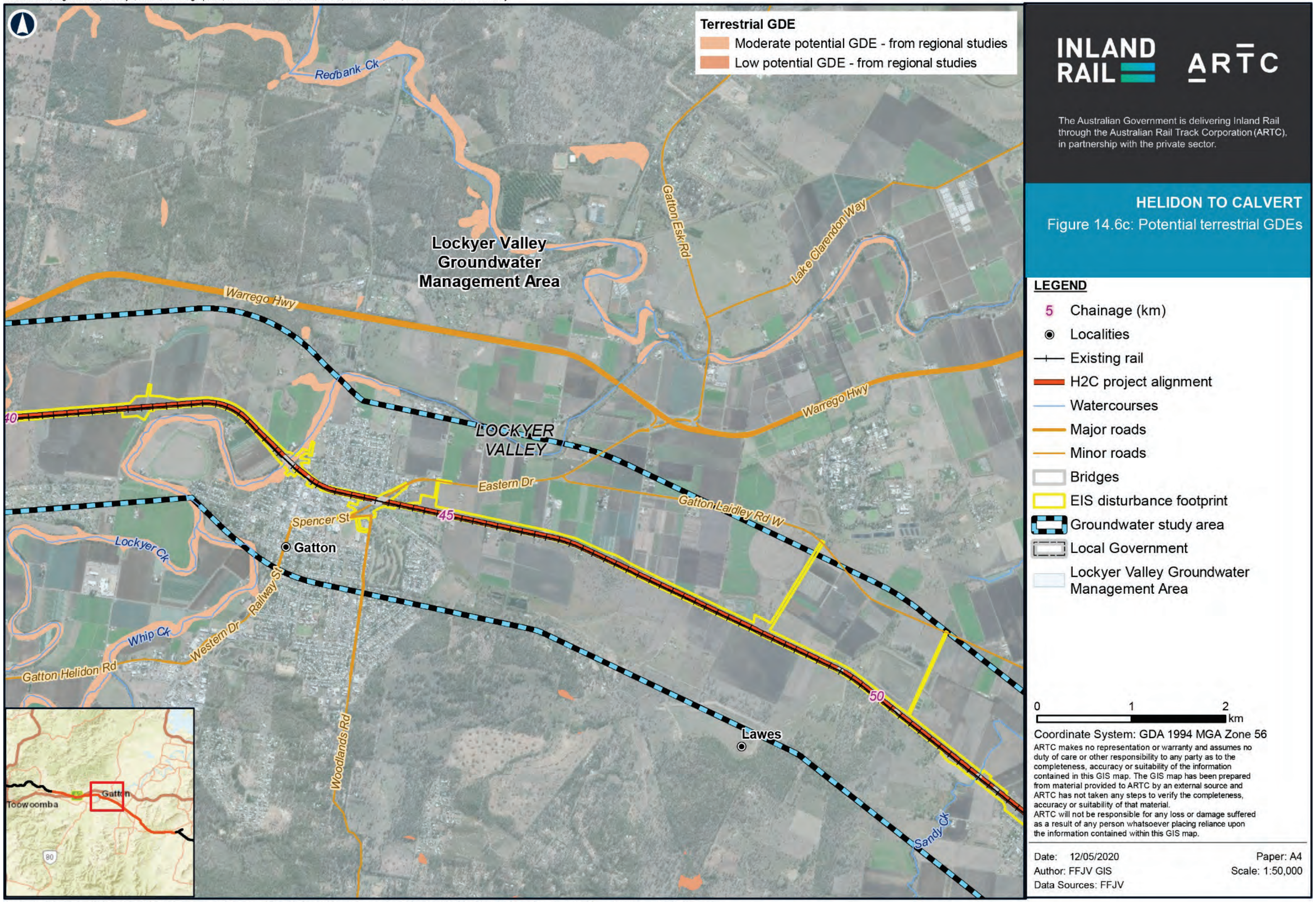

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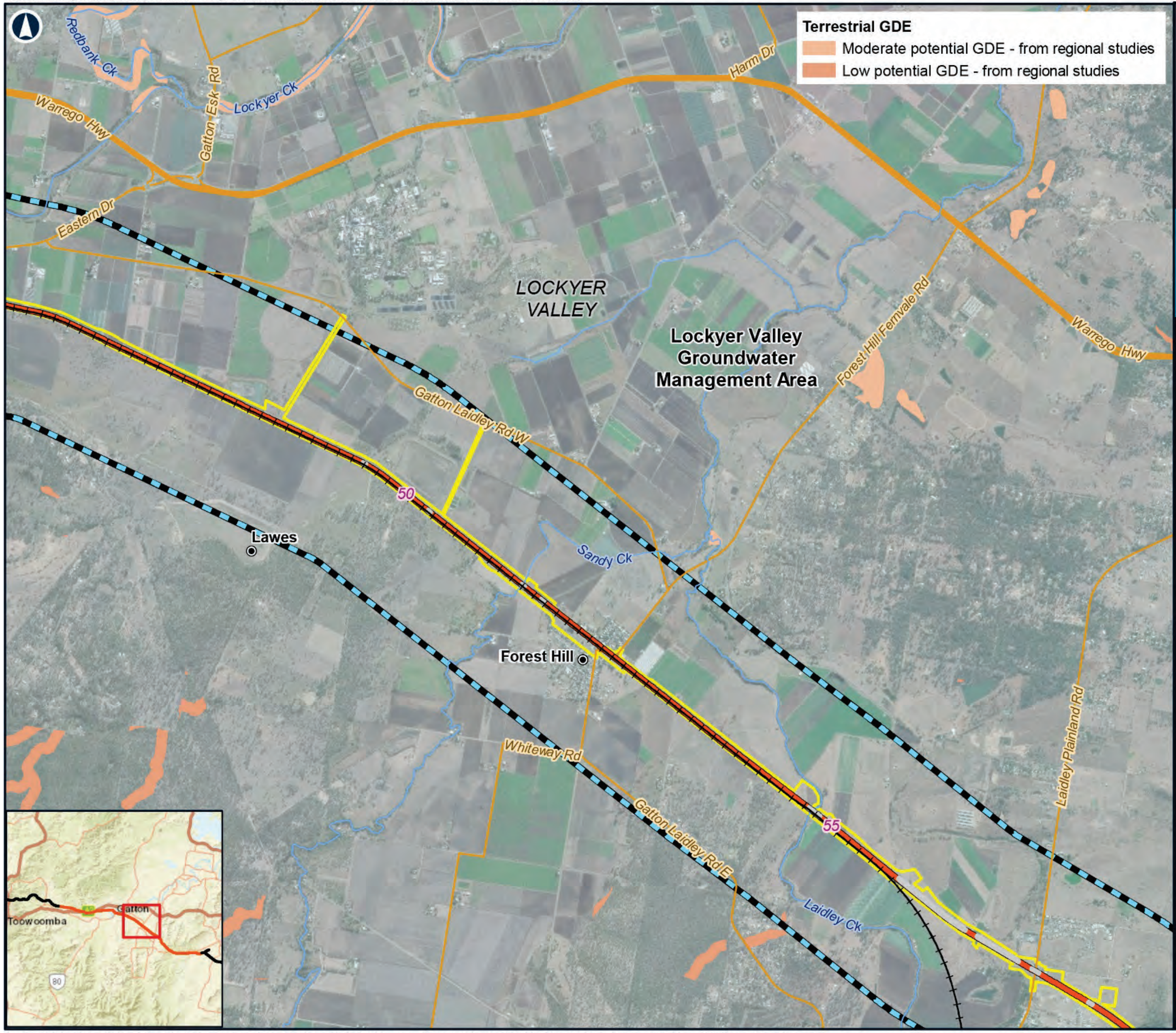

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Figure 14.6d: Potential terrestrial GDEs

LEGEND
- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- Watercourses
- Major roads
- Minor roads
- Bridges
- EIS disturbance footprint
- Groundwater study area
- Local Government
- Lockyer Valley Groundwater Management Area

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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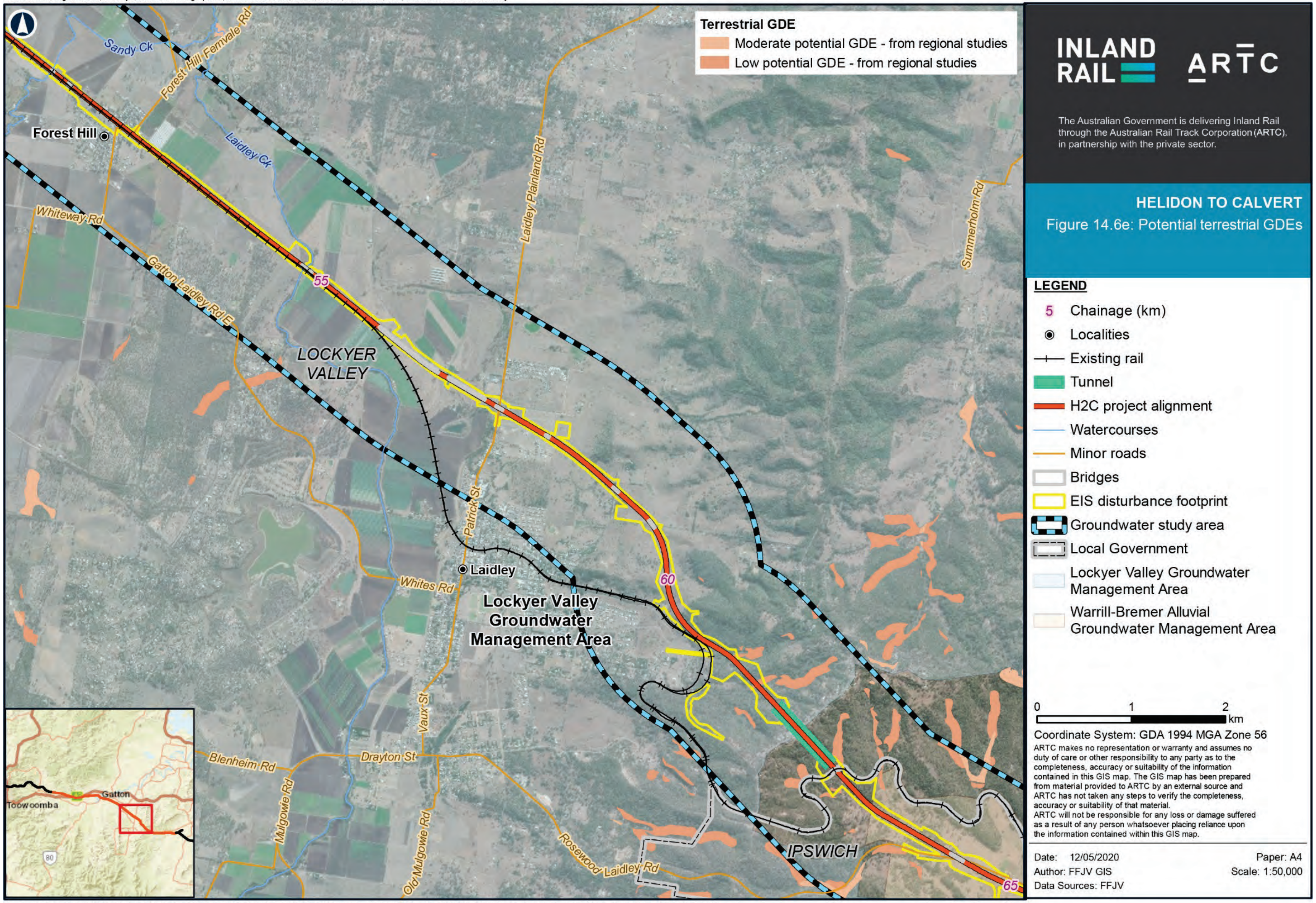

Figure 14.6e: Potential terrestrial GDEs

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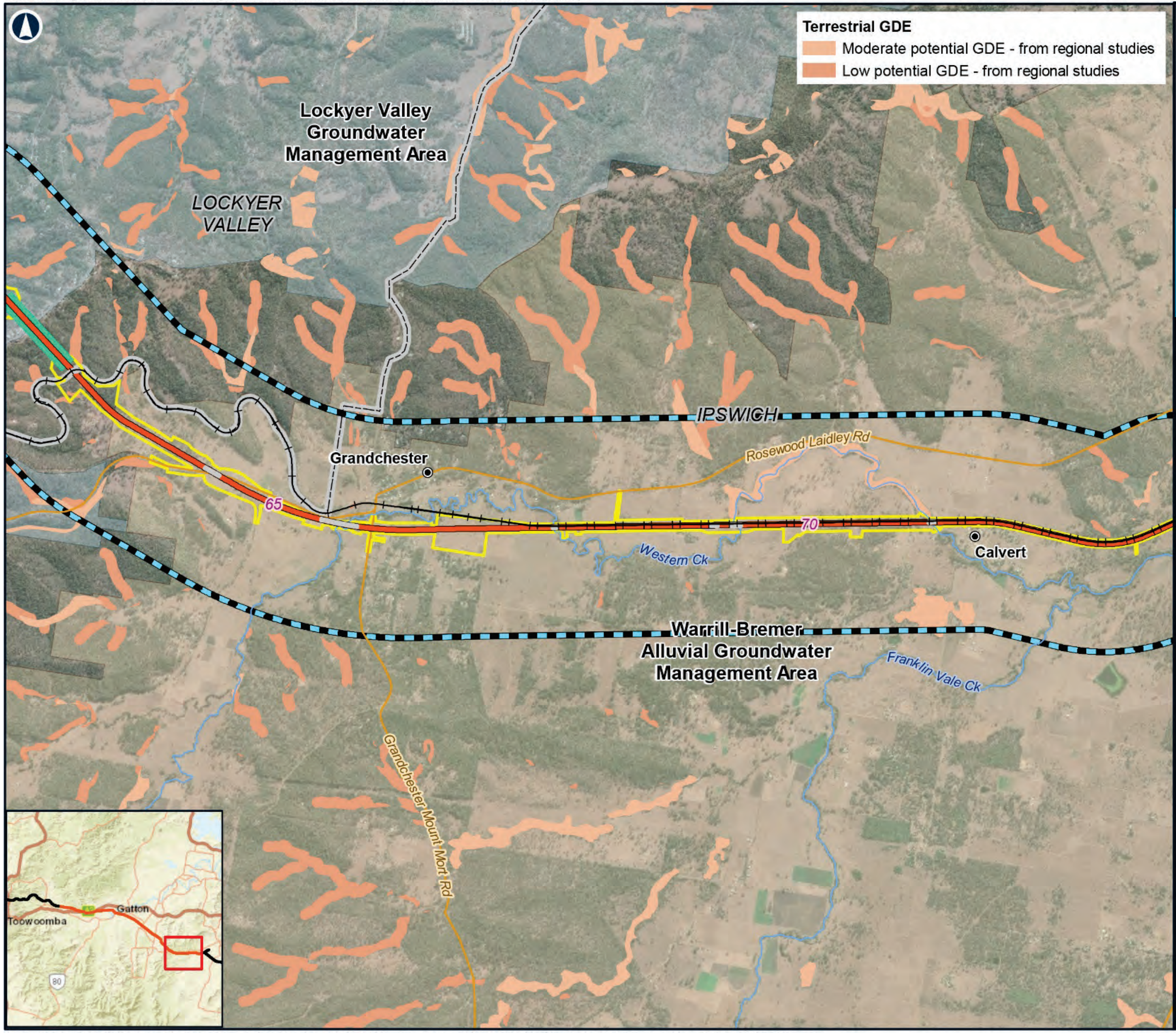

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Figure 14.6f: Potential terrestrial GDEs

LEGEND

- 5 Chainage (km)
- Localities
- Existing rail
- Tunnel
- H2C project alignment
- C2K project alignment
- Watercourses
- Minor roads
- Bridges
- EIS disturbance footprint
- Groundwater study area
- Local Government
- Lockyer Valley Groundwater Management Area
- Warrill-Bremer Alluvial Groundwater Management Area

0 1 2 km

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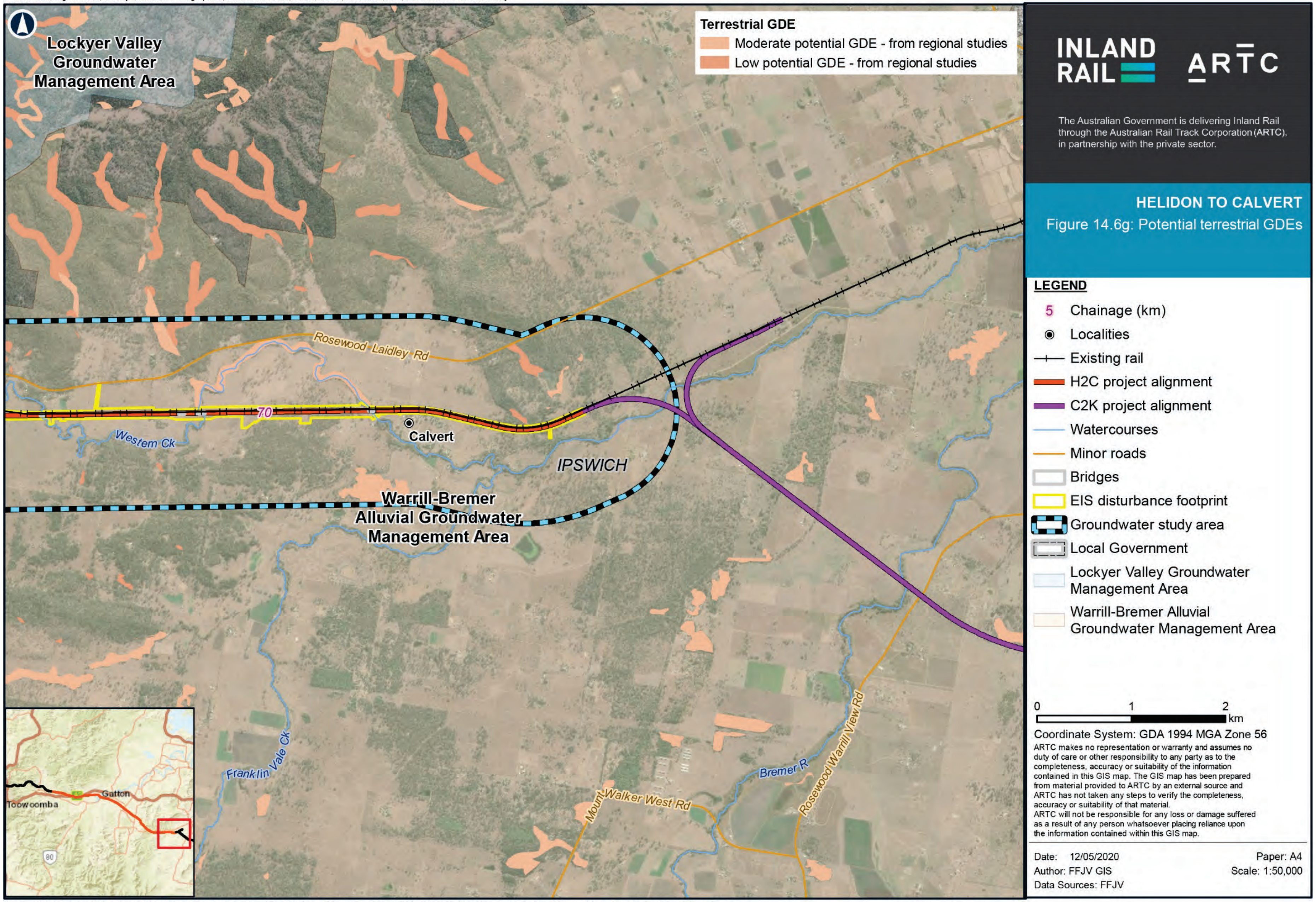

Figure 14.6g: Potential terrestrial GDEs

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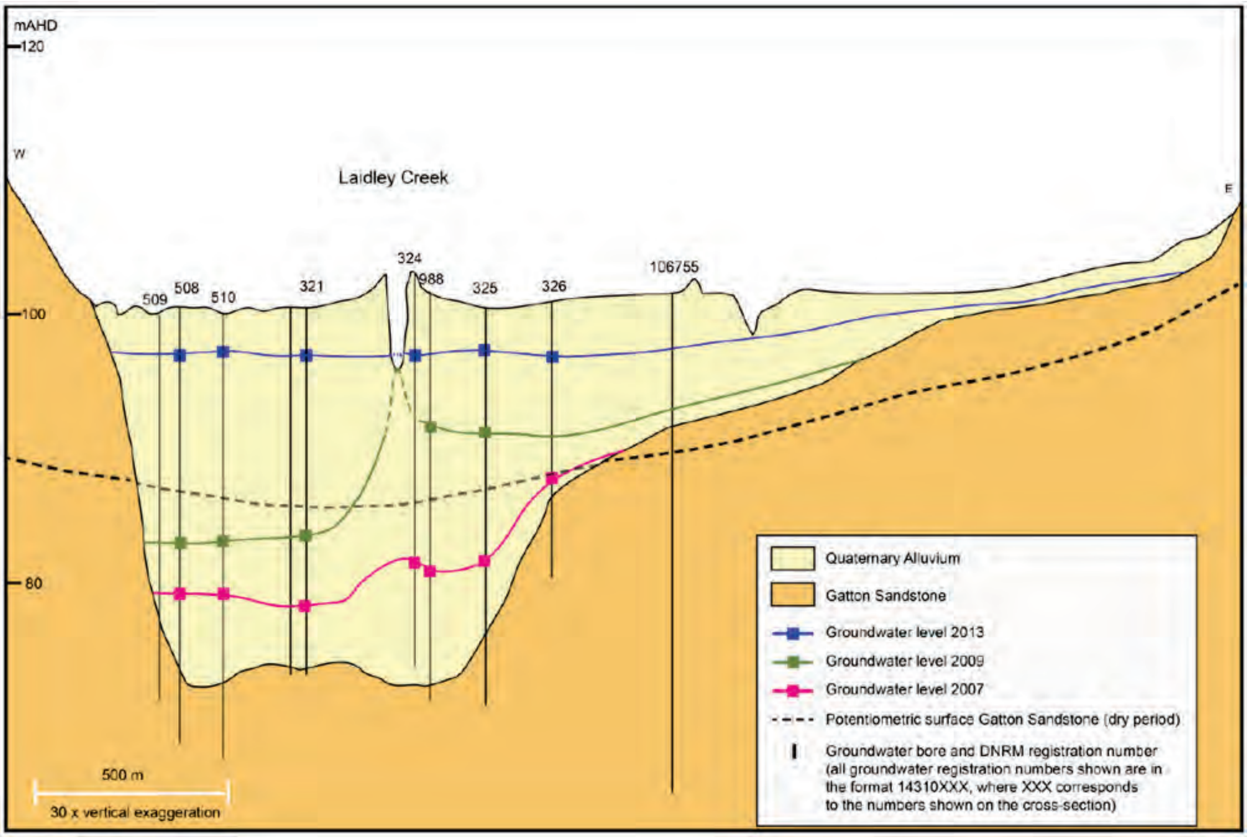


FIGURE 14.7: CROSS-SECTION THROUGH LAIDLEY CREEK CATCHMENT

Source: Raiber et al., 2016

14.6.9 Groundwater environmental values

Queensland water quality (including water in rivers, streams, wetlands, lakes and groundwater) is protected under the EPP (Water). This policy provides a framework for identifying EVs and establishing water quality guidelines and objectives to enhance or protect Queensland waters.

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

Relevant sub-areas under the EPP (Water) are in accordance with Schedule 1 and follow:

- The western part of the Project (approximately Ch 26.00 km to Ch 62.00 km): in the Lockyer Creek catchment (inclusive of Lockyer Creek, Laidley Creek and Sandy Creek), part of the Brisbane Basin. Relevant EVs and water quality objectives are described in the Department of Environment and Resource Management (DERM) (now Department of Environment and Science) document *Lockyer Creek environmental values and water quality objectives* (DERM, 2010a)
- The eastern part of the Project (approximately Ch 62.00 km to Ch 73.00 km): in the Bremer River area, part of the Brisbane basin, with relevant EVs and water quality objectives described in *Bremer River environmental values and water quality objectives* (DERM, 2010b)
- EVs for groundwater to be protected or enhanced in the groundwater study area are listed in Table 14.13.

TABLE 14.13: ENVIRONMENTAL VALUES FOR GROUNDWATER RELEVANT TO THE GROUNDWATER STUDY AREA

Environmental Value	Definition
Aquatic ecosystems	'A community of organisms living within or adjacent to water, including riparian or foreshore area' (EPP (Water), Schedule 2). The intrinsic value of aquatic ecosystems, habitat and wildlife in waterways and riparian areas. For example, biodiversity, ecological interactions, plants, animals, key species (such as turtles, platypus and others) and their habitat, food and drinking water. Waterways include perennial and intermittent surface waters, groundwaters, tidal and non-tidal waters, lakes, storages, reservoirs, dams, wetlands, swamps, marshes, lagoons, canals, natural and artificial channels and the bed and banks of waterways.
Irrigation	Suitability of water supply for irrigation. For example, irrigation of crops, pastures, parks, gardens and recreational areas.
Farm water supply/use	Suitability of domestic farm water supply, other than drinking water. For example, water used for laundry and produce preparation.
Stock watering	Suitability of water supply for production of healthy livestock.
Cultural	Protect or restore Indigenous and non-Indigenous cultural heritage consistent with relevant policies and plans.
Primary Contact Recreation	Primary recreational use of water means full body contact with the water, for example, diving, swimming, water skiing and windsurfing.
Drinking water supply	Suitability of raw drinking water supply. This assumes minimal treatment of water is required, for example, coarse screening and/or disinfection.

The main groundwater EVs identified using available local and regional information and site investigation results include:

- Aquatic Ecosystems (moderate potential GDEs) in Lockyer Creek, Laidley Creek and Western Creek hydraulically connected to groundwater (primarily the alluvium)
- Irrigation (alluvium, Koukandowie Formation and Woogaroo Subgroup)
- Farm water (alluvium)
- Stock watering (alluvium, Koukandowie Formation and Woogaroo Subgroup)
- Drinking water (town water bores) and water supply bores.

14.7 Conceptual hydrogeological model

A conceptual model of the hydrogeological regime across the groundwater study area is summarised below and presented in Figure 14.8. The conceptual mode is a representation of the groundwater systems, which incorporate an interpretation of referenced the geological and hydrogeological conditions. The conceptual mode consolidates the current understanding of key processes of each groundwater system, including the influence of stresses, to assist in understanding potential changes/impacts from the Project.

14.7.1 Main hydrostratigraphic units

The majority (72 per cent) of the Project alignment is underlain by unconsolidated Cenozoic to recent-aged alluvium. Main occurrences are in the floodplains of Lockyer Valley (approximately Ch 40.00 km to Ch 60.00 km), and east of the Little Liverpool Range (approximately Ch 65.00 km to end). They are typically 20 m to 35 m thick and have a distinct fining upwards sequence of gravels and coarse sands at the base, and fine-grained floodplain sediments at the top (Rassam et al., 2014).

The main bedrock sediments in the groundwater study area are the Walloon Coal Measures (2 per cent of alignment), Gatton Sandstone (8 per cent of alignment), Koukandowie Formation (7 per cent of alignment) and Woogaroo Subgroup (11 per cent of alignment).

The Koukandowie Formation outcrops as the Little Liverpool Range (approximately Ch 60.00 km to Ch 65.00 km), and the Woogaroo Subgroup outcrops forming the Helidon Hills (approximately Ch 30.00 km to Ch 40.00 km). The Gatton Sandstone is generally overlain by alluvial sediments, with only minor areas of outcrop.

14.7.2 Levels and flow

The water table is typically a subdued version of topography, with the depth to groundwater increasing beneath topographic highs (for example the Helidon Hills and Little Liverpool Range), and shallower groundwater in lower-lying reaches (such as close to surface water drainage lines). The water table occurs in the alluvial sediments of Laidley Creek and Lockyer Creek through much of the central part of the groundwater study area, and Western Creek alluvial sediments east of Little Liverpool Range. The Woogaroo Subgroup (west), Gatton Sandstone (central) and Koukandowie Formation (east) form the water table aquifer where they outcrop along limited sections.

Intermediate and regional groundwater in the alluvial sediments occurs as baseflow beneath the main drainage channel alignments—generally north-east and north in the central part of the groundwater study area, and east and northeast on the eastern side of the Little Liverpool Range. Local groundwater flow systems are influenced by surface water-groundwater interaction and pumping bores (e.g. water supply).

Regional groundwater in the shallow bedrock generally flows to the northeast, although local variations in flow directions are possible (for example due to pumping bores). Mapping of Woogaroo Subgroup and Gatton Sandstone groundwater elevations indicate that groundwater flow paths are influenced by the Lockyer Creek and Bremer River systems (Raiber et al., 2016). The Koukandowie Formation outcrops in the Little Liverpool Range, and groundwater flow direction is controlled locally by a groundwater divide coinciding with the main ridge line.

14.7.3 Conceptual recharge

There is a net deficit of rainfall, with average evaporation exceeding average rainfall for all months and annually. Recharge is likely to occur in response to higher or more continuous rainfall events, and overall net recharge rates in the groundwater study area are expected to be low.

Recharge to alluvial sediments is anticipated to be supplied by the following:

- Direct infiltration of rainfall (ranging from 2.7 mm/yr to 29 mm/yr across the groundwater study area) and associated stream flow
- Seepage from ephemeral streams during periods of flow following rainfall
- Infiltration by surface water releases from Bill Gunn Dam (Lake Dyer) and Lake Clarendon Dam (off-stream storages that release water back into the creeks of the Central Lockyer as part of the Central Lockyer Water Supply Scheme)
- Sub-cropping rock below alluvium may also act as a source of recharge where upward vertical gradients and hydraulic connection occur, such as vertical discharge from the Gatton Sandstone into overlying alluvial sediments associated with watercourses (Lockyer Creek and Laidley Creek for example).

Recharge to the water table occurs via direct infiltration of rainfall where the formations are exposed at the surface or blanketed by a thin layer of soil. For example, along ridgelines formed by the Woogaroo Subgroup and Koukandowie Formation, and in lower-lying areas where the Gatton Sandstone is not overlain by alluvial sediments. Recharge from overlying alluvial sediments may also occur where a downward hydraulic gradient occurs (i.e. where groundwater elevations in the alluvial sediments are higher than those in the underlying bedrock sediments).

14.7.4 Conceptual discharge

Discharge from alluvial sediments may occur as seepage to ephemeral streams and into underlying bedrock units during periods of higher groundwater levels, as seen in the Laidley Creek alluvial catchment (refer Figure 14.8). Discharge out of the groundwater study area will also occur as 'underflow' beneath creek channels. Evapotranspiration from vegetation growing in the creek beds and along the banks, and via pumping from the heavily utilised Lockyer Creek catchment are also primary discharge mechanisms from this unit.

Discharge mechanisms from the bedrock formations occur via seepage into adjacent aquifers (including the overlying alluvial sediments when upward hydraulic gradients occur), and as throughflow to the north and northeast out of the groundwater study area. Discharge will also occur via evapotranspiration, typically along the ridgelines and in outcrop areas. Pumping bores also extract groundwater from the bedrock sediments, particularly in areas of larger population as water supply/town water, as presented in Section 14.6.6.

14.8 Groundwater modelling

14.8.1 Little Liverpool Range tunnel

Preliminary drawdown and inflow analysis was carried out in the preliminary hydrogeological interpretative report (Golder Associates, 2020; refer Appendix A within Appendix N: Groundwater Technical Report). This analysis informed an assessment of the potential to construct a tunnel through the Little Liverpool Range and associated portal cuts as permanently drained structures.

The assessment was carried out using the Perrochet analytical method (Marechal et al., 2014), and a steady-state numerical modelling approach using the finite element numerical modelling package SEEP/W model code (part of the GeoStudio software suite).[2]

2. geoslope.com/products/seep-w

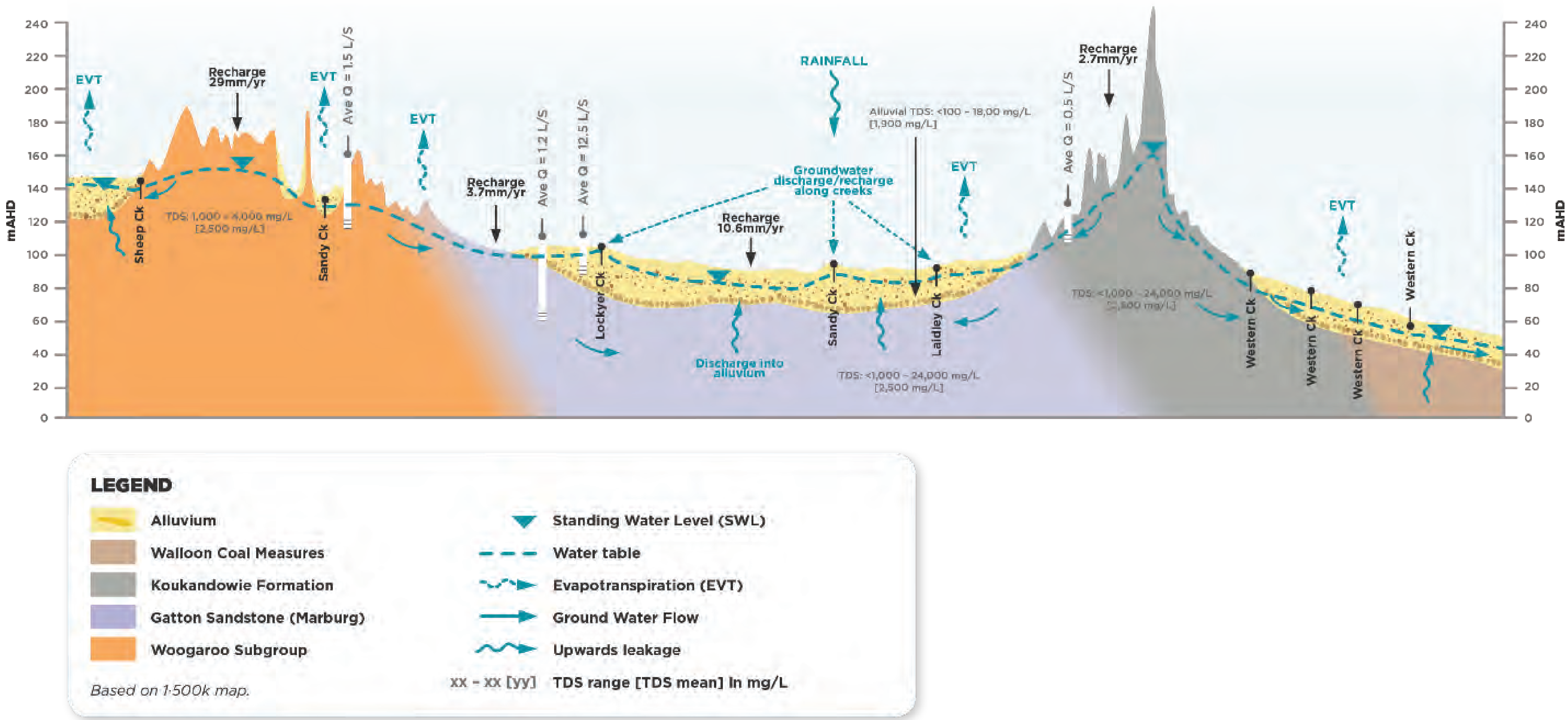


FIGURE 14.8: HYDROGEOLOGICAL CONCEPTUAL MODEL FOR THE PROJECT

Inflow and drawdown analysis using the Perrochet method (refer Appendix N: Groundwater Technical Report) was based on:

- Groundwater flows only horizontally within a plane perpendicular to the tunnel axis towards the tunnel
- Tunnel excavation will start from west to east at construction rate of 4 m/day, over 205 consecutive days
- Water inflows to drained tunnel sections are along the entire length of the tunnel and the tunnel has been divided into 20 m intervals for the calculation
- The Koukandowie Formation is assumed to be homogeneous and isotropic hydraulic characteristics above and below tunnel invert
- Groundwater recharge occurs at a constant rate and does not change along the length of tunnel:
    - Range of recharge values for the Koukandowie Formation was 1.7 mm/yr (lower estimate), 2.3 mm/yr (typical estimate) and 25.7 mm/yr (upper estimate)
    - Typical recharge value used (2.3 mm/yr) is consistent with the regional recharge estimate of 2.7 mm/yr for the Koukandowie Formation
    - Horizontal hydraulic conductivity of 0.00864 m/day to represent the Koukandowie Formation. This is within the range of hydraulic conductivities estimated from regional and site-specific data.

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

- Modelled cross Section at Ch 62.16 km—where rock thickness above tunnel crown is maximum
- Two geological units within the Koukandowie Formation have been included in the model: highly weathered rock with average 10 m thickness and underlying fresh rock[3]
- Constant head boundaries 5 km north (136.1 m AHD) and south (136.2 m AHD) of the tunnel, based on correlation of groundwater depth and ground surface elevation
- Recharge applied to surface (top boundary) of the model, with rates adjusted to match inferred groundwater levels—calibrated average recharge rate of 1.6 mm/yr (close to the lower estimate for regional recharge to the Koukandowie Formation)
- Regional groundwater flow directions have been interpreted from groundwater level contours estimated using the correlation between groundwater level and ground surface elevation. These contours indicate lateral flows along the tunnel alignment (i.e. perpendicular to the orientation of the cross-section model)
- Horizontal hydraulic conductivity of 0.08 m/day (adopting the upper hydraulic conductivity site-specific value)
- Anisotropy ratio of 100 (horizontal to vertical).

A long-term inflow rate of approximately 0.54 L/s was estimated for the approximately 850 m long tunnel, using the Perrochet analytical model. The long-term inflow into Ch 62.16 km (highest water level) was computed by the SEEP/W model to be less than 0.01 L/s per 100 m of tunnel. The predicted estimate of inflow using the analytical method for the 100 m section between Ch 62.14 km and CH 62.24 km was 0.19 L/s

Higher inflows are predicted during construction, with a maximum short-term inflow rate of 2.56 L/s estimated. These short-term (weeks to a month) will need to be managed during the construction. The higher inflows would decline to rates similar to the long-term inflow rates over time (Golder, 2020—refer Appendix A).

As part of an uncertainty analysis, to assess inflow rates, a model scenario using elevated groundwater levels (+ 10 m higher than base case) was simulated. The estimated long-term inflow rate for the elevated water level scenario was 1.30 L/s, a total inflow rate calculated for the entire length of tunnel included in the modelling.

Short-term flow rates during construction were not considered under the uncertainty analysis scenarios, and the tunnel portal cuts were assumed not to intersect groundwater.

The Perrochet analytical method estimated a maximum long-term drawdown to be up to 15 m, with drawdown of up to 5 m extending to 400 m along the tunnel alignment, and to 50 m from the tunnel due to topographical effects (refer Figure 14.9). It is noted that the drawdown mainly extents along the tunnel alignment. This is due to the tunnel construction effects with the inferred water table in the area.

These results were for the 'base case' scenario of 'typical' groundwater levels in the Little Liverpool Range and did not include structural features that might extend beyond the predicted drawdown extent.

3. Consistent with findings of the geotechnical drilling program at BH330-01-BH2101 to BH330-01-BH2104.

FIGURE 14.9: BASE CASE: ESTIMATED LONG-TERM DRAWDOWN AT LITTLE LIVERPOOL RANGE TUNNEL

Source: Golder Associates, 2020

Uncertainty analysis was undertaken to assess predicted long-term drawdown for three scenarios. These scenarios are considered higher than 'typical' groundwater levels, and the presence of two higher permeability structural features over the model length of tunnel. The faults were not observed in the field, but the uncertainty scenarios were based on occasional faults being interpreted in the Little Liverpool Range strata. The modelled faults were nominally placed at Ch 62.16 km (highest groundwater level) and Ch 62.39 km (mid-point between eastern portal and Ch 62.16 km) and oriented perpendicular to the tunnel. The width of the structurally affected zones was conservatively modelled to 10 m and a higher hydraulic conductivity was applied (0.08 m/day) based on the upper value for this parameter from regional data and site-specific testing:

- Scenario 1: Elevated groundwater levels (+10 m), no structural feature—5 m drawdown contour extends to approximately 750 m along the tunnel and 65 m perpendicular to tunnel alignment (refer Figure 14.10)
- Scenario 2: Base case groundwater levels, two structural features—5 m drawdown contour extends to approximately 400 m along the tunnel alignment and 120 m from the tunnel (refer Figure 14.11)
- Scenario 3: Elevated groundwater levels (+10 m), two structural features—5 m drawdown contour extends to approximately 760 m along the tunnel alignment and 170 m from the tunnel (refer Figure 14.2).

Drawdown extents considered to be 'worst-case' are shown in Figure 14.2 (from Golder (2020) predictions), with drawdown impacts of 5 m estimated to extend 760 m along the tunnel and approximately 170 m perpendicular to the tunnel.

FIGURE 14.10: SCENARIO 1 (ELEVATED LEVELS, NO FAULTS): PREDICTED LONG-TERM DRAWDOWN EXTENT

Source: Golder Associates, 2020

FIGURE 14.11: SCENARIO 2 (BASE CASE LEVELS, WITH FAULTS): PREDICTED LONG-TERM DRAWDOWN EXTENT

Source: Golder Associates, 2020

FIGURE 14.12: SCENARIO 3 (ELEVATED LEVELS WITH FAULTS): PREDICTED LONG-TERM DRAWDOWN EXTENT

Source: Golder Associates, 2020

14.8.2 Cuts along the alignment

The hydrogeological interpretive report (Golder Associates, 2020), refer Appendix A within Appendix N: Groundwater Technical Report, considered groundwater inflows to five deep-cuts where groundwater was anticipated to be intersected.

Preliminary analysis of potential groundwater inflows to cuts along the Project alignment was carried out by the method described by Nguyen and Raudkivi (1983) (refer Appendix W: Geotechnical Factual Report). Potential implications and limitations of the models are provided in Section 14.8.4. Key assumptions are summarised as (refer Appendix N: Groundwater Technical Report):

- Slope cuts are permanently drained
- Homogeneous and isotropic geological material
- Impermeable rock below bottom of slope cut i.e. upward flow through cut floor is negligible compared to lateral flow[4]
- Groundwater recharge not considered
- Analysis based on 'typical' hydrogeological parameters from desktop study
- An average groundwater level was applied over the length of each cut i.e. differences in groundwater elevation over length of cuts not included.
- Toe elevation of each cut is the level of discharge, that is, no seepage face and hence conservative estimate of drawdown at cut and conservative estimate of lateral inflow.

Typical values for hydraulic properties were used based on regional data and site-specific hydraulic testing (refer Appendix W: Geotechnical Factual Report). Inferred groundwater elevations at cut locations was compared to base of cuts (although the modelled depth of groundwater in the cut prior to dewatering was not stated).

Long-term inflows were less than 0.1 L/s at all locations, and short-term inflows ranged from less than 0.1 L/s to 2 L/s. The results are summarised in Table 14.14.

TABLE 14.14: ESTIMATED SEEPAGE RATES FOR SLOPE CUTS

Location (cut name)	Length (m)	Median cut elevation (m AHD)	Geology	Hydraulic properties*	Total seepage rate (L/s)	
					1year post-construction	Long-term
Ch 28.26 km to Ch 29.44 km (330-C04)	1,180	165 [167.7–178.1]	Gatton Sandstone	K = 0.00864 m/day Specific Yield = 0.05	0.1	Less than 0.1
Ch 33.01 km to Ch 33.21 km (330-C07)	200	165.7 [176.8–185.8]	Woogaroo Subgroup	K = 0.432 m/day Specific Yield = 0.05	0.2	Less than 0.1
Ch 34.53 km to Ch 35.07 km (330-C08)	540	148.4 [147.9–155.5]	Woogaroo Subgroup	K = 0.432 m/day Specific Yield = 0.05	0.1	Less than 0.1
Ch 59.83 km to Ch 60.66 km (330-C15)	830	141.3 [151.5–156.2]	Koukandowie Formation and Gatton Sandstone	K = 0.00864 m/day Specific Yield = 0.05	0.1	Less than 0.1
Ch 61.17 km to Ch 61.64 km (330-C16)	470	157.2 [159.8–185.5]	Koukandowie Formation	K = 0.00864 m/day Specific Yield = 0.05	Less than 0.1	Less than 0.1

Source: Golder Associates, 2020

Table notes:
GW—groundwater.
Values shown in brackets [xxx–xxx] are GW elevation range.
* Values from Table 5 of Golder Associates (2020).

4. Vertical hydraulic conductivity of formations is assumed to be 100th that of horizontal.

A preliminary estimate of potential drawdown for the five deep cuts is provided in Appendix N: Groundwater Technical Report. This has been based on a mass balance approach—to provide a conservative indication of potential drawdown extents from permanently drained cuts.

Long-term inflow rates to the five cuts were estimated to be less than 0.1 L/s (3,000 cubic metres per year (m^3/yr)) in Golder Associates (2020). Assuming an annual rainfall recharge of approximately 2.7 mm/yr (from Section 14.6.3), a recharge area can be estimated such that the annual recharge volume balances the long-term annual inflow volume to the cut (where: rainfall recharge rate x recharge area = recharge volume).

A buffer distance around each cut length can then be estimated from the required recharge area. This provides an indicative, conservative, maximum drawdown extent where negligible or no change to groundwater levels would be expected (refer Table 14.15). The 'worst-case' drawdown extent would range from 300 m to 470 m. Moderate drawdowns in the order of 0.1 to 0.5 m may be expected closer to cuts.

TABLE 14.15: ESTIMATED EXTENTS OF STEADY STATE DRAWDOWN AT CUTS

Cut location	Cut length (m)	Annual inflow[a] (m^3/year)	Equivalent recharge area (m^2)	Drawdown extent[b] (m)
330-C04	1,180			300
330-C07	200			470
330-C08	540	3,200	1,066,667	400
330-C15	830			350
330-C16	470			420

Table notes:
m^2 square metres.
a. based on inflow of 0.1 L/s from Golder Associates (2020).
b. distance required in all directions to balance recharge (i.e. no drawdown beyond this distance).

The estimates of drawdown extent are used in Section 14.9 when considering the potential for groundwater users (that is, bores and potential GDEs) to be impacted by reduced groundwater levels due to seepage into drained cuts.

14.8.3 Model limitations

The key model limitations identified in the preliminary hydrogeological interpretative report (Golder Associates, 2020) are summarised below and discussed further in Appendix N: Groundwater Technical Report.

Little Liverpool Range tunnel and portal cuts

- The Perrochet method does not allow for anisotropy of models, although vertical hydraulic conductivities are expected to be considerably lower than horizontal hydraulic conductivity values used.
- No account for groundwater recharge parallel to the tunnel alignment, limiting spatial extent of recharge zones and therefore potential overestimate of groundwater drawdown zone.
- Recharge has not been considered.
- Information regarding the extent and location of structurally affected zones is limited, and uncertainty analysis indicated such zones could significantly affect inflow and drawdown associated with the tunnel.

Cuts along the alignment

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

14.8.4 Model risks and mitigation

Groundwater-related risks and proposed mitigation measures were identified by Golder Associates (2020) and are summarised in Table 14.16.

TABLE 14.16: MODEL RISKS AND MITIGATION

Risk	Mitigation measure
Higher groundwater levels in Koukandowie Formation leading to higher than predicted inflows to tunnel and portals	Proposed installation of monitoring bores ay key locations along tunnel alignment and cuts anticipated to intersect groundwater table. To establish groundwater levels and inform final design and construction.
Preferential groundwater flow (i.e. fault structures, dykes) leading to greater than predicted tunnel inflows	Proposed additional geophysical investigations, installation of piezometers and borehole permeability testing. To identify location, extent and characteristics of geological structures along tunnel alignment prior to final design and construction.
Higher or lower hydraulic conductivity values of formations leading to current estimates being under or overestimates of tunnel and/or cut drainage	Proposed additional permeability testing of formations to establish hydrogeological characteristics of the aquifer systems along the tunnel alignment and cut locations.
Higher recharge than anticipated and therefore higher inflows than expected to tunnel and portal cuts	Proposed groundwater level measurements at monitoring bores along tunnel alignment and cuts.

It is noted that proposed cuttings and the tunnel are through topographic highs to achieve an acceptable grade. Based on the hydrogeological conditions described in Section 14.6, and in particular the depth to groundwater, low hydraulic conductivity and proximity of groundwater users (i.e. bores and potential GDEs), the preliminary modelling is sufficient to allow an assessment of potential groundwater impacts. Potential impacts to groundwater and groundwater users due to drained cuts and tunnel are detailed in Section 14.9.

14.9 Potential impacts

Construction activities and ongoing operational elements for the Project have the potential to impact on groundwater resources, such as embankments, cuttings and the Little Liverpool Range tunnel.

14.9.1 Construction phase potential impacts

14.9.1.1 Water resources

Loss or damage to registered groundwater bores

Registered bores within, or near, the temporary construction disturbance footprint have the potential to be damaged or lost during construction, or to become inaccessible during construction (refer Figure 14.4a to Figure 14.4g). All potentially affected landowners will be consulted to ensure that potential damage to, r destruction of, or loss of access to all bores is identified (further ground truthing). Once detailed design has been undertaken and ground truthing of bores has occurred, potential risks can be refined, with targeted and appropriate measures implemented.

Proposed mitigations to address loss or damage to registered groundwater bores are in Table 14.18 and draft Outline EMP (Chapter 23: Draft Outline Environmental Management Plan).

Embankments

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

The potential significance of impact is dependent on the embankment (vertical and lateral extent), compressibility of the underlying materials (clay, silt and sand content of the alluvial sediments) and depths to groundwater. Available data and reasonable assumptions have been used to address these matters.

Depths to groundwater in the alluvial sediments are typically greater than 5 m and, therefore, the potential for impacts is reduced. The potential for mounding and damming of groundwater may be greater in areas of shallower groundwater in alluvial sediments local to active channels (such as Lockyer Creek, Laidley Creek and Western Creek).

The anticipated embankment heights are typically less than 5 m across the floodplains of Lockyer, Sandy and Laidley Creek (Ch 40.00 km to Ch 55.00 km). Embankment heights in the order of 10 m to 15 m are proposed on alluvial sediments near Sandy Creek (Ch 33.80 km) and east of Laidley Creek to the western flanks of the Little Liverpool Range (that is, from Ch 55.00 km to Ch 60.00 km). These areas may present a greater potential to impact groundwater levels and flow.

As part of ongoing geotechnical investigations, an assessment of embankments, including critical sections (typically greater than 10 m in height, located in floodplains and with poor ground conditions) have been reviewed in terms of stability of proposed geometry with respect to geological profile and groundwater levels. Assessment of anticipated subgrade conditions has also been undertaken for the alignment. The type and extent of subgrade treatment has been defined based on the expected ground conditions. Areas identified to likely require treatment include soft subgrades and reactive soils, where global stability or settlement has been identified to be a potential issue, and where drainage blankets may be required.

Overall, there exists some potential for embankments to effect groundwater levels and/or the hydraulic properties of the aquifers locally across some Section of the alignment, as previously described above. This potential will be confirmed as part of further geotechnical investigations before and during detailed design. It is proposed that these further investigations will include additional investigation and monitoring of groundwater levels in low-lying floodplain areas (where required).

Subsidence and settlement

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

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

Further, there are a limited number of cuttings anticipated to be significantly below the water table, with five identified in Golder Associates (2020). These deep cuttings in high relief areas are typically in more competent rock with depths to groundwater in the order of 20 m, and so the risk of settlement is reduced. Reduced groundwater levels due to dewatering and/or seepage into the tunnel are not considered to present a risk of settlement due to the competent sedimentary bedrock material being tunnelled (that is, Koukandowie Formation).

Overall, the potential for settlement and damage to buildings and properties due to subsidence from drained cuttings and the tunnel appears to low. It is anticipated that the potential for settlement will be confirmed as part of ongoing geotechnical investigations and will inform detailed design.

Dewatering and seepage

Reduced groundwater levels during construction due to excavation dewatering as a result of seepage into deep cuts and the tunnel has the potential to impact groundwater users (e.g. registered bores and GDEs).

The long-term extents of drawdown (i.e. reduced groundwater levels) due to continuous seepage into cuts were estimated in Section 14.8.2, based on inflow rates for the five deep cut sections considered in Golder Associates (2020). The long-term extents drawdown (that is, steady-state drawdown at which negligible further drawdown is anticipated) were between 300 m and 500 m from the cuts and can be used as conservative estimates for the construction phase.

There are only two registered bores within the predicted drawdown extents estimated in Section 14.8.2 for the five cuts considered. The use of these registered bores is unknown; however, both are deep bores, constructed to 70 m (RN75520) and 102 m (RN106088), and are located approximately 250 m north of the cut at Ch 28.26 km to Ch 29.44 km (refer Figure 14.4a to Figure 14.4g). The base of cut at this location is approximately 165 m AHD, which is around 15 m below the surface elevation at the deep bores (approximately 180 m AHD). Given that the depth to groundwater in this area of higher relief is anticipated to be in the order of 15 m to 20 m, the water levels at the registered bores are not expected to be adversely affected by cut seepage. The location and use of the bores have not yet been physically confirmed. Further, the static water level, pump depth and pumping water level are also currently unknown. This information will be collected through liaison with the bore owners prior to the construction phase to allow for a detailed assessment of the potential for material impact (deemed a drawdown of 5 m below current groundwater level) at these bores.

Overall, long-term seepage into the five cuts, based on the aquifer hydraulic properties, is considered to not adversely impact groundwater levels in the registered bores.

There are potential aquatic GDEs (refer Figure 14.5a to Figure 14.5g) within the estimated extents of drawdown at four of the five cuts considered in Section 14.8.2. Most of these features are described as wetlands associated with alluvial aquifers (from the BoM GDE Atlas). These wetlands are in lower-lying parts of the landscape and below the elevation of the base of cut that occur in sedimentary bedrock. Reduced groundwater levels in the bedrock due to long-term seepage into the cuts would therefore not be expected to adversely impact those potential aquatic GDEs. The exceptions are potential aquatic GDEs described as wetlands associated with flow from sedimentary rock that are close to the cuts at Ch 29.00 km (approximately 100 m south) and Ch 61.00 km (immediately adjacent).

It is possible that if groundwater levels and/or flows are reduced then adverse impacts may occur to these potential terrestrial GDEs. These features have not been ground truthed and are potential GDEs only, based on BoM GDE Atlas. This is a conservative approach.

Potential terrestrial GDEs (refer Figure 14.6) are within the estimated extent of drawdown for two of the five cuts considered in Section 14.8.2. Several moderate potential terrestrial GDEs (from regional studies) are present immediately adjacent to the cut located at Ch 29.00 km. These features are described as wetlands associated with alluvial aquifers (from the BoM GDE Atlas). They occur in lower lying parts of the landscape and below the elevation of the base of cut, which occur in sedimentary bedrock. Reduced groundwater levels in the bedrock due to long-term seepage into the cuts would therefore not be expected to adversely impact those potential aquatic GDEs. The low potential terrestrial GDEs (from regional studies) immediately adjacent to cut at Ch 61.00 km are described as wetlands associated with saline flow from sedimentary rock.

Preliminary modelling of a drained tunnel through the Little Liverpool Range was carried out to estimate potential drawdown impacts (refer Section 14.8). Under the base case scenario (estimated typical groundwater levels and no structural features) drawdown impacts were limited and no registered bores or potential GDEs were within the predicted 1 m drawdown extent and no unacceptable adverse impacts would be anticipated.

The nearest registered bore (RN106453) to the proposed tunnel is located approximately 240 m southwest of Ch 62.20 km. This registered bore is not located within the modelled 5 m drawdown extent for any of the three modelling scenarios. The use and characteristics of the bore will be confirmed post-EIS. Further, the static water level, pump depth and pumping water level is also currently unknown; however, the total depth of the bore is reported as being 91.5 m. This information will be collected through liaison with the bore owner prior to the construction phase to ensure there are no potential implications of any drawdown at this bore.

The existing low to moderate potential terrestrial GDEs located 1 km to the northeast (refer Figure14.6d) are not predicted to intersect with the modelled 5 m drawdown extent (refer Section 14.9.2.1). However, under this modelled scenario, there are several groundwater levels that may be impacted by the free draining tunnel. The draft Outline EMP provides recommendations to address dewatering and seepage.

Vegetation removal and surface disturbance

Increased groundwater levels (if any) due to vegetation removal across the groundwater study area will be localised and temporary; assuming revegetation across much of the disturbed area post-construction.

Construction and rehabilitation will be carried out progressively and therefore the total area of cleared vegetation will be minimised. Potential impacts to groundwater are likely to be minor, with disturbed area footprints small relative to regional-scale groundwater systems.

Bridge pilings

Changes to groundwater levels may occur during installation of pilings for bridge construction. Any such changes will be temporary, localised and small based on construction design (i.e. diameter, depth and spacing of piles).

Construction water supply

Water will be required for construction activities including dust control, site compaction and reinstatement during construction. It is estimated that up to 564 ML of principally non-potable water will be required for the duration of construction. ARTC recognises water sourcing and availability is critical to supporting the construction program for the Project. Sources of construction water will be finalised as the construction approach is refined during detailed design of the Project (post-EIS) and will be dependent on:

- Climatic conditions in the lead up to, and during, 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.

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

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

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

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

c) Permanently flowing watercourses

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

e) Existing registered and licensed bores

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

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

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

- Legal access
- Volumetric requirement for the activity
- Water quality requirement for the activity
- Source location relative to the location of need.

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

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

Potential impacts to groundwater elevations may occur where bore water is sourced to supply water for construction activities. However, if groundwater is considered for sourcing of construction water, it will be sourced from existing registered and licensed bores. Therefore, the volumes extracted would be within the existing licensing limits and the extent of drawdown experienced would be localised and consistent with that currently permissible for each registered bore.

14.9.1.2 Water quality

Spills and uncontrolled releases

During construction, there is the potential for pollutants to reach groundwater from activities including accidental spills and leaks, and runoff from washdown areas. In areas of low relief, where groundwater is shallower and hence more vulnerable, the flood plain alluvial sediments are typically dominated by clays and silty clays, which will impede vertical infiltration to groundwater.

Contamination

Leaching of contaminated embankment fill could also impact groundwater quality and affect EVs. It is anticipated that the Project will source embankment fill from cut volumes where possible. Any potential impacts would be local to embankments and limited in extent due to the linear footprint of these features. In areas of low relief where groundwater is shallower, and therefore more vulnerable, the flood plain alluvial sediments are typically dominated by clays and silty clays, which will impede vertical infiltration to groundwater.

Bridge pilings

Changes to groundwater quality (for example pH and salinity) may occur during installation of pilings for bridge construction. Such changes (if any) will be temporary, localised and minor.

Acid rock drainage and acid sulfate soils

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

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

- Alluvium—generally low risk due to its young age and lack of sulfide minerals
- Sedimentary units—the Woogaroo Subgroup and Koukandowie Formation, in which cuts and tunnel are proposed, may host disseminated sulfide minerals (i.e. pyrite), particularly within shale and mudstone units.

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

14.9.2 Operational phase potential impacts

14.9.2.1 Water resources

Access to registered groundwater bores

Registered bores located within, or near to, the permanent operational disturbance footprint may become inaccessible or difficult to access due to rail corridor restrictions following construction (refer Figure 14.4a to Figure 14.4g). All potentially affected landowners will be consulted to ensure that potential loss of access to bores is identified (ground truthing). After detailed design has been undertaken and ground truthing of bores has occurred, potential risks can be refined, and mitigation determined.

Embankments

As discussed in Section 14.9.1.1, surface loading from embankments can cause compaction of compressible materials (that is, alluvial sediments) leading to increased groundwater levels (i.e. mounding) upstream of the embankment and reduction in groundwater levels downstream of the embankment. Compaction will also reduce the ability of the aquifer material to transmit shallow groundwater (i.e. reduction in aquifer's hydraulic properties and damming effect). This can result in more frequent and prolonged inundation of low-lying ground, particularly during times of higher groundwater levels, for example, following significant rainfall recharge events.

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

Depths to groundwater in the alluvial sediments are typically greater than 5 m and therefore the potential for impact is reduced. The potential for mounding and damming of groundwater may be greater in areas of shallower groundwater in alluvial sediments local to active channels (such as Lockyer Creek, Laidley Creek and Western Creek).

The anticipated embankment heights are typically less than 5 m across the floodplains of Lockyer, Sandy and Laidley Creek (Ch 40.00 km to Ch 55.00 km). Embankment heights in the order of 10 m to 15 m are proposed on alluvial sediments near Sandy Creek (Ch 33.80 km) and east of Laidley Creek to the western flanks of the Little Liverpool Range (that is, from Ch 55.00 km to Ch 60.00 km). These areas may present a greater potential to impact groundwater levels and flow.

As part of ongoing geotechnical investigations, an assessment of embankments, including critical sections (typically greater than 10 m, floodplains and poor ground conditions) have been reviewed in terms of stability of proposed geometry with respect to anticipated geological profile and groundwater levels. Assessment of anticipated subgrade conditions has also been undertaken for the alignment. The type and extent of subgrade treatment has been defined based on the expected ground conditions. Areas identified to likely require treatment include soft subgrades, reactive soils where global stability or settlement has been identified to be a potential issue, and where drainage blankets are required.

Overall the potential for embankments to significantly affect groundwater levels and/or the hydraulic properties of the aquifer(s) is considered to be low. This will be confirmed as part of further geotechnical investigations that will include additional investigation and monitoring of groundwater levels in low lying floodplain areas to inform final design.

Seepage to cuts and tunnel

Lowered groundwater levels due to long-term seepage into cuts and the Little Liverpool Range tunnel has the potential to impact groundwater users. This included registered bores and surface water flows. Long-term dewatering may also have the potential to impact vegetation (GDEs) such as deep-rooted trees.

The maximum steady state extents of drawdown (i.e. reduced groundwater levels) due to long-term seepage into cuts were estimated in Section 14.8.2, based on inflow rates for the five deep cut sections considered. The long-term drawdown extents were predicted between 300 m and 500 m from the cuts and can be used to consider potential to impact groundwater users during operational phase.

There are only two registered bores within the drawdown extents estimated for the five cuts considered in Section 14.8.2. The use of the bores is unknown; however, both are deep bores, constructed to 70 m (RN75520) and 102 m (RN106088), and are located approximately 250 m north of the cut at Ch 28.26 km to Ch 29.44 km (refer Figure 14.4a to Figure 14.4g). The base of cut at this location is approximately 165 m AHD, which is around 15 m below the surface elevation at the deep bores (approximately 180 m AHD). Given that the depth to groundwater in this area of higher relief is also anticipated to be in the order of 20 m, the water levels at the registered bores are not expected to be adversely affected by cut seepage. The location and use of the bores have not yet been physically confirmed. Further, the static water level, pump depth and pumping water level is also currently unknown. This information will be collected through liaison with the bore owners prior to the construction phase to allow for a detailed assessment of the potential for material drawdown impact at these bores.

Overall, long-term seepage into the five cuts considered are not anticipated to adversely impact groundwater levels in registered bores.

There are potential aquatic GDEs (refer Figure 14.5a to Figure 14.5g) within the estimated extents of drawdown at four of the five cuts considered Section 14.8.2. Most of these features are described as wetlands associated with alluvial aquifers (from the BoM GDE Atlas). These are in lower-lying parts of the landscape and below the elevation of the base of cut. Reduced groundwater levels in the bedrock due to long-term seepage into the cuts would therefore not be expected to adversely impact those potential aquatic GDEs. The exceptions are potential aquatic GDEs described as wetlands associated with flow from sedimentary rock that are close to the cuts at Ch 29.00 km (approximately 100 m south) and Ch 61.00 km (immediately adjacent). It is possible that if groundwater levels and/or flows are reduced then adverse impacts may occur to these potential terrestrial GDEs. These features have not been ground truthed and are potential GDEs only, based on BoM GDE Atlas. This is a conservative approach.

Potential terrestrial GDEs (refer Figure 14.6) are within the estimated extent of drawdown for two of the five cuts considered in Section 14.8.2. Several moderate potential terrestrial GDEs (from regional studies) are present immediately adjacent to the cut located at Ch 29.00 km. These features are described as wetlands associated with alluvial aquifers (from the BoM GDE Atlas). They occur in lower-lying parts of the landscape and below the elevation of the base of cut. Reduced groundwater levels in the bedrock due to long-term seepage into the cuts would therefore not be expected to adversely impact those potential aquatic GDEs. The low potential terrestrial GDEs (from regional studies) immediately adjacent to cut at Ch 61.00 km are described as wetlands associated with saline flow from sedimentary rock. It is possible that if groundwater levels and flow are reduced then adverse impacts may occur to these potential terrestrial GDEs. These features have not been ground truthed and are potential GDEs only, based on BoM GDE Atlas. This is a conservative approach.

Preliminary modelling of the drained tunnel through the Little Liverpool Range was carried out to estimate potential drawdown impacts (refer Section 14.8). Under the base case scenario (estimated typical groundwater levels and no structural features) drawdown impacts were limited in magnitude and lateral extent, and no registered bores or potential GDEs were within the predicted 1 m drawdown extent and no unacceptable adverse impacts would be anticipated.

The nearest registered bore (RN106453) to the proposed tunnel is located approximately 240 m southwest of Ch 62.20 km. This is not located within the modelled 5 m drawdown extent for any modelling scenario. The use and characteristics of the bore will be confirmed post-EIS. Further, the static water level, pump depth and pumping water level is also currently unknown; however, the total depth of the bore is reported as being 91.5 m. This information will be collected through liaison with the bore owner before the construction phase to ensure there are no potential implications of any drawdown at this bore.

The existing low to moderate potential terrestrial GDEs located 1 km to the north-east (refer Figure14.6d) are not predicted to intersect with modelled 5 m drawdown extent (refer Section 14.8). However, under this modelled scenario, there are several groundwater that may be impacted by the free draining tunnel. Mitigation measures are proposed to manage this potential issue.

It is currently assumed that cuttings, portals and the Little Liverpool Range tunnel will be free draining and dewatering effects will be ongoing over the long-term. Final design construction techniques will consider mitigation of groundwater inflows to reduce the lateral extent of dewatering effects and the volume of groundwater to be managed and discharged.

Bridge pilings

Bridge pilings may change groundwater flow patterns. Such changes would be very localised and small given the diameter and spacing of pilings compared to regional flow patterns.

14.9.2.2 Water quality

Spills and uncontrolled releases

Water quality impacts, as a result of contamination from unintended spills and leaks of hydrocarbons (oils, fuels and lubricants) and other chemicals related to use of heavy plant and equipment and water mixtures and emulsions related to washdown areas, are not anticipated after the construction phase.

In the instance a spill or leak occurs from normal operational activities, the impact is likely to be superficial in nature and not expected to impact on shallow aquifers. Spill kits and environmental response equipment will be stored at areas of heavy plant, for example a repair shop or plant/equipment storage shed.

Derailments and tunnel fires also have the potential to impact groundwater quality. The development and implementation of an appropriate incident and emergency management planning will effectively address these types of rare events.

Embankments

Surface loading from embankments can cause compaction of compressible materials (that is, alluvial sediments) leading to increased groundwater levels (mounding) and the potential for increased salinity in shallow groundwater from evaporative effects. Depths to groundwater in the alluvial sediments are typically greater than 5 m and, therefore, the potential for impacts are reduced; however, in areas of shallower groundwater such as alluvial sediments local to active channels (such as Lockyer Creek, Laidley Creek and Western Creek) the potential for impacts may be greater.

Further geotechnical investigations will include additional investigation and monitoring of groundwater levels in low-lying floodplain areas to inform detailed design.

14.10 Mitigation measures

14.10.1 Design considerations

The mitigation measures presented in Table 14.7 have been incorporated into the Project design. These design measures have been identified through collaborative development of the design and consideration of environmental constraints and issues. These design measures are relevant to both construction and operational phases of the Project.

TABLE 14.17: INITIAL MITIGATION—DESIGN

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

14.10.2 Proposed mitigation measures

To manage Project risks during construction mitigation measures have been proposed, as presented in Table 14.18. These proposed mitigation measures have been identified to address Project-specific issues and opportunities, legislative requirements, accepted government plans, policy and practice:

- Table 14.18 identifies the relevant Project phase, the aspect to be managed, and the proposed mitigation measure, which is then factored into the assessment of residual significance in Table 14.20
- The draft Outline EMP provides further context and the framework for implementation of these proposed mitigation and management measures (refer Chapter 23: Draft Outline Environment Management Plan).

TABLE 14.18: GROUNDWATER MITIGATION MEASURES

Delivery phase	Aspect	Proposed mitigation measures

Detailed design	Water resources	▸ Undertake additional investigations and assessment of potential drainage/dewatering impacts associated with the Little Liverpool Range tunnel, portals, and deep cut sections to refine current understanding and inform detailed design, verify potential impacts and ensure proposed mitigation measures are appropriate.
		▸ Refine seepage analysis for deep cuts to inform detail design (for example drainage blanket specifications, shotcrete and weep hole specifications).
		▸ Review the proposed groundwater monitoring network to ensure locations are accessible during pre-construction, construction, and commissioning and operation of the Project. Continue collection of baseline groundwater monitoring data (levels and quality) to confirm seasonal variation and inform detail design and the development of the final Groundwater Management and Monitoring Program (GMMP). Include monitoring at any additional bores identified during the development of the GMMP prior to construction and operation.
		▸ Engage with relevant landowners to confirm the location of existing bores, identification/confirmation of new monitoring bore locations and/or unregistered bores and procure access agreements to existing registered groundwater bores included in the GMMP.
		▸ Confirm (i.e. physical survey or ground truth) the location of registered and unregistered bores that may be lost due to construction or operation of the Project. Where a groundwater bore is expected to be decommissioned or access to it impaired as result of the Project, 'reasonable options and potential make-good' arrangements will be agreed, where feasible, in consultation with the potentially affected landowner. These measures could include:
		  ▸ provision of an alternate water supply/new bore
		  ▸ 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 tap a deeper part of the aquifer
		  ▸ reconditioning of the water bore to improve its hydraulic efficiency
		  ▸ monitoring of the bore water levels and efficiency to provide a level of confidence to the landowner that the impacts are being effectively managed.
		▸ Undertake ground truthing of identified potential aquatic and terrestrial GDEs within the groundwater study area that can potentially be impacted by the Project and confirm their status.
		▸ Confirm sources for construction water requirements via consultation with relevant stakeholders (including landholders/occupants) prior to construction. Appropriate approvals and agreements will be sought for the extraction of water. Where private water sources are used for construction, monitoring will be undertaken during extraction to ensure volumes and conditions stipulated by licence requirements and/or private landholder agreements are met.

	Water quality	▸ Undertake detailed geotechnical investigations at deep cut sections to inform design and location-specific construction management of groundwater. ▸ Risks associated with dewatering (i.e. water table lowering) and environmental management requirements during construction will be identified through appropriate baseline groundwater monitoring, modelling, and analysis.
Pre-construction	Water resources	▸ Continue collection of baseline groundwater monitoring data (levels and quality) to confirm seasonal variation and inform detail design and the development of the GMMP. Include monitoring at any additional bores identified during the development of the GMMP to establish a comprehensive monitoring regime prior to construction and operation.
	Water quality	▸ Undertake site inspections before the construction of cuts, including visual examination of surface outcrops for sulfide minerals or evidence of sulfide mineralisation. Use the information from these inspections to inform the management of potential ARD from cuttings prior to Project works. ▸ If ARD-contaminated discharge water is found to be generated from the deep cuts, this water will be impounded in ponds and neutralised via treatment (hydrated lime or dilution or similar) prior to release into the surrounding catchment or other discharge mechanism. ▸ Identification and/or reuse of contaminated, hazardous or potentially contaminated material on site (i.e. soil, ballast) will be subject to a risk assessment and managed accordingly.

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

Delivery phase	Aspect	Proposed mitigation measures
Operation	Water resources	▸ Implement the operational-phase GMMP. ▸ Groundwater levels at the Little Liverpool Range tunnel will be monitored in accordance with the GMMP, or as required under the tunnel operational requirements.
	Water quality	▸ Operators will notify their employees of the storage, handling, or transport of hazardous substances or dangerous goods to raise awareness and reduce potential of associated incidents. ▸ Operator will ensure appropriate controls are in place to prevent environmental incidents including leaks or spills from refuelling activities and locomotive operations and to protect the environment in the event of an incident. ▸ In the event of a spill, all necessary actions will be taken to contain the spill and follow ARTC emergency response protocols. ▸ Little Liverpool Range Tunnel and potential deep cut seepage water will be monitored and discharged in accordance with the Project's produced water management plan, as confirmed during detailed design. ▸ Groundwater quality will be monitored in accordance with the operational phase GMMP, assessed against trigger levels and contingency measures followed (as required). ▸ Any groundwater supply and/or monitoring bores that are decommissioned will be in accordance with the *Minimum Construction Requirements for Water Bores in Australia—Edition 3* (National Uniform Drillers Licensing Committee, 2012).

14.10.3 Groundwater monitoring and management plan

A groundwater management and monitoring program is recommended to assisting with Project environmental management and compliance requirements.

The groundwater monitoring plan (levels and quality) will be developed as outlined in the draft Outline EMP.

It is expected that the program will be conducted before, during, and after the construction works to ensure a suitable groundwater baseline dataset is established before starting any construction activities, with monitoring to confirm that construction and operation are not impacting on the groundwater resources. An indicative minimum network of three existing landholder bores and nine existing design phase investigation bores is summarised in Table 14.19. Landholder approval will be procured before landholder bores are included in the network. The focus of the groundwater network is to monitor groundwater levels and quality at or near cuts and the tunnel.

It may be beneficial to also install dedicated environmental monitoring wells to these existing locations and refine this network after the detail design is complete. The additional environmental monitoring bores could be sited in areas where storage of potentially contaminating materials is proposed, or in locations to provide adequate coverage up and down hydraulic gradient in areas of potential groundwater impact (for example at other deep cuts and significant embankments on compressible alluvial sediments). In particular, additional monitoring bores screened in the alluvial sediment will be considered. Approximately 72 per cent of the alignment is underlain by alluvial sediments, with one monitoring well (330-01-BH2203) constructed in these sediments to date as part of geotechnical site investigations.

TABLE 14.19: INDICATIVE MINIMUM GROUNDWATER MONITORING NETWORK

Chainage (km)	Bore ID	Easting[1]	Northing[1]	Aquifer[2]	Monitoring type	Rational
28.8	RN106088	414745	6953654	Woogaroo Subgroup[3]	Water level only Data logger	Registered bore within estimated extent of drawdown for cut at Ch 28.20 km–Ch 29.40 km.
29.0	330-01-BH2301	414866	6953376	Gatton Sandstone	Water levels and quality Data logger	Background water levels and quality at cut location Ch 28.20 km–Ch 29.40 km.
29.4	RN75520	415336	6953557	Woogaroo Subgroup[3]	Water level only Data logger	Registered bore within estimated extent of drawdown for cut at Ch 28.20 km–Ch 29.40 km.
32.0	330-01-BH2303	417589	6952572	Woogaroo Subgroup	Water levels and quality Data logger	Background water levels and quality at cut section.
33.5	330-01-BH2203	419239	6952190	Alluvium	Water levels and quality Data logger	Background water levels and quality in floodplain near bridge and fill sections.
34.5	330-01-BH2207	420000	6951909	Woogaroo Subgroup	Water levels and quality	Background water levels and quality along alignment and cut at Ch 35.00 km.
51.5	330-01-BH2212	436009	6948601	Gatton Sandstone	Water levels and quality	Background water levels and quality along alignment.
61.5	330-01-BH2104	443345	6942248	Koukandowie Formation	Water levels and quality Data logger	Monitor water levels and quality at west portal.

Chainage (km)	Bore ID	Easting[1]	Northing[1]	Aquifer[2]	Monitoring type	Rational
61.8	330-01-BH2102	443525	6942102	Koukandowie Formation	Water levels and quality Data logger	Monitor water levels and quality at west portal.
62.2	330-01-BH2101	443843	6941833	Koukandowie Formation	Water levels and quality Data logger	Monitor water levels and quality at tunnel.
62.6	RN106453	443535	6941700	Koukandowie Formation[3]	Water levels only Data logger	Registered bore closest to drained tunnel.
62.8	330-01-BH2103	444151	6941339	Koukandowie Formation	Water levels and quality Data logger	Monitor water levels and quality near east portal.

Table notes:
1. MGA94 Z56.
2. From Golder Associates (2020).
3. From surface geology mapping (refer Figure 14.2).

After completion of baseline monitoring program, and with consideration to the detailed design, the frequency and location of level measurements will be reviewed and amended for suitability to achieve GMPP objectives.

The shallow aquifer data will be considered together with regular surface water level monitoring data to inform the local hydraulic connectivity between surface water and shallow groundwater in the study areas.

14.10.3.1 Groundwater level monitoring

Manual measurements on all bores is proposed during establishment of the baseline groundwater dataset as this will be the basis of comparison for the Project.

Automated pressure transducers/level loggers, to be installed in selected bores, with proposed locations indicated in Figure 14.4a and Figure 14.4g. The groundwater level monitoring across 12 existing design phase investigation bores will continue, and data recorded after October 2018 will be incorporated in the detailed design phase.

Ideally, the baseline groundwater monitoring program will comprise a period to account for natural (seasonal) or anthropogenic fluctuations of groundwater levels prior to construction.

14.10.3.2 Groundwater quality monitoring

The baseline groundwater monitoring program will include the bores included in Table 14.19 at a minimum to characterise the local groundwater quality before construction activities. The data collected during the baseline program will be used to assess potential impacts of the Project on local groundwater resources and inform likely discharge quality from cut and tunnel seepage.

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

Field parameters to be collected during sampling should include pH, EC, temperature, redox potential, and dissolved oxygen (DO).

The analytical suite used in previous baseline sampling (conducted in October 2018) is proposed for laboratory analyses for continued baseline groundwater sampling:

- pH, EC and TDS
- Major anions (HCO_3^-, Cl^-, SO_4^{2-})
- Major cations (Ca^{2+}, Mg^{2+}, Na^+, K^+)
- Dissolved and Total Metals (Al, As, B, Cd, Cr, Cu, Mn, Pb, Ni, Se, Mo, Ag, Zn, B, Fe, Hg)
- Nutrients (ammonia, nitrite, nitrate, total nitrogen, total phosphorus).

The results from Chapter 9: Land resources will be considered to ensure a robust and comprehensive dataset is obtained. In addition to the analytical suite applied for the October 2018 groundwater monitoring event, the following will be considered for future baseline groundwater monitoring:

- Hydrocarbons (BTEX, TPH/TRH, naphthalene)
- Pesticides/herbicides.

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

Groundwater monitoring and sample collection will be conducted in accordance with recognised groundwater sampling guidelines such as *Monitoring and sampling manual* (DEHP 2009) and *Groundwater Sampling and Analysis—A Field Guide* (Geoscience Australia, 2009) unless an updated version is available before the monitoring program starts.

Any trigger levels derived for the Project will be developed in reference to the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2018 edition).

14.10.3.3 Data management and reporting

The following data and reporting are proposed:

- All groundwater data will be validated with suitable QA/QC controls applied
- Monitoring data will be assessed to identify trends and compare to trigger levels (pre-construction)
- After baseline monitoring, data will be assessed on an annual basis to identify monitoring data trends. Where consecutive data points for the same bore(s) indicate divergence from the baseline trends or previous data, the bore data will be further investigated to determine appropriate actions. This may include more rigorous monitoring or trigger a re-assessment of impacts and/or mitigation measures
- Relevant reporting will be completed on an annual basis and present the assessment of water levels and water quality trends, including hydrographs and hydrochemical trilinear plots. The annual assessment will recommend if the location and frequency of monitoring needs to be modified and recommend whether monitoring will cease.

14.11 Impact assessment

A significance-based impact-assessment approach has been adopted for evaluating potential impacts to groundwater resources from the Project. A summary of the significance assessment is provided in Table 14.20.

For each of the potential impacts discussed in Section 14.9, the sensitivity of the EV and the magnitude of the potential impacts have been considered to determine the pre-mitigated significance. Mitigation measures detailed in Section 14.10 were then applied to derive a residual significance for each potential impact on groundwater values.

A qualitative impact assessment using the significance assessment approach (as described in Chapter 4: Assessment methodology) has been adopted for evaluating the potential impacts to groundwater described in Section 14.9).

For each of the potential impacts discussed in Section 14.9, the initial significance assessment was undertaken on the assumption that the design considerations (or initial mitigation) factored into the design phase (refer Table 14.17) have been implemented.

Proposed mitigation measures, including those listed in relevant subplans (including the GMMP), were then applied as appropriate to the phase of the Project to reduce the level of potential impact (refer Section 14.10.2 and Table 14.18).

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

A summary of the significance assessment is provided in Table 14.20.

14.11.1 Temporary impacts

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

Final construction design, engineering controls and monitoring are generally considered to adequately mitigate potential impacts to groundwater. However, it is noted that additional investigations and assessment of potential drainage or dewatering impacts associated with the proposed Little Liverpool Range tunnel and deep-cut sections is proposed to inform detailed design.

14.11.2 Long-term impacts

The main potential long-term impacts identified beyond the construction stage are: changes to groundwater levels and flow associated with loading from embankments and ongoing dewatering/draining of the proposed tunnel and deep cuts; and management of discharge from dewatering/drainage of the tunnel and deep cuts.

Final construction design, engineering controls and monitoring are generally considered to adequately mitigate potential impacts to groundwater. However, additional investigations and assessment are proposed to inform detailed design with respect to potential drainage/dewatering impacts of the tunnel and deep cuts, and to potential loading impacts near significant embankments.

TABLE 14.20: SIGNIFICANCE ASSESSMENT SUMMARY FOR GROUNDWATER

Potential impact	Phase	Pre-mitigated significance			Application of proposed mitigation measures presented in Table 14.17 by aspect	Residual significance	
		Sensitivity	Magnitude	Significance		Magnitude	Significance
Loss of registered bores (through damage, destruction or loss of access)	Construction	Moderate	Moderate	Moderate	Water resources (pre-construction)	Low	Low
	Operations		Moderate	Moderate		Low	Low
Embankments—increased groundwater levels leading to surface inundation and/or increased groundwater salinity	Construction	Moderate	Low	Moderate	Water resources (detailed design) Water quality (detailed design)	Low	Low
	Operations		Moderate	Moderate		Low	Low
Ground movement due to reduction in groundwater levels (from dewatering/ seepage to cuts and tunnel)	Construction	Moderate	Moderate	Low	-	Low	Low
	Operations		Low	Low	-	Low	Low
Reduced groundwater levels affecting groundwater users (bores and GDEs) due to seepage into cuts and groundwater extraction for construction water supply (if required)	Construction	Moderate	Moderate	Moderate	Water resources (detailed design, pre-construction, construction and operation)	Low	Low
	Operations		Moderate	Moderate		Low	Low
Reduced groundwater levels affecting groundwater users (bores and GDEs)—due to drained tunnel	Construction	Moderate	High	High	Water resources (detailed design, pre-construction, construction and operation)	Moderate	Moderate
	Operations		High	High		Moderate	Moderate
Contamination or water quality degradation of groundwater resources requiring remediation (including leaks and spills, flow between aquifers due to borehole intersections, contaminated spoil)	Construction	Moderate	Moderate	Moderate	Water quality (pre-construction, construction and operation)	Low	Low
	Operations		Low	Low		Low	Low
Acid rock drainage (ARD) from cuts and/or tunnel impacts on EVs (i.e. GDEs)	Construction	Moderate	Moderate	Moderate	Water quality (pre-construction, construction and operation)	Low	Low
	Operations		Low	Low		Low	Low
Vegetation removal and surface alteration affecting recharge/discharge, increasing associated salinity risks	Construction	Moderate	Moderate	Moderate	Water resources (pre-construction and construction)	Low	Low
	Operations		Low	Low	-	Low	Low

14.12 Cumulative impacts

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

14.12.1 Surrounding projects and timeline relationships

Projects and operations surrounding the groundwater study area are summarised below and shown in Figure 14.13. Due to the localised potential groundwater impacts associated with the alignment, only applicable projects and operations (with potential impacts on groundwater) in Table 14.21 have been considered for this CIA.

TABLE 14.21: APPLICABLE PROJECTS AND OPERATIONS CONSIDERED FOR THE CUMULATIVE IMPACT ASSESSMENT

Project and proponent	Location	Description	EIS status	Timeline	Relationship to the proposal
Gowrie to Helidon (ARTC)	Rail alignment from Gowrie to Helidon (G2H)	26 km single-track dual-gauge freight railway as part of Inland Rail	Draft EIS being prepared by ARTC	Construction: 2021–2026 Operation: >50 years	Potential overlap of construction for Helidon to Calvert (H2C) and G2H
Calvert to Kagaru (ARTC)	Rail alignment from Calvert to Kagaru (C2K)	53 km single-track dual-gauge freight railway as part of Inland Rail	Draft EIS being prepared by ARTC	Construction: 2021–2026 Operation: >50 years	Potential overlap of construction for H2C and C2K

The timeline relationships for projects are provided in Table 14.22. To be conservative, it has been assumed the construction phase of all three Inland Rail projects will be run concurrently.

TABLE 14.22: PROJECT RELATIONSHIP TIMELINE FOR HELIDON TO CALVERT PROJECT

Project	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	>Year 9
G2H (ARTC)	Construction	Construction	Construction	Construction	Construction	Operation	Operation	Operation	Operation	Operation
H2C (ARTC)	Construction	Construction	Construction	Construction	Construction	Operation	Operation	Operation	Operation	Operation
C2K (ARTC)	Construction	Construction	Construction	Construction	Construction	Operation	Operation	Operation	Operation	Operation

Legend:

Construction Operation

14.12.2 Assessment of potential cumulative impacts

A qualitative significance assessment has been applied for evaluating cumulative impacts from the Project and surrounding projects. The qualitative assessment assigns a relevance factor of 1 (low), medium (2) or 3 (high) to the potential cumulative impacts for each of the following aspects:

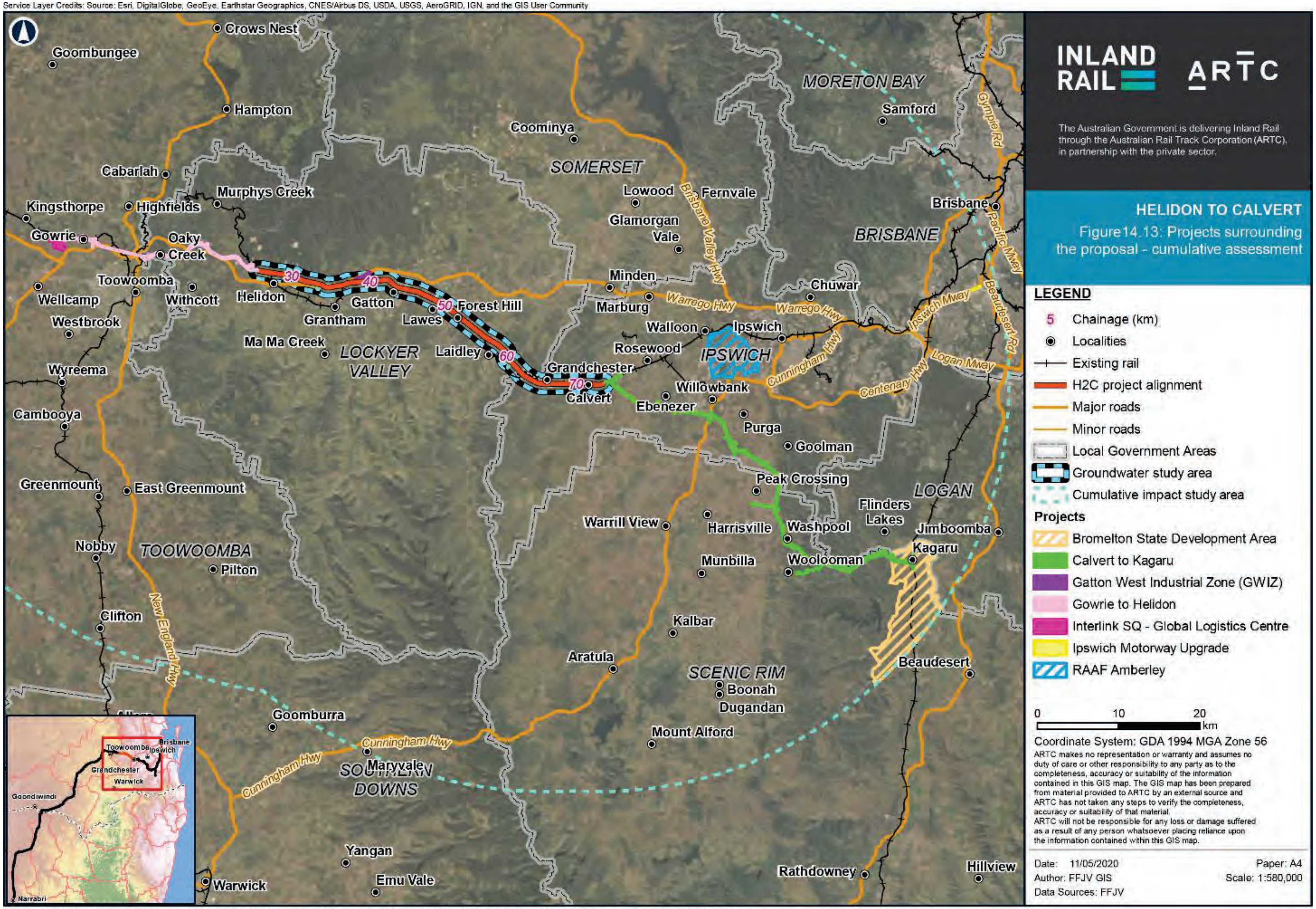
- Probability of the impact
- Duration of the impact
- Magnitude/intensity of the impact
- Sensitivity of receiving environment.

The significance of the cumulative impact is then determined by summing the relevance factors. The impact categories are as follows:

- Low (relevance sum 1–6): Negative impacts will be managed by standard environmental procedures. Special approval conditions are unlikely. Monitoring required as part of the general Project monitoring.
- Medium (relevance sum 7–9): Mitigation measures likely required and specific management practices to be applied. Specific approval conditions are likely.

High (relevance sum 10–12): Alternative actions will be considered and/or mitigation measures applied to demonstrate improvement. Specific approval conditions are likely and targeted monitoring is required.

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



Map by: LUC/RB/GN/KG Z:\GIS\GIS_3300_H2C\Tasks\330-EAP-201810021057_H2C_Project_Figures\330-EAP-201810021057_ARTC_Fig14.13_Cumulative_Assessment_v4.mxd Date: 10/06/2020 14:24

Based on the above methodology the cumulative groundwater impacts for the Project are summarised in Table 14.23.

TABLE 14.23: SUMMARY OF THE CUMULATIVE IMPACT ASSESSMENT

Cumulative impact	Aspect	Relevance factor	Sum of relevance factors	Impact significance	Comments	Mitigation measures
Change in groundwater levels	Probability of impact	1	6	Low	▸ Localised impacts on shallow groundwater levels considered unlikely to be compounded at ends of the Project alignment with either ARTC projects. ▸ Overlap of construction activities at the ends of the Project alignment with either ARTC projects.	▸ Adherence to dewatering and water supply mitigation measures discussed in Section 14.10. ▸ Adherence to the draft Outline EMP to respond effectively to groundwater level drawdown.
	Duration of the impact	2				
	Magnitude/intensity of the impact	1				
	Sensitivity of receiving environment	2				
Groundwater quality and contamination	Probability of impact	1	6	Low	▸ Primarily related to the shallow alluvial aquifer where potential intersections by excavations and contaminant spills can impact on water quality. ▸ Overlap of construction activities at the ends of the Project alignment with either ARTC projects.	▸ Implementation of the groundwater monitoring program to identify and respond to Identified issues. ▸ Adherence to the draft Outline EMP to prevent and respond effectively to spills and leaks.
	Duration of the impact	2				
	Magnitude/intensity of the impact	1				
	Sensitivity of receiving environment	2				

It is expected construction water will be acquired only after relevant agreements and approvals (post-EIS). Construction water supply and use, and management of anticipated cumulative access and demand issues, will be considered further once details are fully known and understood (during detailed design).

Applying for Queensland approval within the relevant water plans issued under the Water Act will ensure that impact of water demand between the projects (and potential impact to water resources and users) will be avoided. Sources for construction water requirements will also be confirmed via consultation with relevant stakeholders (including landowners/occupants) prior to construction.

14.13 Conclusion

To meet the study scope and objectives outlined in the ToR, the groundwater impact assessment provides a description of the existing hydrogeological environment and an assessment of the potential impacts of the Project. A staged approach was adopted for development of the groundwater assessment including a desktop study, review of geotechnical site investigation information and reports, a groundwater impact assessment and a significance assessment.

The potential impacts of the Project on groundwater levels, flow and quality were assessed and a significance assessment carried out, with the key outcomes being:

- A moderate residual significance risk was identified for the potential of reduced groundwater levels to impact groundwater users (registered bores and potential GDEs) due a drained Little Liverpool Range tunnel under model scenario 1. Under this scenario groundwater levels were modelled as being 10 m higher than the anticipated base case model of 'typical' groundwater levels. Additional groundwater level monitoring data have since indicated that the higher groundwater level (under model Scenario 1) can occur in response to wet season and provides a representative simulation of seasonal groundwater fluctuation and impact assessment.

  Continued groundwater level monitoring will confirm groundwater levels at the tunnel and inform additional design investigations and modelling.

- Residual significance risks were identified as being low for all other potential impacts including loss of registered bores through destruction or loss of access, reduced groundwater levels from seepage to cuttings impacting groundwater users (bores and GDEs) and changes to groundwater levels due to loading from embankments (i.e. upstream mounding and damming, and downstream groundwater level reductions).

  Additional geotechnical works, including investigation and monitoring of groundwater levels at deep cuts and areas of foundation treatment in low lying floodplain areas will further inform detailed design.

An indicative groundwater monitoring program is proposed to provide an ongoing assessment of the potential impacts of the Project on the identified groundwater EVs. The program includes an indicative monitoring well network for periodic water level and groundwater quality monitoring.

The cumulative impact assessment considered the adjoining Inland Rail projects. Potential cumulative impacts are anticipated to be of 'low significance'. This is due to the physical distance of each adjoining Inland Rail project from the Project and with consideration of proposed mitigation measures. With proposed mitigation measures in place for each project, the Project is not expected to have an adverse impact on existing groundwater EVs (each delivery phase).